Chapter 1: Communication Systems

Chapter 1 Objectives

At the conclusion of this chapter, the reader will be able to…

- Explain the difference between systems and subsystems.
- Describe the functional blocks in a practical radio communications system.
- Calculate the *wavelength* of a radio wave and relate it to physical antenna length.
- Define modulation and explain why it is needed in a radio communications system.
- List the three steps for troubleshooting systems.

1-1 Communication Systems

Today, every facet of our lives is touched by modern electronics. Being human, we take most of it for granted. It's easy to forget that for the largest part of recorded history, we've lived with no telephones, radios, televisions, or computers. Before the development of electronic communications, the speed of information travel was limited by the physical distance a runner or horseman could cover in a day. During the colonization of America, it was accepted that a letter might take several months to reach its destination across the ocean, and several more months for the reply to return. Today, the distance across the globe is measured in fractions of a second.

Electronic Communications is Everywhere!

Have you recently:

Watched a TV broadcast or listened to the radio? These are probably the most visible applications of communications technology. Analog television uses very sophisticated electronic techniques. The latest television technology, high-definition television (HDTV), uses complex digital and software technology together with advanced analog circuit techniques. These techniques are readily understood by anyone with a firm grasp of electronic fundamentals.

Used a telephone? Your voice may be sent using many different technologies. Analog transmission carries your conversation to the central office. From there, the signal is converted to digital (digitized). The digital signal is sent (along with thousands of other calls) on a beam of light through fiber-optic cables. The process is reversed at the destination. During the process, your conversation may also travel by radio wave to and from a satellite. Cellular telephones transmit and receive voice signals as streams of digital data over UHF (ultra high frequency) radio-frequency carrier signals.

Used a remote-control for a garage door, TV, or other appliance? Many remote-controls are actually tiny radio transmitters. A small microprocessor encodes digital data onto the transmitted radio wave to represent the user's commands.

Taken a commercial flight? Aircraft use numerous types of communications to ensure flight safety. Both voice and digital (data) communications are used by aircraft. Many of the communications are computer-automated. The Global Positioning System (GPS) is used to help provide accurate navigation.

Used a credit or debit card? If so, the verification was completed electronically. A credit card reader contains a microprocessor and a *modem* (modulator-demodulator). Your individual information record is recorded in three parallel "tracks" which are read from the card's magnetic stripe by the microprocessor. Newer credit cards have a memory chip containing the customer's account information in encrypted form. The modem allows the microprocessor to transmit the data to a host computer operated by the credit card company, typically through an Internet connection, and in some cases, an analog phone line.

Electronic Systems

In your previous electronic studies, you have been primarily concerned with the *theory* of circuits. For example, you might have constructed an amplifier stage with a transistor or op-amp IC (Integrated Circuit). The amplifier you built was studied for its own sake; it didn't fit into anything "bigger." This book will be your first study of *systems*.

A system can be defined as a group of components that work together to complete a job or task.

Many technicians are a little frightened when first asked to learn a new system. Part of this might be a natural fear of the unknown. The technician might wonder if he or she is capable of learning the necessary technical details. The best way to learn a system is to break it down into functional blocks, or *subsystems*. Upon study of these parts, the technician soon recognizes familiar circuits and principles and gains an understanding of how the system actually works.

A subsystem is just part of a system; it helps to complete a task. A subsystem is often shown in a *block diagram*.

Section Checkpoint

1-1 Classify each of the following as a system or subsystem:
- a) A radio transmitter
- b) An automobile
- c) An automatic transmission
- d) A radio transmitter and receiver

1-2 What type of diagram is used to show how systems work?
1-3 How can a technician understand a very complicated system?

1-2 A Simple Radio System

A simple radio system could be constructed as shown in the block diagram of Figure 1-1 below. This system has some severe problems, but it will serve as a good starting point.

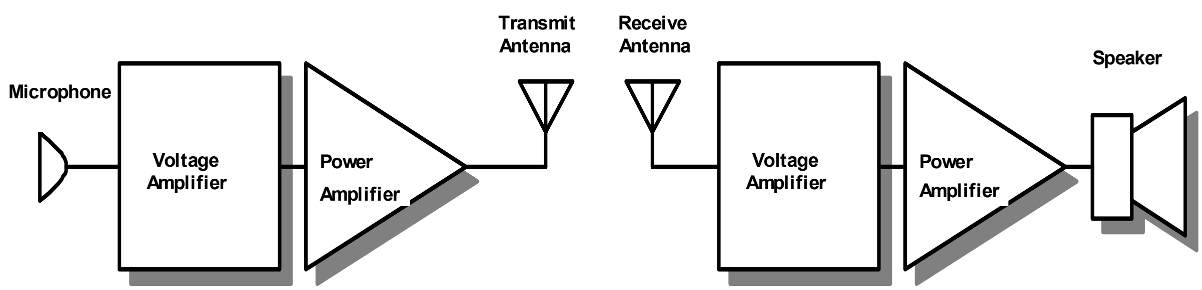


Figure 1-1 - A Simple Radio System

The radio system above begins with a *microphone*. A microphone is a type of *transducer*. It converts the pressure variations in a sound wave (such as from a speaker or musical performer) into electrical energy. A microphone has a thin plastic or paper cone connected to a coil of wire. This coil is placed within the field of a permanent magnet. When sound strikes the cone, it vibrates, moving the coil back and forth within the magnetic field.

Thus, a voltage is generated in the coil that is a copy of the sound wave that entered the microphone.

Figure 1-2: A Typical Dynamic Microphone Element

We call the electrical signal from the microphone the *intelligence* or *information* signal. The information signal is an electrical replica of the original sound wave, and has the same shape.

A transducer is any device that converts one form of energy into another.

The signal from the microphone is quite small. Most microphones produce about 10 mV (millivolts), at a power level of about 40 μW (microwatts). This isn't enough power to cross any significant distance in space, so both voltage and power (current) amplification must take place. The final power level reached at the output of the **power amplifier** depends on how far we need to communicate, and under what conditions. This power level can range from a few milliwatts (personal communications devices such as walkie-talkies) to thousands of watts (military and broadcast communications).

The transmitting *antenna* next converts the amplified information signal into a new form of energy that is capable of traveling through space. This new energy is called *electromagnetic energy*, or a *radio wave*. Electromagnetic energy consists of two fields, a voltage or electric field, and a magnetic field. It travels through space at the speed of light; in fact, visible light is itself electromagnetic energy with a very high frequency.

The energy from the radio wave moves outward from the transmitting antenna at the speed of light, which is about 3×10^8 meters/second. It spreads out over space much like an inflating balloon. By the time it reaches the receiver's antenna, it has very little energy. Imagine the thickness of a toy balloon when it is deflated; then imagine the new thickness if the balloon were inflated to a diameter of 10 miles! This is a very close to how the energy will be distributed in a radio wave. A radio receiver typically receives picowatts (1×10^{-12} watt) or femtowatts (1×10^{-15} watt) of energy from its antenna!

At the receiver, the antenna receives the weak signal. It will typically be just a few microvolts, which is too small for any practical use. Therefore, voltage and current amplification will be needed to bring the signal back up to a useful level. The receiver drives a *loudspeaker*, another transducer (Figure 1-3). The loudspeaker converts the electrical signal back into sound. It works by passing electrical current through a coil (the voice coil) suspended in a strong magnetic field. The electrical current causes the voice coil to become a magnet, and it is then attracted and repelled from the permanent magnet in step with the original information signal. A paper cone attached to the voice coil pushes on the air, which recreates the original sound.

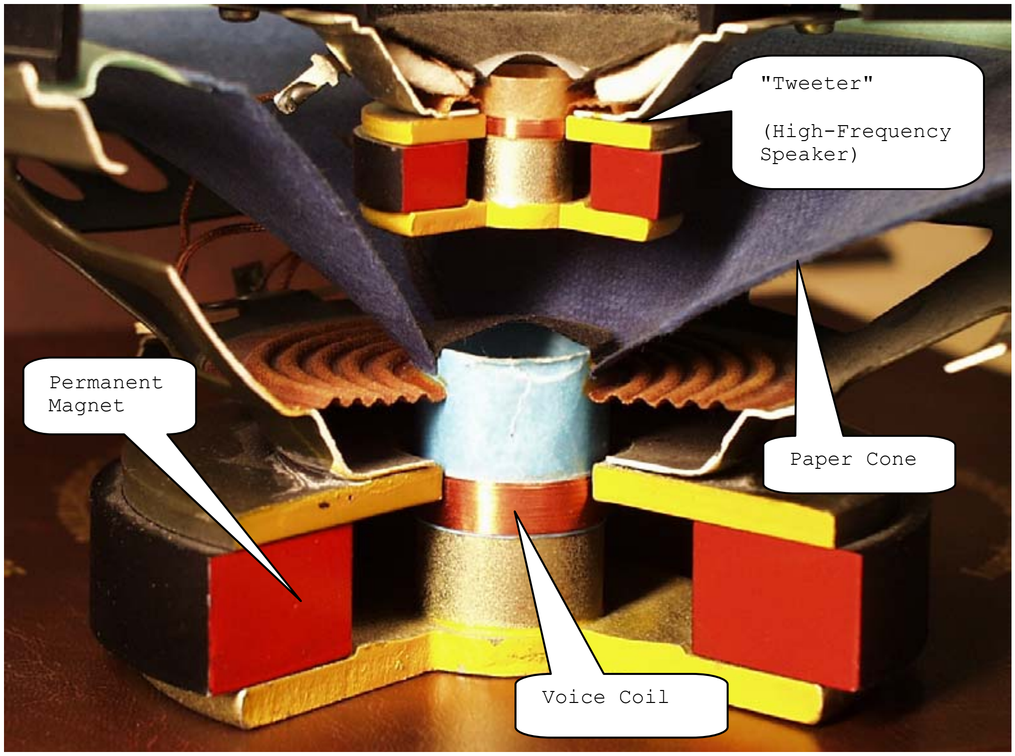


Figure 1-3: Cutaway of a Coaxial Loudspeaker

This is theoretically how a radio system *should* operate. However, there are two practical problems that prevent us from doing it this way! The next section will demonstrate these problems, and how they are avoided.

Section Checkpoint

1-4 What is a transducer?
1-5 Explain the workings behind a microphone and loudspeaker.
1-6 Why must a transmitter use a power amplifier? How is the power level decided?
1-7 What is the *information signal*?
1-8 What are the two types of energy in an electromagnetic wave?
1-9 What types of voltage and power levels are typical at a radio receiver's antenna?
1-10 Answer the following questions about power units:
  a) How much power is a *femtowatt?*
  b) How much power is a *picowatt?*
  c) How many femtowatts in a picowatt? Microwatt? Milliwatt?

1-3 The Need for Modulation

A radio communication system like the one of section 1-2 would not work very well. There are two problems: First, it would be nearly impossible to build a transmitting antenna to work with the system; second, there is no way of having two (or more) transmitters on the air at the same time. There's no way of *separating* individual stations. Let's explore these problems in more detail.

Transmitting Antenna Requirements

In order to be efficient, radio transmitting antennas need to be at least one-quarter of a *wavelength* long. Shorter antennas can be made to work, but they don't radiate energy very well. The term *wavelength* refers to the distance a radio wave travels in one cycle. It is measured in meters, a unit of length. Figure 1-4 represents a radio wave in space. It is traveling into the page.

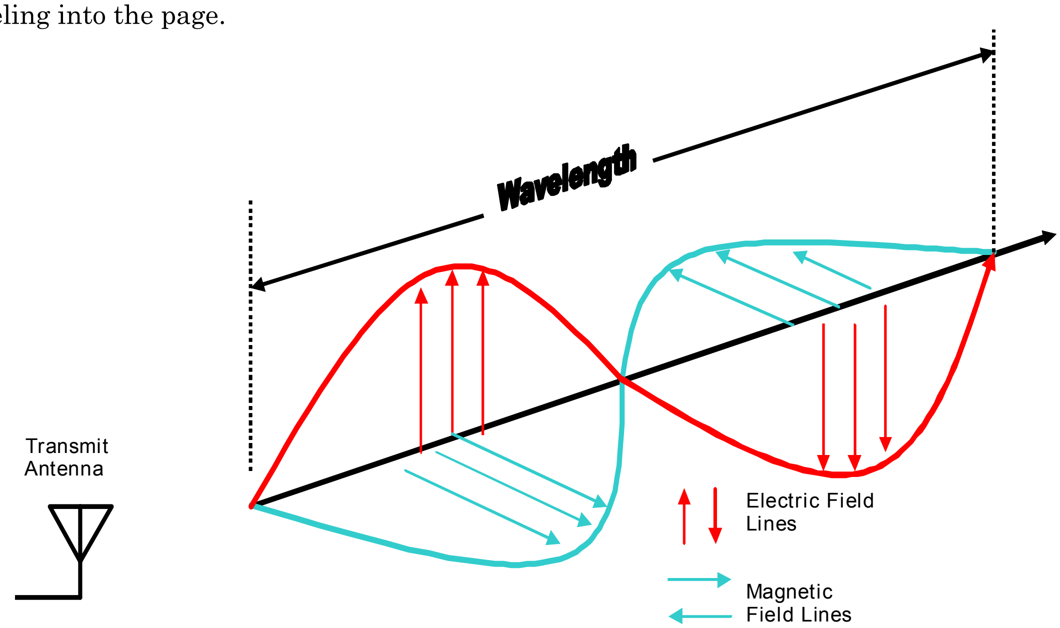


Figure 1-4: A Radio Wave in Free Space

Wavelength can be easily calculated. A standard formula states that to find distance, multiply rate (speed) by time:

$$D = R \times T$$

The speed of a radio wave is the same as the speed of light, and we can give it the letter v (for velocity). We also know that frequency and time are *inverses*; f = 1/T. Therefore, we can write:

$$D = v\left(\frac{1}{f}\right) = \frac{v}{f}$$ (Where v is the speed of light, 3×10^8 meters / second).

It is very common to use the Greek symbol lambda (λ) to stand for the distance of one wavelength. Therefore, we get:

$$\text{(1-1)} \quad \lambda = \frac{v}{f}$$

Wavelength is the distance that a radio wave travels in one cycle. It is measured between two peaks or two troughs. It is always in distance units (usually meters).

Back to our problem. The radio system of Figure 1-1 needs to transmit *audio frequencies*. Audio frequencies are those that we can hear. They are from 20 Hz to 20,000 Hz. (Most persons over the age of 15 have great difficulty hearing anything over 15,000 Hz). An audio frequency that is in the "middle" of our hearing range is 1000 Hz, or 1 kHz. Let's calculate the wavelength of a 1 kHz electromagnetic wave:

According to Equation 1-1:

$$\lambda = \frac{v}{f} = \frac{3 \times 10^8 \, meters/\sec}{1 \, kHz} = 300{,}000 \, m = \underline{\underline{300 \, km}}$$

300 km is quite a large distance -- about 186 miles! Of course, the antenna doesn't have to be *this* long. It need only be *one-quarter* of this distance, or 75 km (46.6 miles). No big deal, right? Of course, it isn't practical to build an antenna this large. Our system won't work very well. The required antenna length is too long!

Another Problem

As if the inability to build a suitable antenna weren't enough, another serious problem exists with the system of Figure 1-1. Imagine that somehow, practical antennas were invented to work at audio frequencies. We'll want to operate several stations at the same time; having just one broadcaster "hogging" the airwaves just won't do! Do you see the problem? Yes! *All the stations will be sharing the same frequencies (the audio frequencies).* It will be impossible to separate different stations at the radio receiver, since they'll all be on the same group of frequencies.

You can see that the system of Figure 1-1 is hardly practical. Can you think of a way to make it work? How could we get the antennas to be shorter?

Making it Shorter

Equation 1-1 gives a clue about how to proceed. It tells us that wavelength is velocity divided by frequency. We can't change the velocity -- that's the speed of light in free space. But we can easily change the *frequency* of the wave. If we increase the frequency, the wavelength will get *shorter*. This looks promising!

Increasing frequency always decreases wavelength. Decreasing frequency always increases wavelength.

Let's try changing to a 10 kHz wave. What will the wavelength be? How long will the antenna have to be? By using equation 1-1 again, we get:

$$\lambda = \frac{v}{f} = \frac{3 \times 10^8 \, meters/\sec}{10 \, kHz} = 30{,}000 \, m = \underline{\underline{30 \, km}}$$

This is much better! *The wavelength got 10 times shorter*. The minimum antenna length would be one-quarter of a wavelength:

$$L_{\min} = \frac{\lambda}{4} = \frac{30 \, km}{4} = \underline{\underline{7.5 \, km}}$$

The antennas are still too long to build. If we continue to increase the frequency further, the wavelength will get even smaller. For example, many mobile FM radio units operate near 150 MHz. At this frequency:

$$\lambda = \frac{v}{f} = \frac{3\times 10^{8}\, meters/\sec}{150 MHz} = 2\ m$$

And:

$$L_{\min} = \frac{\lambda}{4} = \frac{2\ m}{4} = \underline{\underline{0.5\ m}} = \underline{\underline{19.7''}}$$

Antennas of this type are very practical. You can often estimate the frequency of a transmitter by "eyeballing" the antenna. The longer the antenna, the longer the wavelength -- and you guessed it, the lower the operating frequency.

Radio Frequencies

Frequencies above the range of hearing are called *radio frequencies.* Any frequency above 20 kHz is considered a radio frequency.

Example 1-1

What is the wavelength of a 710 kHz AM broadcast signal? What is the minimum height of the antenna tower in *feet* if it is one-quarter of a wavelength long?

Solution:
Equation 1-1 calculates wavelength:

$$\lambda = \frac{v}{f} = \frac{3\times 10^{8}\, m/s}{710\ kHz} = \underline{\underline{422.5\ m}}$$

The tower need not be a full 422.5 meters high. In fact, a quarter of that length will do just fine:

$$\frac{\lambda}{4} = 422.5\ m \times \frac{1}{4} = 105.6\ m$$

So the tower height will really be 105.6 meters. However, the answer was requested in *feet*, so we need to convert:

$$L_{feet} = 105.6\ m \times \frac{3.28 ft}{1\ m} = \underline{\underline{346.6 ft}}$$

The physical height of the tower will be close to 346.6 feet. This is very typical of AM broadcast installations.

Example 1-2

An quarter-wave (λ/4) whip antenna measures 108". What is the approximate operating frequency of the transmitter?

Solution:
By manipulating equation 1-1, we get:

$$f = \frac{v}{\lambda}$$

We know v since it is the speed of light, but not λ (the wavelength). We have been given the dimension of *one-quarter of a wavelength* in inches. This needs to be converted into *meters* to be useful to us:

$$\frac{\lambda}{4} = 108'' \times \frac{1m}{39.37''} = 2.74m$$

This figure is one-quarter of a wavelength (λ/4) in meters. The wavelength must be equal to:

$$\lambda = 4 \times ({}^{\lambda}\!/_{4}) = 4 \times 2.74m = 10.97m$$

Now with this answer in hand, we can plug back into the manipulated equation 1-1:

$$f = \frac{v}{\lambda} = \frac{3 \times 10^{8}\, meters / \sec}{10.97 meters} = \underline{\underline{27.3MHz}}$$

This frequency is in the middle of the class-D citizens band.

The Need for Modulation

A 150 MHz signal may transmit just fine, but there's one more problem. We can't hear a 150 MHz signal; it's too high in frequency! However, there is a solution; it's called *modulation*. When we modulate a wave, we place a low-frequency information signal onto it. The low-frequency signal is just along for the ride. It is, in effect, "carried" on top of the high-frequency signal. The high-frequency signal is therefore called the *carrier* signal.

There are three ways we can impress information onto a carrier. We can change the voltage (or power) of the wave in step with the information. This is called *amplitude modulation*, or AM. We can alter the frequency of the wave with the information; this is called *frequency modulation*, or FM. Finally, we can change the phase of the carrier wave. This is called *phase modulation*, or PM.

Section Checkpoint

1-11 What are two problems with the system of Figure 1-1?
1-12 How is the wavelength of a radio wave calculated?
1-13 Why are high frequencies used for carrier waves?
1-14 What is meant by the term *modulation*?
1-15 What are three ways a carrier can be modulated?
1-16 What is the lowest *radio frequency*?

1-4 A Practical Radio System

An actual radio system looks very much like the diagram of Figure 1-5:

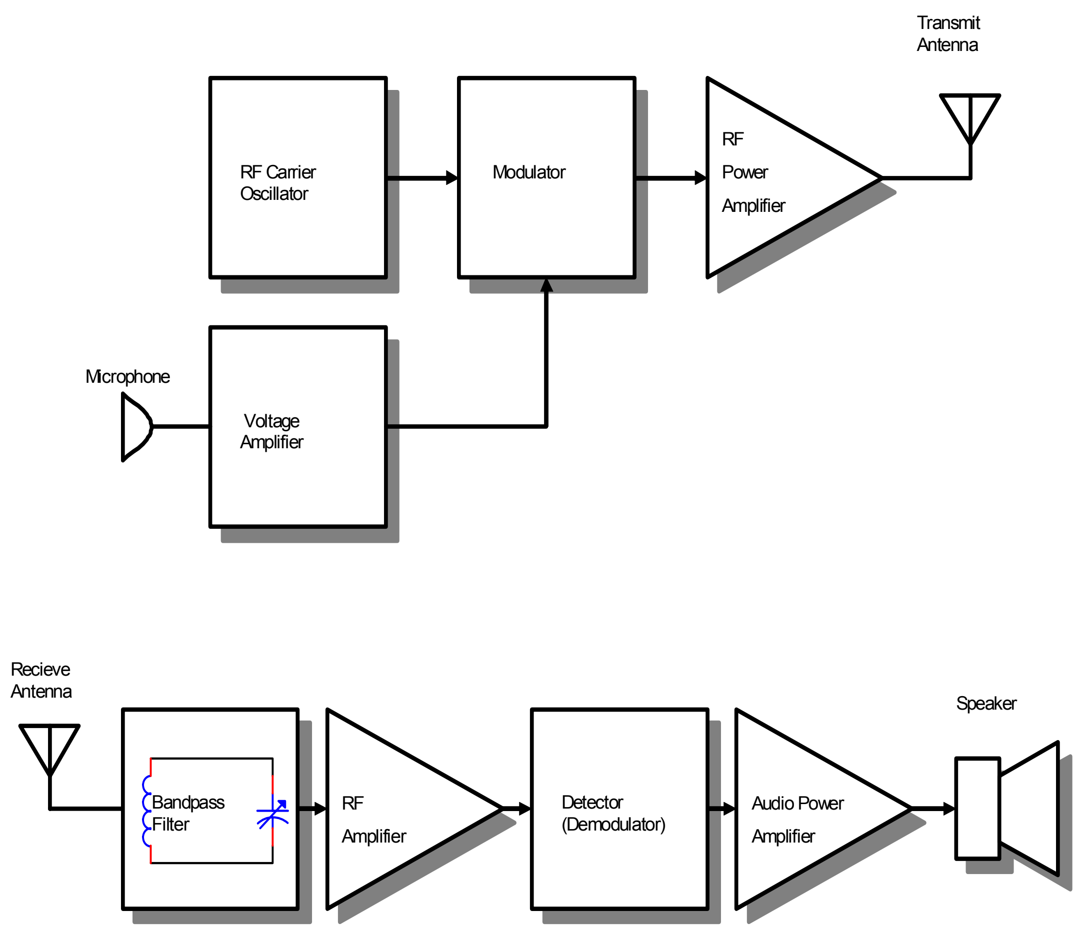


Figure 1-5: A Practical Radio System

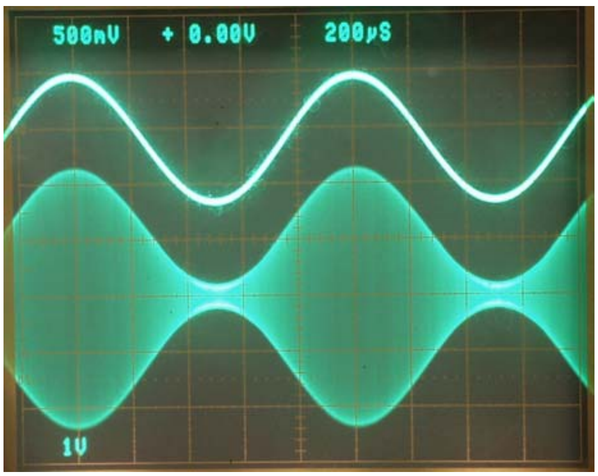
Transmitter Components

Every radio transmitter is assigned to operate on a specific *carrier frequency*. The job of the carrier oscillator is to generate this frequency. From your electronic fundamentals coursework, you'll recall that the purpose of an oscillator is to convert the DC from the power supply into an AC signal. The output of the carrier oscillator is a nearly-pure sine wave. The sine wave from the carrier oscillator carries no information at this point.

The modulator stage is a little unusual -- it has *two* inputs! One of the inputs is the radio-frequency sine wave from the carrier oscillator. The other is the *information* signal. The modulator combines the carrier and information in a special way. The output of the modulator is a *modulated carrier wave.* You might wonder why a voltage amplifier is needed between the microphone and modulator. Right! The microphone produces very little voltage or power, so its signal still needs a little "boost" before it can modulate the carrier.

The output from the modulator drives the radio frequency (RF) power amplifier. The signal at the modulator's output is too small to cover any significant distance, so additional amplification is needed. RF amplifiers use circuit techniques a little different from the low-frequency amplifiers you might have studied in fundamentals courses. These techniques are necessary because of the high frequencies involved.

Figure 1-6 shows typical waveforms used to test an AM transmitter. The top waveform is the *information*; a sine wave is often used as a convenient test signal, since it's available from most benchtop signal generators. The bottom waveform shows the resultant AM signal at the modulator stage output.



1 kHz Information Signal

Modulated Carrier Wave

Figure 1-6: Intelligence and AM Carrier Waves

Receiver Concepts

The receiver of Figure 1-5 reverses the steps taken in the transmitter. After the incoming signal is received from space by the antenna, it is fed into a bandpass filter. Recall that a bandpass filter rejects frequencies above and below its design frequency. Most receivers use an LC resonant circuit as the bandpass filter. This filter is tuned to the *carrier frequency* of the transmitting station. There are thousands of signals reaching the receiver's antenna at any given instant, yet the receiver must reproduce only one of them. That is a tall order! Because each incoming carrier signal has a different frequency, it is possible to separate them by using a frequency-selective circuit. In other words, we use a filter to do the job of "selecting" the appropriate station.

You might have noticed the variable capacitor in the filter of Figure 1-5. Yes, that's the receiver's tuning control. The tuning knob on a receiver is coupled to a variable capacitor, which is part of the bandpass filter. When the capacitance is changed, the resonant frequency of the filter changes. When a user is tuning in a radio station, he or she is actually adjusting the resonant frequency of a tank circuit!

After selection of the appropriate carrier frequency, we will still have a very weak signal. Several stages of **RF amplification** are needed to bring the modulated wave up to a level that is useful.

The **detector** or **demodulator** stage does exactly the *opposite* of the modulator stage. It takes the incoming modulated carrier waveform and strips away the carrier frequency, leaving a copy of the original information signal. The output of the detector will look very much like the original information signal from the microphone. This is the *recovered information* signal.

The recovered information is still too weak to drive a loudspeaker (or other device), so an **audio power amplifier** is used to boost the signal's voltage and current. In most modern radio receivers, the audio power amplifier is likely to be on a single integrated-circuit (IC) chip. The loudspeaker completes the process, converting the amplified information signal back into sound.

Section Checkpoint

1-17 What is the purpose of an *oscillator* circuit?
1-18 How does an RF amplifier differ from an AF amplifier?
1-19 What is the purpose of the *modulator* circuit?
1-20 How many radio signals can be expected in the antenna circuit of a receiver?
1-21 How does a radio receiver "select" one signal from thousands?
1-22 What happens in a *detector* circuit?

1-5 The Radio Frequency Spectrum

RF Frequency Ranges and Names

There are many different radio frequencies available for use. Each group of frequencies has different operating characteristics. Radio spectrum is divided into "bands" to help people plan their use of the frequencies. Table 1-1 shows some common bands and their intended uses. Note how we can refer to bands by either frequency or wavelength. For example, the 10-meter band really refers to the frequencies at or around 30 MHz. A technician should memorize these. They're used often in RF work.

Band Name	Frequency Range	Wavelength Range	Primary Applications and Users
LF	30 - 300 kHz	10 km - 1 km	Subterranean communications; aircraft navigation
MF	300 - 3000 kHz	1000 - 100 m	AM broadcast; Amateur radio; military
HF	3 MHz - 30 MHz	100 m - 10 m	SW (Shortwave) broadcast; amateur, military, and commercial long distance communications. CB band at 27 MHz.
VHF	30 MHz - 300 MHz	10 m - 1 m	FM and television broadcast. Local amateur, commercial, and public safety communications.
UHF	300 MHz - 3 GHz	1 m - 10 cm	UHF television broadcasts. Amateur, commercial, public-safety, and satellite communications. Cellular telephones at 800 MHz.
SHF	3 GHz - 30 GHz	10 cm - 1 cm	Microwave bands. Satellite communications; radar measurement of distance and speed.
EHF	30 GHz - 300 GHz	1 cm - 10 mm	Highest radio frequencies. High definition radar. Satellite and experimental communications modes.

Table 1-1: The RF Frequency Spectrum

1-6 Digital Communications

Computers are an important part of modern life. Part of the power of computers arises from their ability to communicate information rapidly over a distance. A *network* is a group of computers that are connected together and share data. Computers use digital or *binary* signals in their operation (recall that a binary signal has one of two possible states, 1 or 0). However, digital signals can't be directly sent over a long distance directly. Long-distance digital communication usually requires that the computer's digital signals be converted into analog form for transmission, as shown in Figure 1-7.

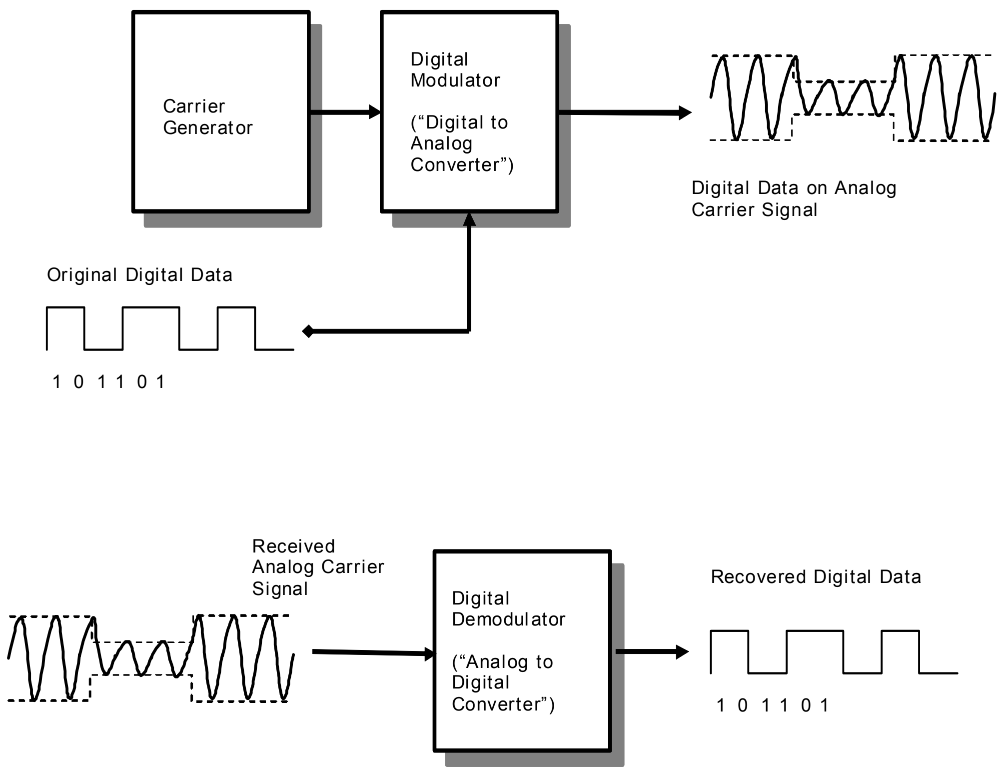


Figure 1-7: Computer Data Transmission Process

In Figure 1-7, the original computer data is transmitted in serial form (one bit at a time) to the digital modulator (which really acts as a digital-to-analog converter). Just as in voice applications, the modulator places the digital information onto a carrier signal supplied by the carrier generator circuit. The result is a digital signal that rides on top of an analog carrier wave, which can then be transmitted over a distance. The process is reversed to recover the digital data.

Figure 1-7 shows amplitude shift keying (ASK) carrying the data. ASK represents ones and zeros by varying the amplitude of the sine wave carrier signal. It is really just amplitude modulation. FM and PM are also widely used to carry digital signals.

PCS (personal communications service) cellular telephones and HDTV both convert the sound (or picture) signals into digital representations, then transmit them on analog carriers. In the case of PCS, digital transmission enables compression of the voice signal, which allows more people to make calls from the same cellular tower. Digital transmissions can also be encrypted to prevent eavesdropping, unlike most analog mobile transmission. In HDTV, digital compression allows more stations to share the allotted frequencies, and error-correction methods allow crystal-clear picture and sound, even in the presence of interference signals.

Analog transmission technology is still important in the age of digital. Wherever there is a human interface, there will likely remain an analog device; and analog carrier transmission will likely always be needed to bridge distance.

Section Checkpoint

1-23 Explain the difference between digital and analog signals.
1-24 What type of modulation is used in Figure 1-7?
1-25 List two advantages of digital PCS phones over their analog counterparts.
1-26 Where are two places that analog components will always be needed in communication systems?

1-7 How to Troubleshoot Systems

Technicians are at the center of the action in electronics. When sophisticated equipment fails to operate correctly, or operating problems occur, it's often the tech who is called on to remedy the trouble.

Only a minority of technicians actually perform component-level repairs. At a job site, there is generally insufficient time for this type of work. Replacing individual components in today's high-tech electronics is best done on the bench, where proper tools are available.

When trouble is found, a field technician is very likely to *substitute* working modules or assemblies for those found to be defective. Often this is referred to as "board swapping."

Some assemblies must be tested with specialized, automated equipment. This is becoming commonplace, as microprocessors and software are now an indispensable component of modern communication systems.

A Three-Step Approach to Troubleshooting

The successful technician follows a systematic method of troubleshooting. Many use the following three-step approach:

1. Visual (and other) Inspection
2. Check Power Supplies
3. Check Inputs and Outputs

Visual Inspection means to look carefully at the equipment, as well as the operating conditions. Are the controls set properly? Has someone changed a software setting? Do you smell something hot or burning? See any smoke? Is something cold that should be getting warm? Any unusual sounds? All of these things are important clues.

Be careful and use common sense. For example, a finger is not really well-suited as a "temperature probe." It's too easy to get burned or shocked. Never touch a live circuit! Also, if appropriate, use eye protection. Certain components (such as electrolytic capacitors) may fail explosively, especially in high-power circuits.

Check Power Supplies means to check the actual operating voltages <u>at the point in the circuit where the power is actually used</u>. This should *never* be directly attempted in high-voltage or high-power circuits. Appropriate (safe) test points are almost always provided to test these circuits.

<u>More than 90% of electronic failures can be attributed to power supply troubles</u>. It makes sense; the power supply is the most highly-stressed section in electronic equipment. The power supply must pass all energy used by the equipment. It also must absorb

transients and *spikes* from the AC power line on a regular basis. Just as a car won't run without gas, electronics won't work correctly if the power supplies aren't right.

When the first two steps have been followed, then it's generally safe to start on the third step, *checking inputs and outputs*. When you get to this step, you know that everything is getting proper power, and therefore, something is stopping the signal from passing. Sometimes the signal passes, but becomes distorted in some way. Waveform charts in a service manual are invaluable here when they're available. Often, you'll be on your own. You will have to devise an appropriate test procedure on the spot. Your background in fundamentals will help you to do this (plus your experience in courses like this one!)

Example 1-3

Figure 1-8 shows a slightly more detailed picture of an AM transmitter. This unit is a 100-watt aviation transmitter. It was "swapped out" after it malfunctioned. The complaint on the repair order reads: "Unit transmits dead carrier. The listener (on the other end) can not hear anything said into the microphone, but can tell that we are transmitting (silence)."
Work out a plan for troubleshooting the unit. Which areas are suspect given the symptoms?

Solution
There are several ways of attacking the problem. First, the block diagram of the unit must be understood. It is similar to the diagram of Figure 1-5. There are a couple of new stages. The *buffer amplifier* slightly amplifies the RF carrier from the oscillator. It can be seen that the RF power amplifier has two stages, the *driver* and *final* amplifiers. The final amplifier is simply the *last* or "final" amplifier before the antenna. Note how the RF driver and final amplifiers operate on a high-voltage, high-current power supply. (You'll likely see these stages mounted on a metal *heatsink*.)

Since no modulation is occuring, we will be interested in the portion of the circuit that performs that task. That will include the *microphone*, the microphone *voltage amplifier (preamplifier),* and the *modulator*.

Proposed Troubleshooting Steps

Perform a visual inspection of the unit. Sometimes you'll notice a detail such as a dented cabinet corner -- which could mean that the device has been *dropped* or *crushed*. The DC power supplies should be tested at the appropriate test points. There are *three* different DC levels: +48 V, +12 V, and +8 V. The service manual may suggest the best place to make power supply measurements.

Once power supplies have been checked, we will check *inputs and outputs*. The original complaint is that no modulation is taking place. The *modulator* stage will be the best starting place. Test point F will be checked using an oscilloscope for an information signal. The technician may have to provide an "information" signal to do this test. Most commonly, the tech either talks or whistles into the microphone to provide a signal.

If information is seen at test point F, we know the microphone and microphone amplifier are both working, so we'll look closer into the modulator stage to find out why it isn't working.

If we do not see information at test point F, then the trouble lies either in the voltage amplifier or microphone itself. (We can check test point G with a scope to see if the microphone is producing an output).

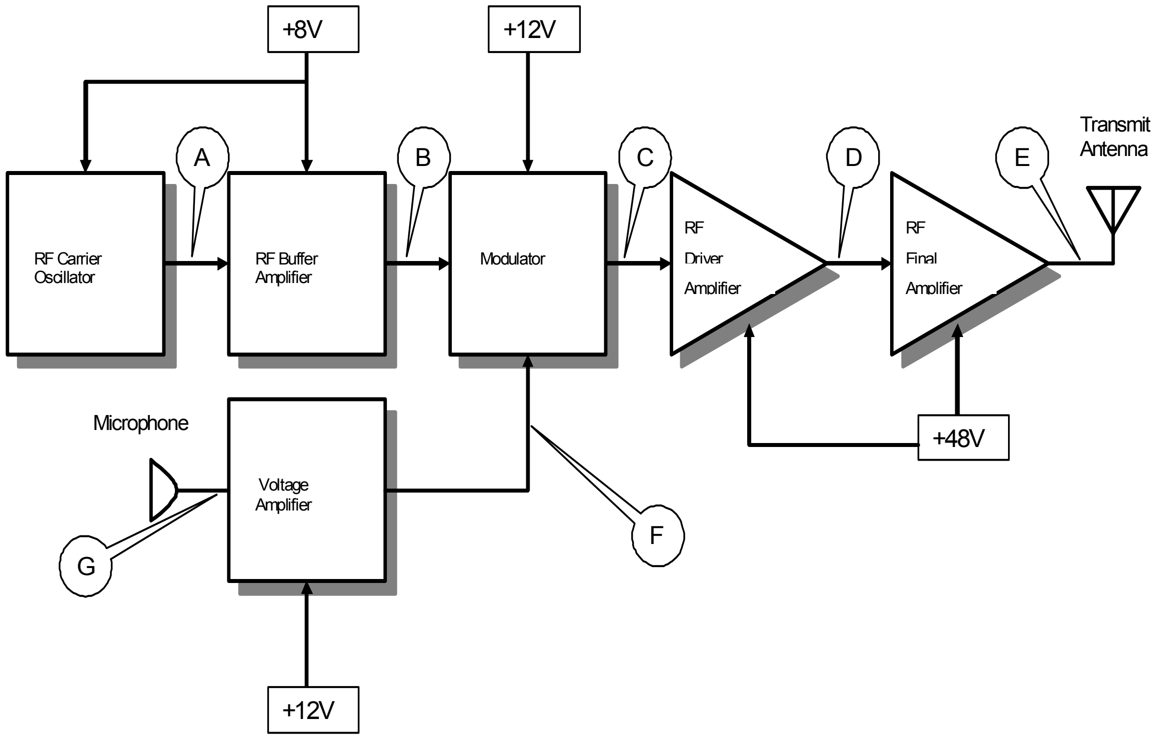


Figure 1-8: Example Transmitter for Troubleshooting

Chapter 1 Summary

- All systems, no matter how complex, can be broken down into functional blocks or *subsystems*.
- Radio systems work by converting intelligence signals into *electromagnetic energy*, which can travel freely through space.
- Devices which transform intelligence energy from one form into another (such as sound into electricity) are called *transducers*.
- Radio signals travel as waves. The *wavelength* of a radio signal can be calculated if the frequency of the signal is known (Equation 1-1). The higher the frequency of a wave, the shorter its wavelength becomes.
- *Modulation* is the process of placing information onto a radio-frequency carrier. At a radio receiver, a *demodulator* or *detector* reverses the process to recover the information.
- Each radio station uses a different *carrier frequency*. This makes it possible to separate stations at a receiver by using a tunable band-pass filter.
- The RF spectrum is divided into *bands*. Technicians commonly refer to the bands by name (VHF, HF, and so on).
- Digital communications usually requires placing the computer's digital signal onto an analog carrier wave; the process is sometimes called digital-to-analog conversion. There are many advantages to digital communications; however, analog is far from dead!
- Troubleshooting is not impossible to learn. It's important to use a systematic approach when hunting for troubles.

Problems

1. Draw a block diagram of a practical radio transmitter. Explain the function of each block.
2. Draw a block diagram of a radio receiver. Explain what happens in each block.
3. Define *modulation*. List the three ways a carrier wave can be modulated.
4. What are two reasons why modulation is necessary in radio?
5. List all the transducers shown in Figure 1-5. For each transducer, give the type of input and output energy.
6. What is the purpose of the oscillator in a radio transmitter?
7. Define *wavelength*. How do changes in frequency affect wavelength?
8. Calculate the wavelength of the following radio signals:
   a) 1 MHz b) 10 MHz c) 2.8 MHz d) 54 MHz
9. How long is one-quarter wavelength at each of the frequencies of Question 8?
10. Calculate the frequency that corresponds to each of the following wavelengths:
    a) 10 m b) 2 m c) 15 m d) 70 cm
11. What is the approximate operating frequency of each antenna listed below? The fraction of a wavelength is given for each unit.
    a) length = 56", 1/4 λ
    b) length = 56", 1/2 λ
    c) length = 0.5m, 1/4 λ
    d) length = 10m, 1/2 λ
12. Draw the block diagram of a digital communication system. Using outline form, explain the function of each major block in the system.
13. List the three steps of troubleshooting a system, in order.
14. Why are power supplies the most failure-prone portion of electronic systems?
15. A unit just like the one of Figure 1-7 has come in for servicing. The complaint on the repair order states "won't transmit." When connected to a dummy load and RF power meter, the set shows *no* power output when the microphone is keyed.
    a) What will be the first step taken when this unit is troubleshot?
    b) List the power supply voltage test points (by voltage) that will be measured in the second step of troubleshooting.
16. The power supply test points in the set of Question 14 measured good. The following oscilloscope measurements were made *with the microphone keyed*:
    * Test point E, 0 Vpp RF
    * Test point C, 10 Vpp RF
    * Test point B, 5 Vpp RF
    * Test point D, 0 Vpp RF
    * Test point F, 1 Vpp AF (Intelligence)

    What stage or stages is most likely causing the problem?