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WHY TWO-WAY RADIO

The need for two-way radio was first recognized by the public safety community. It had its true beginning during the exciting and fast moving Prohibition days of the late 1920s. One reason for this was the automobile, which allowed the "criminals" of the day to be very mobile. On the other hand, few police cars actually patrolled. Instead, they remained at police stations so they could be dispatched by telephone. Such delays offered little chance of criminal apprehension. Repeated attempts to make a radio receiver work reliably in a police car failed.

Success first came in Detroit in 1928 with the first functional mobile receiver. In 1933, the Bayonne, New Jersey police went on the air with the first mobile transmitter, thus completing a two-way system. These early radio systems were amplitude modulated (AM) and had significant receiver stability and sensitivity problems.

In 1940, the Connecticut state police had the first frequency modulated (FM) two-way radio system, developed by Daniel E. Noble of the University of Connecticut.

Paul Galvin, Motorola's founder and president, inspected this new system and promptly brought Dan Noble to Chicago to develop Motorola FM two-way equipment. This new equipment outperformed existing AM equipment under all conditions, including range, and it was quiet where AM was very noisy. FM soon became the standard of the industry.

During the 1940s, the number of different users requesting frequency spectrum for two-way radios grew dramatically. One of World War II's by-products was accelerated radio technology development, especially in mobile radio.

Official recognition of this emerging new class of radio service occurred in 1949 when the FCC established the General Mobile Radio service. There was little awareness that this modest frequency allocation made in 1949 would give rise to a new industry that would join the nation's workforce in serving police, transportation, manufacturing, utilities, media, retail sales, and businesses of every category.

The primary function of virtually all radio systems is to communicate with people on the move. There are two main reasons why people want to do this. People utilize two-way radio both for economic and safety reasons.

Economic reasons include all the ways that two-way radio can be used to cut the costs associated with the user's business operations, and increase profitability. For example, in the delivery or courier business, this means eliminating the wasted time and mileage that a vehicle runs up when traveling empty.

Economic reasons also have another side—profits can be increased with a radio system as the users find they are able to respond more quickly and offer better service than their competitors.

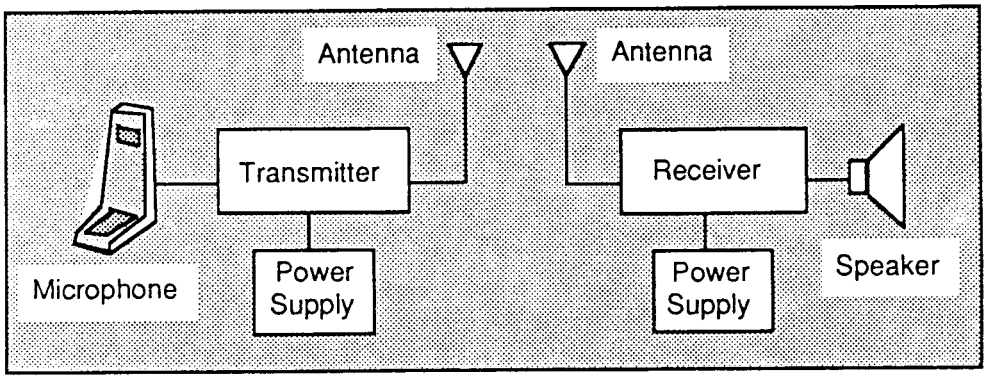
Safety reasons for having two-way radio include the ability to quickly respond to emergency situations. Another reason is the radio system's ability to let the user keep tabs on the personal safety of people in dangerous or potentially dangerous environments. A call for help, or a failure to reply when called, can send support or back-up personnel into that area.

The common denominator to both safety and economic reasons for two-way radio is that ***radio users have improved control over the resources they manage***.

Another aspect of modern two-way radio is the ability to be interconnected with telephone networks. Telephone interconnect allows the radio user to communicate over standard telephone lines from their mobile two-way radios. This capability adds an exciting new dimension to two-way radio.

HOW TWO-WAY RADIO WORKS

For radio communications to take place between two points, we need a transmitter to send the message, and a receiver to pick it up. At the transmitter, a microphone is used to convert the sound of the human voice (or spoken message) into an equivalent electrical signal. However, this signal is too weak, and because it is in the audio range, its frequency is too low to be sent very far. The transmitter processes and amplifies the audio signal into a radio signal and delivers it to the antenna. The antenna radiates the radio signal into the air.



Located at the other end of this simple radio system is the receiver. Now the process is reversed and the receiving antenna picks up the radio signal and sends it to the receiver. Here the radio signal is processed into the original audio signal, which is fed into the speaker so that the original voice message can be heard.

In addition, the transmitters and receivers need a power source from which to operate. Therefore, all radios utilize a power supply. How the radios obtain power depends on the type of equipment and is discussed later.

Converting an audio signal into a radio signal is called modulation. In this process, the message is impressed on a radio frequency (RF) signal called the RF carrier. The RF carrier is usually modulated by a voice message. However, it can also be modulated by tone signals or by digital information. In this manner, data can also be transmitted via two-way radio in addition to voice messages.

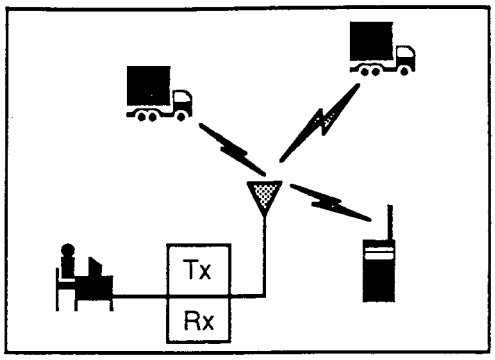
Two basic types of modulation are amplitude (AM) and frequency (FM) modulation. AM is typically used by broadcast stations and in "Citizens Band" radio and is very susceptible to noise and static. FM, on the other hand, is used by broadcast and TV stations, and virtually dominates the two-way market. The most important reason for this is that FM is far less susceptible to noise than AM.

TYPES OF RADIO SYSTEMS

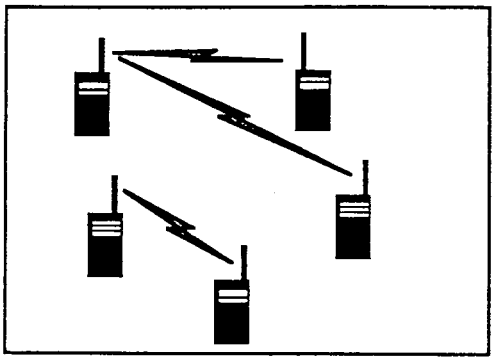
There are three basic types of radio systems:

- Central Dispatch
- Unit-to-Unit
- Paging

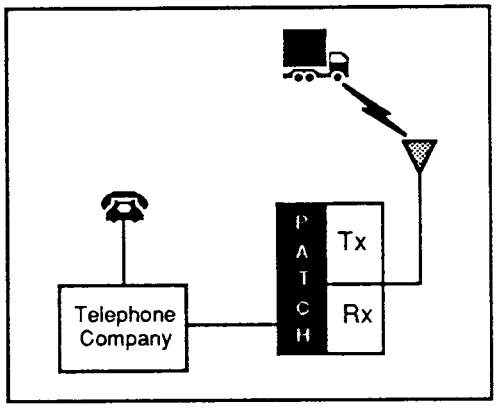
Let's take a quick look at each of these.



The most common type of radio system is the Central Dispatch system. In this type of system, a communications link is established between a dispatcher and people in the field or on the premises. When the dispatcher wants to call one or more people, he or she transmits the message over the radio system. People on the job, with radios tuned to the same frequency, hear the message. Likewise, field personnel may initiate a conversation with a dispatcher or respond to the dispatcher's message. There is no need to find a telephone.

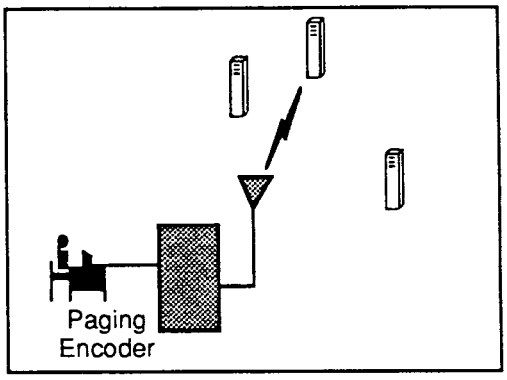


Another basic type of system is a unit-to-unit system. Some systems may not require a central dispatcher, instead field or on-site personnel communicate directly with each other. In this type of system, field people are equipped with two-way radios (mobiles and portables) so that each person has the ability to both talk and listen. In this type of system, everyone in the system can hear each message.



Capabilities such as telephone interconnect can also be added to these basic types of systems. For example, suppose a courier driver needs to call a customer for directions. With telephone interconnect, the driver can use the two-way radio to access two-way equipment in a fixed location which has been equipped with a phone patch. The call request is then automatically interconnected to the telephone company and the call is completed over standard land line service.

Another type of system that we will cover only briefly is a paging system. A radio paging system provides one-way communications to selective individuals.



For example, suppose a manager has the need to contact one or more people in an organization. The page is electronically addressed to the intended person, or group of people. The person, or persons, receive the message on pocket-sized radio receivers called pagers.

Other people with pagers will not be disturbed, or alerted, because the message is not addressed to them. However, unlike a two-way radio system, the people who do receive the paging message must respond by phone or in person since the pagers cannot talk back.

An important point to remember is, that while simple systems do exist as they have been described here, you're much more likely to find that users require a combination of these system to meet all of their communications needs. For example, the field radios in a dispatch system can also have the ability to talk unit-to-unit.

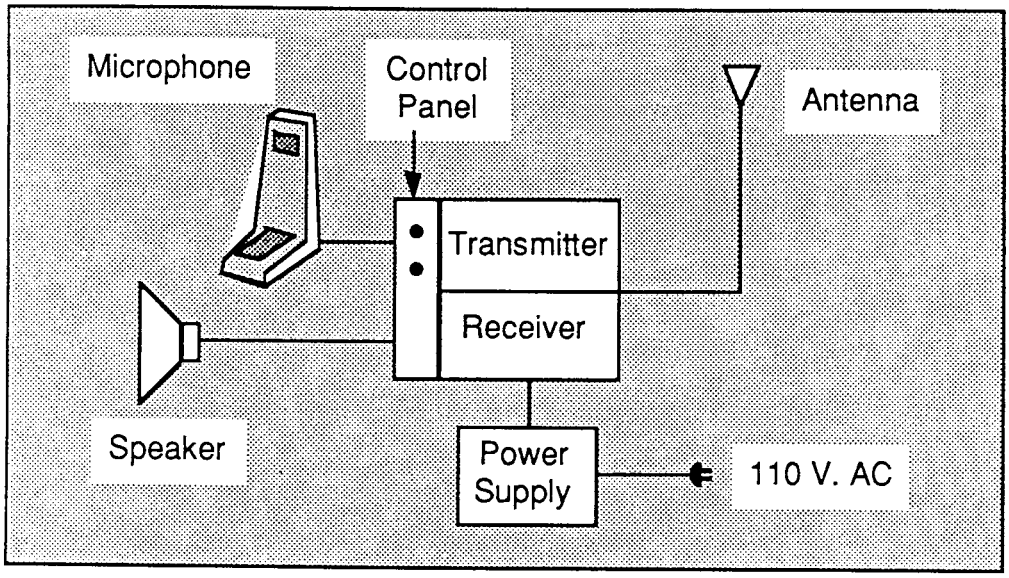
TWO-WAY RADIO EQUIPMENT

For both Central Dispatch and Unit-to-Unit systems, two-way radio equipment is required. That is, these radios must be capable of transmitting and receiving. This equipment can be classified as:

- Fixed
- Mobile
- Portable

Fixed Equipment

The radio equipment located at the central dispatching site is called a base station. Since it is installed in a stationary location, like an office or headquarters, it is often referred to as fixed equipment. It is from this type of radio that a manager, or dispatcher, controls the business operation of the field force.



The base station contains a transmitter, receiver, power supply, and typically has a built-in speaker. The base station is usually powered by a standard 110-volt A.C. power source. A base station microphone and antenna are also required. In a simple system, the base station is merely a mobile unit mounted in a tray with a power supply for desktop use. The term "Control Station" is often used interchangeably with "Base Station."

The base station also includes all radio controls. These are typically contained on a panel on front of the radio and include:

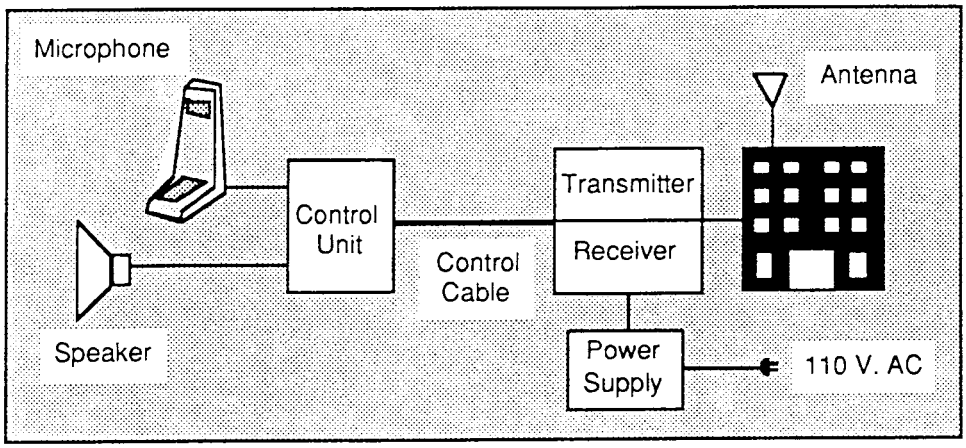
- On/Off Power Switch
- Volume Control

There may also be additional controls (such as a frequency selector) depending on the types of options available on the radio.

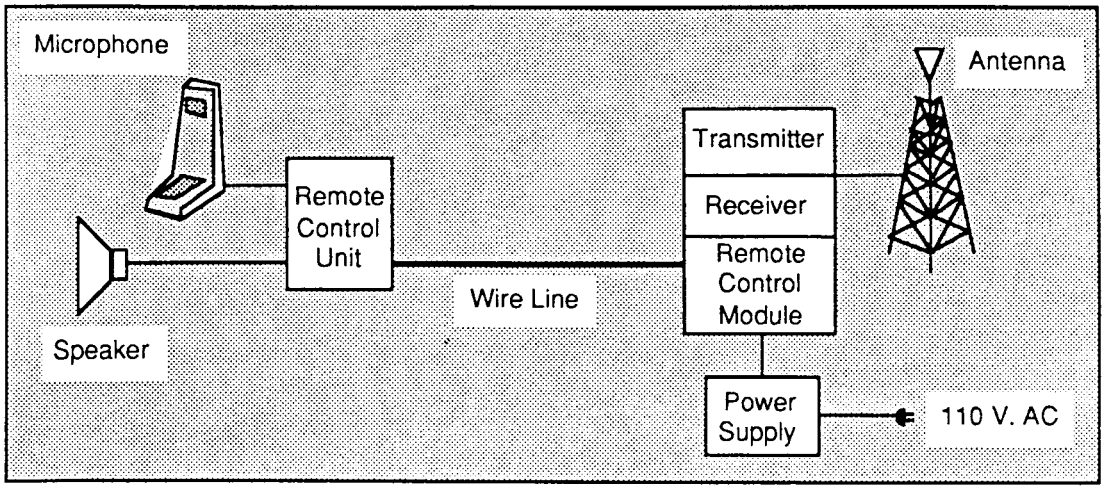
The Volume Control adjusts the speaker output level and the frequency switch is used to change channels if more than one frequency is available in the system. In addition, there is a Push-To-Talk switch on the microphone. This is used to switch the radio from the receiving mode to the transmitting mode.

Using the controls on mobile and portable radios is relatively easy since the radio and antenna are either in the user's hand or in a vehicle. But what happens if the best location for a fixed station antenna is far from the dispatch point? Fixed stations can have a number of different control configurations depending on the location of the antenna site. A ***Local Control*** base station is used when the dispatcher's position is close to the antenna site. In this case, the entire radio unit usually sits on a desk.

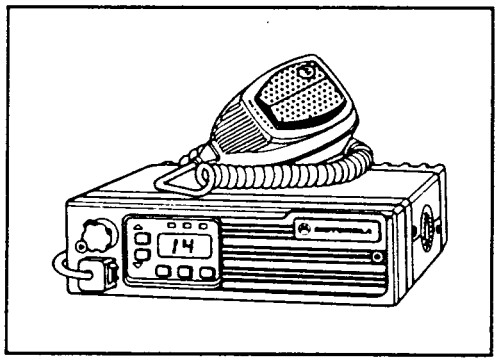
When the antenna site is located away from the dispatcher's position, the transmitter, receiver and power supply sections of the radio are located near the antenna site. The radio's controls are placed in a separate unit at the dispatcher's position. This is referred to as ***Extended Local Control*** and may be used in situations where the dispatch point is up to 1000 feet from the antenna.



For those situations when the antenna site is located even further from the dispatcher's position, such as on a hill top or on the top of a tall building, it may be necessary to use wireline, or lease telephone lines to the radio's transmitter and receiver with the control unit at the dispatch point. A Remote Control Module is added to the base unit to interface with the wire-lines. This type of system is called ***Remote Control***. It is possible to use more than one remote control unit with the same base station so the station can be controlled from several locations.



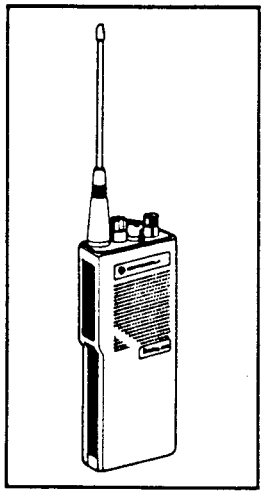
Mobile Equipment



The mobile unit is the type of two-way radio that is installed in the car, truck, or just about any type of vehicle used by the business. Its power comes from the vehicle's battery. Mobile radios contain a transmitter and receiver and usually include the speaker and microphone. Antennas are normally ordered separately. Today, most mobile radios are compact enough to be mounted under, or near, the dash. These radios include a built-in speaker and have the controls located on the front panel.

In some applications, the mobile radios transmitter, receiver, and power supply are mounted in the trunk, or under a seat, etc. The radio's controls are contained in a small ***Control Head*** and are mounted under, or near, the dash. The control head is connected to the main radio unit via cables. An external speaker is also available which is mounted under the dash.

Portable Equipment



A radio unit small enough to be carried around by a person on the job is called a portable radio. A portable radio gets its power from a self-contained battery. The portable unit comes complete with a transmitter and receiver, and has a built-in speaker and microphone. An antenna is attached to the top of the radio.

Basic Considerations Of Equipment Design

Two-way radio equipment is comprised of sophisticated high-technology circuitry. This state-of-the-art circuitry enables the radios to meet all of their associated specifications. One of the most important is that of frequency generation. Until recently, all radio frequencies were crystal controlled. That is, all transmitter and receiver frequencies were determined by silicon crystals which were manufactured to operate at a single specific frequency. If a radio had multiple channels, then multiple sets of transmit and receive crystals has to be installed—one set for each channel.

Many of today's two-way radios are "frequency synthesized." That is, their frequencies are generated and controlled electronically by programmable microprocessor circuits rather than crystals. This allows radios to have much greater frequency, or channel, capability in a much smaller sized unit. For example, it is not uncommon for radios today to have up to 40 channels. This was virtually impossible in older radios. It also provides greater flexibility because a radio's frequency can now be changed (or reprogrammed) as the user's requirements change.

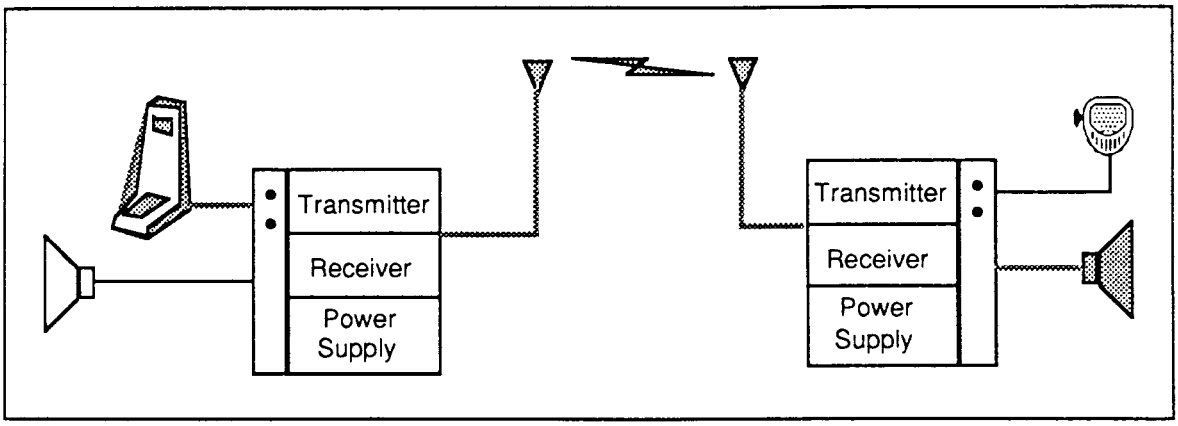
In addition to the frequency generation circuitry, many other circuits in today's radios are controlled by the microprocessor—which is really the "brains" of the radio. This allows many of a radio's functions to be programmed to meet specific user needs.

When determining the best radio to meet a customer's needs, remember that a programmable forty-channel synthesized radio may be overkill if the customer only needs a basic two-channel radio. In many applications, a basic-featured, crystal-controlled radio can sufficiently meet the customer's communication requirements.

A BASIC TWO-WAY RADIO SYSTEM

In a basic two-way radio system a microphone is used to convert your voice into an audio signal which is fed to a transmitter. By a process known as modulation, the audio signal from the microphone is combined in the transmitter with a high-frequency radio signal known as a carrier, because it carries your voice signal. The modulated carrier signal is sent to the antenna which radiates the carrier for reception by mobile or portable radios.

A portion of the radiated carrier is detected, or received, by the receiving radio's antenna. The antenna sends the modulated carrier to the receiver. In the receiver, the audio signal is demodulated, or removed from the carrier, and fed to the speaker which allows the message to be heard. This entire process is reversed if the mobile or portable radio user wishes to respond to the message.



Simplex Radio System

What was just described is the most basic type of two-way radio—the single-frequency simplex system. Two-way simplex systems have the following characteristics.

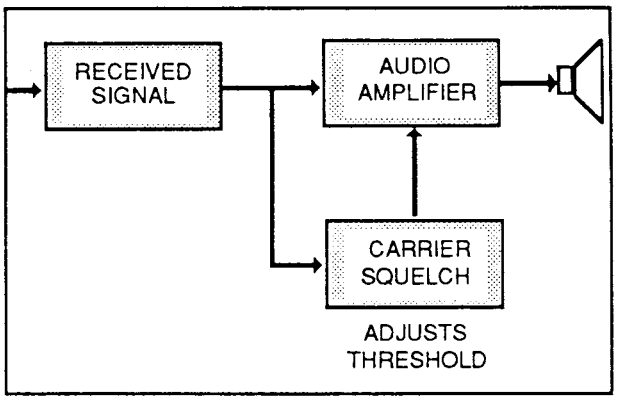
- All units can both transmit and receive.
- Both transmitter and receiver operate on the same frequency.
- You cannot talk and listen simultaneously. ***Simplex means transmission in only one direction at a time.***
- Regardless of the number of radios in the system, only one radio can talk at a time.
- There is no privacy of communications. ***All radios in the system can hear all conversations.***

There are many other types of radio systems available. Some of these are discussed later in this booklet.

SQUELCH

Ideally, radios such as those in the two-way simplex system just described, would receive only those messages they need to hear. Unfortunately receivers hear everyone else's transmission and they also hear any noise that may be present in the radio signal. While nothing can be done to prevent the receiver from hearing all of this, it doesn't mean that the listener has to hear it. By adding special electronic circuitry to the receivers and transmitters, it is possible to reduce, or ***squelch***, unwanted signals before they are heard in the speaker. There are two basic types of squelch:

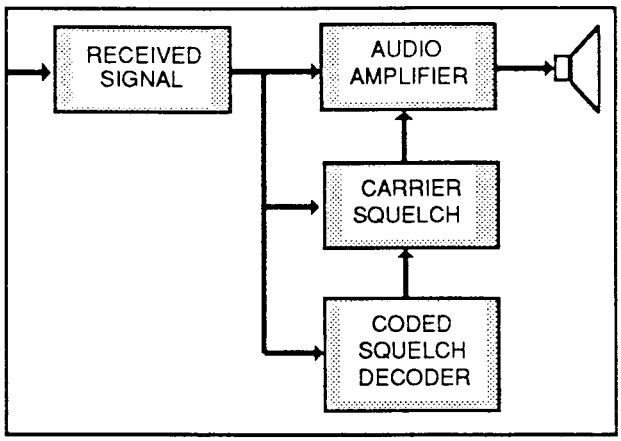
- Carrier squelch
- Coded squelch



Carrier, or noise compensated, squelch, is used to prevent noise from being heard in the speaker when there are no transmissions taking place. On some radios, a squelch control allows the user to adjust the level of the squelch setting. To set squelch, the control is turned until the noise just stops. This position is called ***threshold squelch***, and allows only the stronger message transmissions to be heard in the speaker. Other radios have a preset squelch level which is set to open at a predetermined signal strength.

The disadvantage of carrier squelch is that it cannot distinguish between one message transmission and the other. Remember that there can be many radio users on the same channel. This means that the radio will receive all transmissions on the channel, and they will be heard in the speaker. This can be annoying if there is a lot of activity on the channel.

Coded squelch, on the other hand, allows listeners to hear only those messages intended for them. Like carrier squelch, a coded squelch receiver picks up all messages transmitted on its frequency. However, with coded squelch, the speaker only opens up if the message is received along with a preassigned code. This coded squelch capability is known as Continuous Tone-Coded Squelch System (CTCSS).



Coded squelch requires circuitry in the transmitter. Just as your voice is modulated onto the RF carrier, a coded squelch signal is also modulated and transmitted. At the receiver, the voice and coded squelch signals are demodulated. A decoder in the receiver examines the demodulated squelch code and compares it to its own built-in preassigned code. If the codes match, the speaker opens up and the message is heard.

You can think of coded squelch as the key which opens up the speaker in order to hear a message. An incoming signal on the same frequency with a different code, or no code at all, will not open up the speaker, and will not be heard.

Motorola offers two-types of coded squelch:

- Tone coded, called "Private-Line" (PL)
- Digital coded, called "Digital Private-Line" (DPL)

Tone coded squelch systems use sub-audible tone frequencies. Up to 29 different tone codes are available. Digital coded squelch performs the same function as tone coded squelch but uses one of 80 different digital codes, instead of tones, to open up the receiver.

It is important to remember that even though coded squelch users do not hear other transmissions on the same frequency, those signals are still present. And, while coded squelch systems eliminate the annoyance of listening to other transmissions, they do not provide privacy. In fact, each radio is supplied with a switch that defeats the coded squelch circuit. This is necessary since users attempting to transmit a message must first monitor the frequency for any activity to make sure that it is clear. That is, they must listen to be sure there is no other voice traffic on the channel before transmitting. Otherwise, a transmission already in progress could be overridden, or garbled, by someone else transmitting at the same time.

Selective Signalling

Dispatchers or supervisors often have the need to call an individual unit or a select number of units within a group. To accomplish such a selective call, the target unit, or group, must have a unique identification (ID) code assigned to it. When the radio transmission is sent to the target unit, this ID is sent before the radio message. The target unit is capable of recognizing this particular ID so that the message can be received. Other units in the system will not receive this message unless they are monitoring all activity on the channel.

A selective signalling system includes radios which are capable of sending and/or receiving these unique codes. There are several different signalling schemes available today to accomplish this. One of the signalling types is two-tone sequential (called QuikCall II by Motorola). In this signalling scheme, two tones are sent in sequence, and the receiver responds to the proper combination. Another signalling method is called Dual Tone Multi-Frequency (DTMF). This is the telephone tone system developed by AT&T. Finally, high speed digital signalling schemes are also used. Motorola has its own proprietary signalling format called MDC 1200.

Many of the Radius products have the capability to send and/or receive selective calls. The P50+, P100, and P200 are all sold with the ability to receive QuikCall II messages as a standard feature.

All three of the signalling formats, QuikCall II, DTMF, and MDC 1200 are available with the Radius mobiles if ordered with the signalling package called Radius RapidCall. With this option, the radios can be programmed to both send and receive selective messages and includes other features which are described in detail in a separate Radius RapidCall booklet.

REVIEW QUIZ

Before continuing, take a few minutes to check your understanding of two-way radio. Answer the questions that follow, the check your answers with the Answer key on the pages that follow.

1. A radio system's primary function is to communicate:

   a. With groups of people at the same time.
   b. Along a two-way path.
   c. With only one person at a time.
   d. With people on the move.

2. What are the two main reasons for communicating by radio?

   a. To reduce costs and increase profits.
   b. Economic and safety.
   c. Cheaper and faster than mail.
   d. Wider range and more private than phone calls.

3. Which of the following statements best describes the one benefit radio communications can provide to all managers?

   a. Improves the control over the resources they manage.
   b. Reduces costs and increases profit.
   c. Provides faster response to emergencies.
   d. Prevents vehicles from returning empty.

4. Which of the following types of radio systems require two-way communications?

   a. Paging.
   b. Central Dispatch.
   c. Unit-to-Unit.
   d. Both a and b.
   e. Both b and c.

5. The type of radio installed in an office or at headquarters is called:

   a. A mobile unit.
   b. A portable unit.
   c. A fixed station.
   d. A receiver.

6. In a mobile unit, the primary source of power is:

   a. The vehicle's battery.
   b. A self-contained battery.
   c. An AC line.
   d. A DC line.

7. A radio unit carried by a guard, or foreman, or someone on the job is called a:

   a. Mobile unit.
   b. Base station.
   c. Fixed station.
   d. Portable unit.

8. The type of radio unit installed in a car or truck is called a:

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   d. Portable unit.

9. A fixed station receives its primary power from:

   a. The vehicle's battery.
   b. A self-contained battery.
   c. An AC line.
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10. In a radio communication system, the audio is added to the radio signal in the transmitter and sent to the:

    a. Microphone.
    b. Transmitter.
    c. Speaker.
    d. Antenna.

11. In a radio communication system, the audio is separated from the radio signal in the receiver and sent to the:

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12. Amplitude modulation is less susceptible to noise and interference than frequency modulation.

_____ True _____ False

13. Telephone interconnect allows two-way radio users to make telephone calls over standard land line telephone company circuits.

_____ True _____ False

14. In order to change (or reprogram) frequencies in a "Frequency Synthesized" radio, the crystals must be changed.

_____ True _____ False

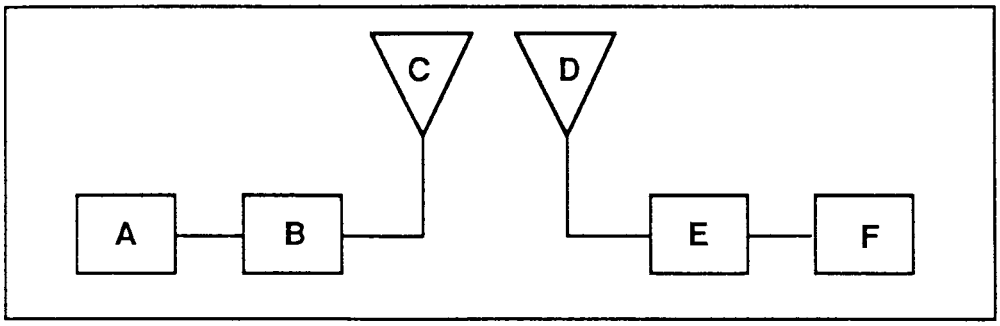
15. The Radius RapidCall feature can accommodate QuikCall II, DTMF, and MDC 1200 signalling schemes.

_____ True _____ False

16. To receive a selective call, the radio must have a unique ID code.

_____ True _____ False

Use the following diagram to answer the remaining questions.



17. With what letter is the receiving antenna labelled?

    a. A.
    b. B.
    c. D.
    d. E.

18. With what letter is the speaker labelled?

    a. A.
    b. B.
    c. E.
    d. F.

19. With what letter is the microphone labelled?

    a. A.
    b. B.
    c. E.
    d. F.

20. With what letter is the transmitting antenna labelled?

    a. B.
    b. C.
    c. D.
    d. E.

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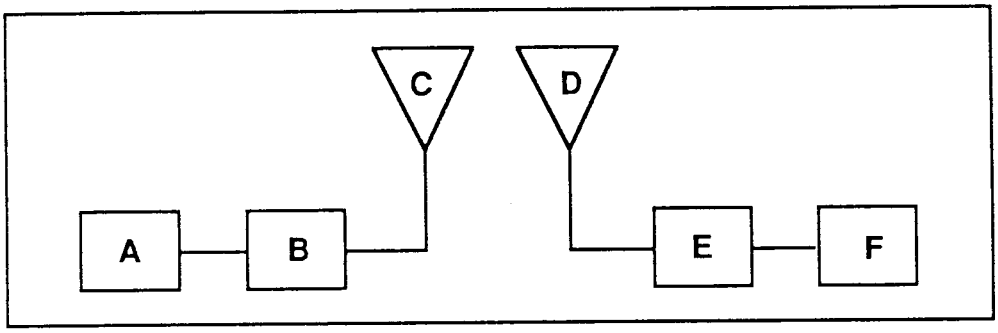
___✔___ True _____ False

Use the following diagram to answer the remaining questions.



17. With what letter is the receiving antenna labelled?

a. A.
b. B.
c. D.
d. E.

18. With what letter is the speaker labelled?

a. A.
b. B.
c. E.
d. F.

19. With what letter is the microphone labelled?

a. A.
b. B.
c. E.
d. F.

20. With what letter is the transmitting antenna labelled?

a. B.
b. C.
c. D.
d. E.

FREQUENCY, SPECTRUM AND THE FCC

The RF (Radio Frequency) signal that is radiated from the radio's antenna begins in the transmitter's electronic circuits. In order for the signal to be able to break away from the antenna and an become a radio wave, the signal is driven back and forth by the transmitter at a very high speed. The rate at which the signal moves, or oscillates, back and forth is called its frequency. Each complete back and forth movement is called a cycle. Thus, if a signal moves back and forth at a rate of 1000 times per second, it has a frequency of 1000 cycles per second. The term for "cycles per second" is Hertz. Therefore, the frequency would be 1000 Hertz. Most two-way radio signals are in the millions of cycles per second range. This is referred to as a MegaHertz and is abbreviated MHz. You will often see the terms kiloHertz (kHz) which is 1000 Hertz, and GigaHertz (GHz) which is 1,000,000,000 Hertz.

The electromagnetic spectrum is the total range of frequencies of electromagnetic radiation and extends from the longest radio wave to the shortest cosmic ray. For example, the light falling on this page is part of the electromagnetic spectrum and lies between 600,000 GHz to 900,000 GHz. The diagram on the following page shows the major portions of the spectrum.

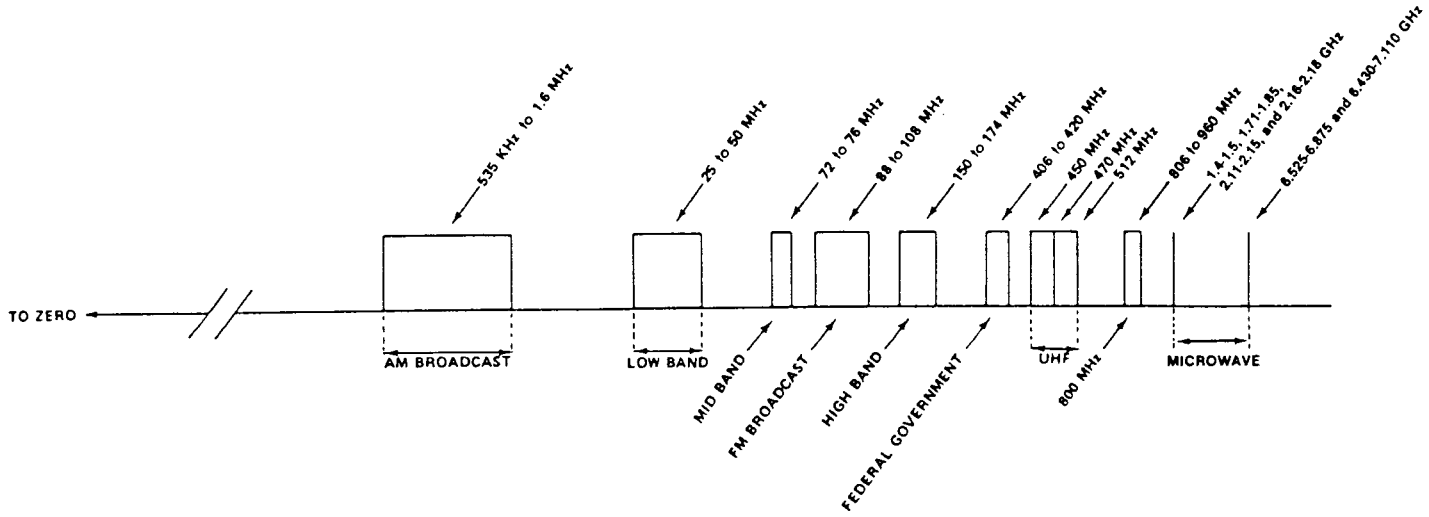
The spectrum is divided into segments called bands. The part of the spectrum we are concerned with are the frequency bands used for radio communications. These are identified as follows:

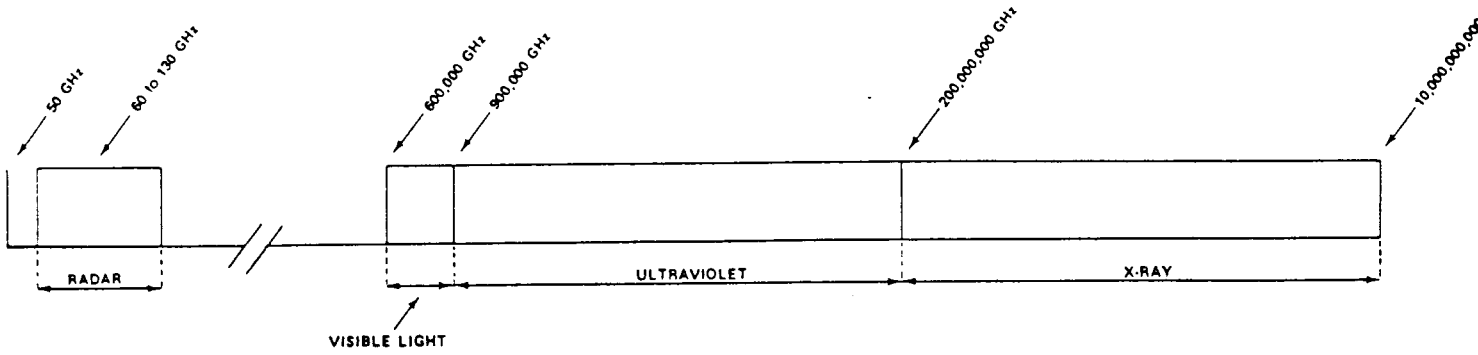
30 kHz	Very Low Frequency (VLF)
30 - 300 kHz	Low Frequencies (LF)
300 - 3,000 kHz	Medium Frequencies (MF)
3 - 30 MHz	High Frequencies (HF)
30 - 300 MHz	**Very High Frequencies (VHF)**
300 - 3,000 MHz	**Ultra High Frequencies (UHF)**
3 - 30 GHz	Super High Frequencies (SHF)
30 - 3,000 GHz	Extremely High Frequencies (EHF)

The frequency bands that Radius Radios operate in are the VHF and UHF bands. These bands are further broken down as follows:

Band		Frequencies
VHF	Low	25 - 50 MHz
	High	150 - 174 MHz
UHF		406 - 420 MHz
		450 - 470 MHz
		470 - 512 MHz
	800 MHz	806 - 960 MHz

SIMPLIFIED SPECTRUM CHART





Although not technically accurate, the labels for each band in common usage today are shown in the chart below. Each of these specific bands have characteristics which offer advantages and disadvantages to radio users.

	Low Band 25 - 50 MHz	VHF 150 - 174 MHz	UHF 450 - 512 MHz	800 MHz
Interference	Severe	Minimum	None	None
Antennas	Long Low Gain	Short High Gain	Short High Gain	Short High Gain
Rural Range	Excellent	Good	Fair	Fair
Suburban Range	Good	Excellent	Good	Fair
Urban Range	Poor	Good	Excellent	Excellent

Each of these bands is further subdivided into many single frequency channels, or in some case, pairs of single frequency channels. Because there is a finite number of available frequencies, most channels are shared by several groups of users.

Channel loading is a term used to describe the number of users assigned to the same frequency. Channel loading is so heavy in some parts of the United States that additional users are no longer allowed on particular channels. Therefore, although a user may qualify for a frequency, the user might be better off going to another frequency, band of frequencies, or another type of system because of severe channel loading. The use of these channels is authorized and licensed by the Federal Communications Commission (FCC).

The FCC

In the United States, the Federal Communications Commission (FCC) is charged with regulating communications by radio, television, wire, satellite, and cable. Although the term "radio" initially brings to mind broadcast or commercial radio, it also includes two-way radio. The FCC, which was established by the Communications Act of 1934, is an independent United States Government agency responsible directly to Congress.

Most two-way communications systems fall within the jurisdiction of the FCC's Private Radio Bureau. This bureau regulates radio communications for users in the Land Mobile Radio Services. The purpose of these regulations is to help avoid interference, while at the same time offering each user an effective radio system.

A brief history might give you a better understanding of how all of the frequency bands described in the previous section evolved and why the rules governing these bands differ.

Low band was the first frequency band utilized and was primarily used for police and the military. After World War II in 1945, the FCC opened up the 152 - 162 MHz high band spectrum to meet the "Emergency Radio" requirement. In 1946, taxi-cabs were authorized to use two-way radio equipment. In the following years, the FCC expanded the use of two-way radio to support commercial service to the public enabling many more types of users to become eligible to operate two-way equipment.

In 1952, the FCC opened up the 450 - 470 MHz band. These channels are assigned in frequency pairs with transmit and receive frequencies spaced 5 MHz apart to better accommodate high power fixed equipment and extended coverage. In the 12 largest cities, where the channel congestion is especially severe, certain channels in the 470 - 512 MHz range can be used for two-way radio. More recently, the advance of technology and growing requirements for more channels resulted in allocations of the 800 and 900 MHz spectrum.

As you can see, spectrum allocations were an evolutionary process and each time a new allocation was made, the rules for frequency assignment and usage were somewhat modified to take advantage of improved technology and increased experience. One of the most important tasks of the FCC is to improve spectral efficiency to somehow meet the growing needs of all competing users. Another critical task is the licensing of all users to maintain the orderly use of the frequency spectrum. Just as you must be licensed to operate certain types of businesses, a potential radio user must learn about FCC regulations and be licensed prior to operating a radio system.

FCC Licensing Information

Radius radios operate on FM radio communications frequencies and are subject to the rules and regulations of the FCC. The FCC requires that all operators using Private Land Mobile or General Mobile Radio frequencies obtain a radio license before operating their equipment. Application for an FCC license is made on FCC Form 574 for low band, VHF, and UHF frequencies. For a license in the 800 MHz band, Form 574 and Supplemental Form 574-A must be used. These forms as well as a booklet titled "Form 574 Instructions" can be obtained from the FCC Supply Section, Administrative Services Division, 1919 M St., NW, RM B-10, Washington DC 20554; telephone 202-632-7272.

To receive a license to operate radio equipment in the Private Land Mobile Service, the user must be engaged in any of a wide range of commercial, institutional, or government activities. This qualifies one to obtain a license or, in other words, determines ones eligibility. The license is then granted to operate on a particular frequency, or set of frequencies, and under a specific eligibility. The FCC rules are contained within the Code of Federal Regulations and the Private Land Mobile Services are described in Part 90. The following subparts describe general eligibility requirements.

Subpart B:	Public Safety Radio Services
Subpart C:	Special Emergency Radio Services
Subpart D:	Industrial Radio Services, which include among others, Business, Manufacturers, and Special Industrial Services
Subpart E:	Land Transportation Radio Service

The General Mobile Radio Service frequencies consist of 8 UHF frequency pairs. This service is described in Part 95 of the Code of Federal Regulations. Eligibility to be licensed for these frequencies is limited to personal and non-profit applications.

Frequencies may be selected by the potential user or by an FCC designated group. But in all cases, the frequencies must be approved by this group which is called a frequency coordination agency. Their task is to "coordinate" frequency assignment to avoid interference and channel congestion. Once a license application form is completed, it must be forwarded to the appropriate frequency coordination agency which is determined by the operator's eligibility classification. The coordination agency assigns a frequency, or frequency pair, to the application and forwards it to the FCC for final processing. There is a frequency coordination fee which must be included with the license application.

An exception to the requirement for frequency coordination in the Private Land Mobile Radio Services is licensing for use of itinerant frequencies. *Itinerant operation is defined by the FCC as operation of a radio station at unspecified locations for varying periods of time. Those applications do not need frequency coordination and may be sent directly to the FCC. Frequency coordination is also not required for licenses in the General Mobile Radio service and these applications are also sent to the FCC.*

The FCC charges a processing fee for all new, modified, or renewal license applications. This fee is payable by check or money order made out to the "Federal Communications Commission" and ***must*** be enclosed with the application. Any application without a check will be returned. (Exception: Applicants who are government entities and all applicants in any Public Safety or Special Emergency Radio Service are exempt from the FCC license fee.) Applications requiring coordination must have the FCC check, as well as the coordinator's check, attached when mailed to the coordinating agency. The coordinating agency will remove their check and will forward the coordinated application and FCC check on to the FCC Licensing Division. Upon grant, the FCC will mail the radio station license to the address shown on application Form 574.

RANGE AND COVERAGE

The purpose of a radio system is to provide communications over a distance. How far we are able to communicate, and to where we can communicate, therefore, become prime considerations. These are determined by the radio system's range and coverage area. There are a number of factors that affect range and coverage.

Frequency Band Selection

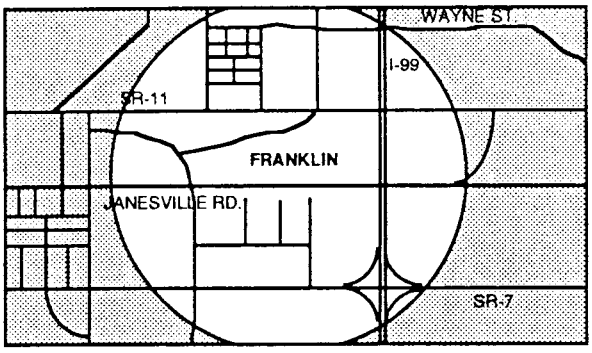
The first step in selecting a frequency band is to determine the category of user for which the radio system is eligible. The FCC rules for that category of users lists the available channels for which an organization can apply. It also points out any limitations on use of the channels. For example, assume a user wants to talk from a base to a mobile. If the user is located in a medium sized community, say up to 100,00 or even 200,000 population, and he desires coverage of the city and the surrounding area, you might select a VHF high band channel if available. If the user desires coverage of the downtown area of a larger city, and has available a high antenna site such as a tall building, the best band selection would be UHF. This is because radio waves in the UHF frequencies do a good job of radiating around tall buildings. If the user were located in the suburbs of a large metropolitan area, and desired coverage of that suburb and the immediate surrounding area, high band would probably be the best selection.

Factors such as available antenna sites, future expansion of the area, and the local noise problems will all affect the frequency band choice. Of course, channel availability is the primary consideration.

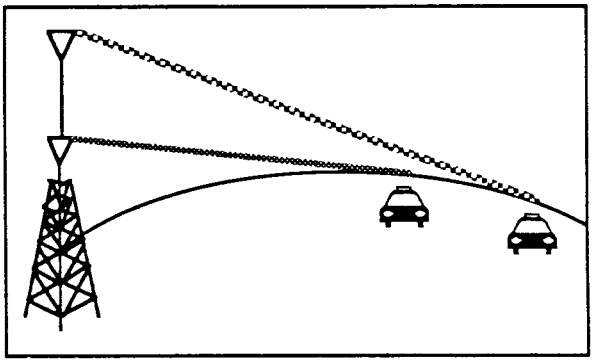
Antennas

Antennas radiate energy in all directions, much like a light bulb radiates light. A mobile radio moving further away from the transmitting antenna receives less and less radiated energy. This distance from the antenna is known as range. At some point, a radio moving away from the base antenna receives too little energy for reception, or is unable to generate enough energy from its own antenna to talk back to the base station. That radio has reached the limits of its range.

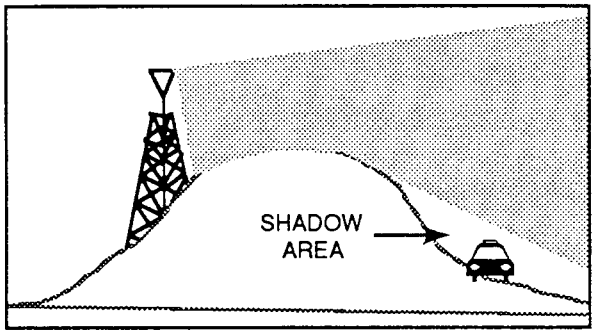
If you think of range as the radius of a circle, the circle itself will be the coverage area. In a radio system, this circle drawn on a map indicates the usable area of the radio system. Range is affected by many different factors.



The most critical coverage factor is base station antenna height and location. This is because the range of a radio system is theoretically limited to the radio horizon as seen by the radio antenna. Thus the range of a radio system, for the most part, depends upon the effective height of the base station antenna. This is because other factors such as increased base station power do not increase range both ways. Basically the higher up in the air that an antenna can be installed, the greater an area that will be covered. This is because the radio waves follow a line-of-sight path.



Terrain variations can cause difficulties in communications. Hills and valleys create shadows in a coverage area. These shadow areas are often called holes. Tall buildings can also have the same effect on coverage.

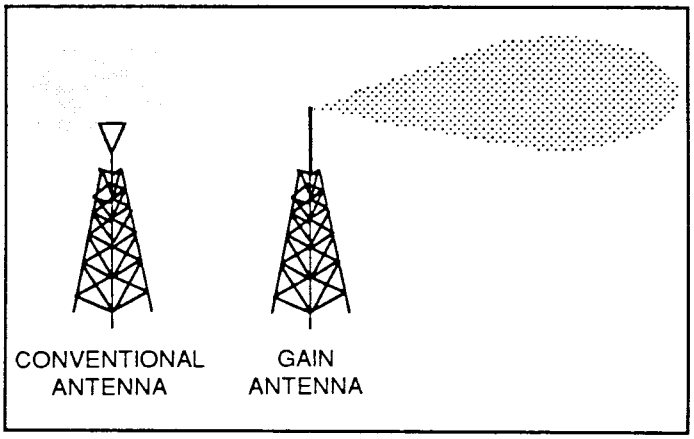


In the case where a hill causes a shadow, or hole, if we raise the antenna height, we can eliminate most of the hole. Thus, antenna height, to a large extent, cures terrain problems.

In addition to the height of an antenna, its location is also important. For example, selection of a three thousand foot hill for an antenna site would serve little purpose if it was surrounded by five thousand foot mountains. Less obvious is the necessity for avoiding noisy locations. By noise we mean interference of any and all types. Some causes of electrical noise are power lines, neon signs, electric motors and other radio systems.

Noise also affects radio system coverage. Noise is the unwanted energy generated by such things as sunspots, other radio frequencies, and electrical equipment. Did you ever have someone turn a vacuum cleaner on while watching television? If so, you might have noticed that the vacuum cleaner motor generates too much electrical noise and reduces the clarity of the signal your television receives.

Much of what we do to reduce noise problems is part of the electrical design of the radio equipment. Intelligent system design can also help. Remember, we said that at some point, a radio moving away from the base station antenna eventually receives too little energy for effective communications reception. Noise problems at these limits of the coverage area can be severe. The noise level is simply higher than the received energy level. Noise problems are also severe near noise sources, such as electrical generating equipment. In fringe areas, increasing transmitter power will increase the energy level at the receiving radios antenna, and will help to overcome the noise.



Increasing transmitter power is not always economically feasible, nor is it always allowed by the FCC. Another way to overcome this problem is through the use of ***Gain Antennas***. Gain represents an antenna's ability to increase its effective radiated power. This is done by channeling the antenna's radiation pattern in a particular direction and thus extending the distance it will cover. The use of a high gain antenna ensures better reception in the fringe areas of a system.

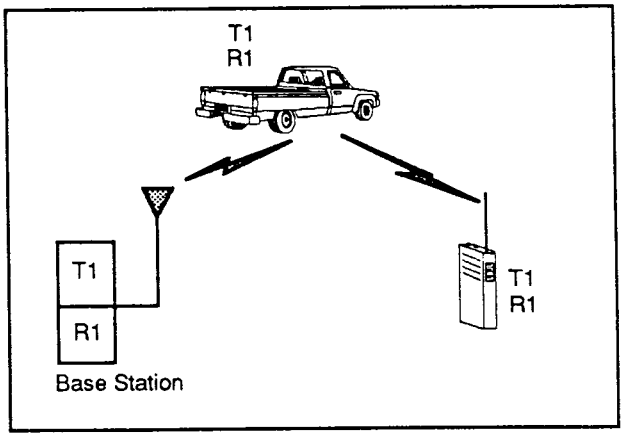
Defining Coverage Area

Coverage area is a statement about our confidence in what kind of communications can be expected in an area. We could say that 90% of the time, in 90% of the locations, a radio will be able to communicate. This is an expression of statistical probability in terms of time and area. If the customer can accept a lower quality of service, say 80% and 80%, usually we can cover a larger area. However, we generally recommend 90% time and 90% area coverage as the most preferable grade of service. The most desirable two-way radio system meets the customer's specific communication's requirements for the lowest cost.

TWO-WAY RADIO SYSTEMS

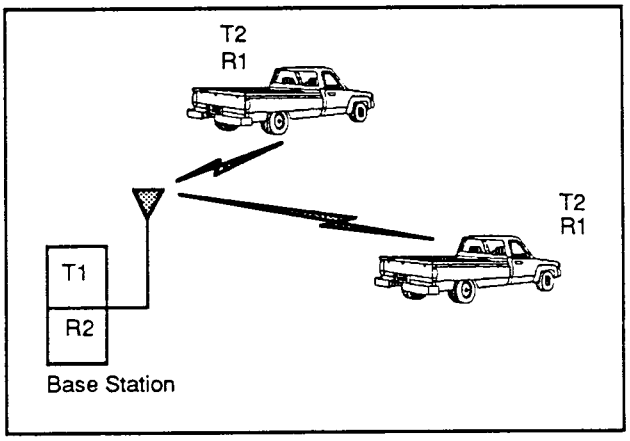
The basic radio system that was described earlier may not meet the customer's communications needs. Other types of two-way radio systems may be required. Let's take a quick look at a few of these.

Simplex



The simplex system is the simplest form of radio communications. It consists of two or more radio units operating on a single frequency. One or more units may be base stations, and one or more may be mobile units or portable units. Because everyone is transmitting and receiving on the same frequency, vehicles can hear other vehicles if they are within range. A large communications system may use several different simplex frequencies to cover different areas.

Two-Frequency Simplex



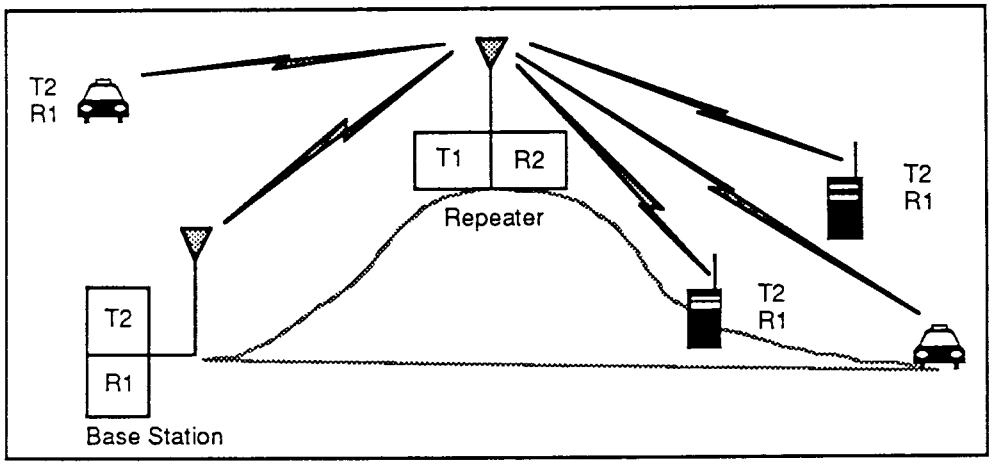
In this type of system, the transmitters operate on one frequency, and the receivers operate on another frequency. This type of system is used when the dispatcher must control the system. In this system, the base station transmits on frequency 1, and the mobile receives on frequency 1. Likewise, the mobile transmits on frequency 2 and the base station receives on frequency 2. The mobile units cannot hear each other because their receivers are operating on a different frequency than their transmitters. The dispatcher is the only person who can hear all traffic.

Repeaters

A radio repeater is a special type of base station remotely located from the system's base of operations. The repeater consists of a transmitter and receiver, just as any base station does. However, it operates a little differently. When the repeater receives a signal from the base station, or a mobile unit, it immediately retransmits that signal. It acts as a relay.

The repeater operation is called duplex because it can receive and transmit at the same time. The radio system is called half-duplex since the mobile and portable units are still simplex. Some repeaters use two antennas, one to receive and one to transmit. The diagram below shows one antenna to do both at the same time. This is possible when the repeater is equipped with a "duplexer."

Properly located on a high building, tower, or mountain top, a radio repeater will increase the operating range of a communications system. In addition, a radio repeater can get a radio signal into what would otherwise be dead spots, or remote areas that normally can't be reached by a typical two-way radio system. A radio repeater, therefore, is an excellent way to extend the range of a radio system, to improve mobile-to-mobile, portable-to-portable, or base-to-mobile/portable communications.



The most common type of repeater is used to relay messages between mobile or portable units. In this type of system, the mobile transmitters operate on one frequency, and the mobile receivers operate on another. The repeater transmitter operates on the mobile units' receiver frequency. When the repeater receives a signal from a mobile unit, its transmitter is turned on, and the message repeated, typically at a higher power and from a better vantage point than the originating mobile unit. In this type of system, all mobiles and portables communicate through the repeater.

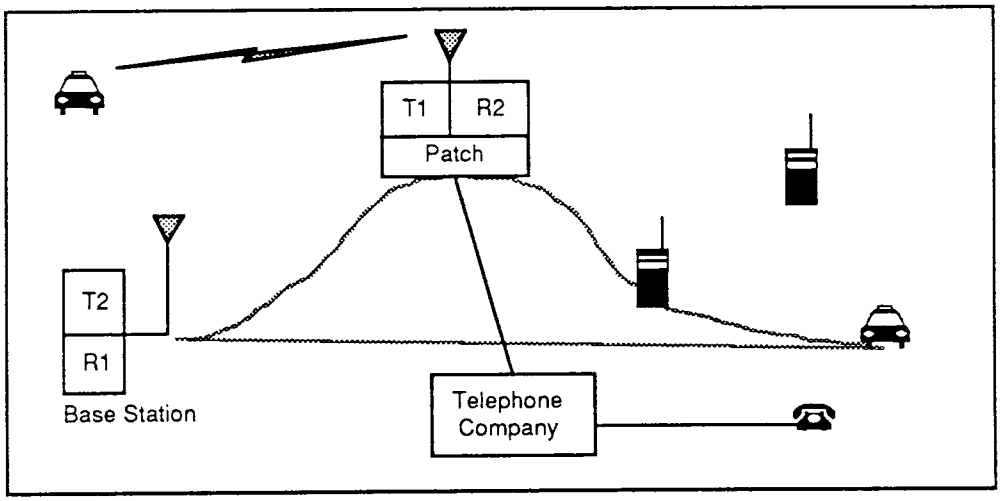
In some systems, the mobile unit's radio can be switched to transmit on the mobile receiver frequency, so that mobile-to-mobile communications is possible. This allows mobile units to talk with one another when they are out of range of the repeater and is called "Repeater Talkaround."

Community Repeaters

One way to obtain the benefits of a repeater system without the expense is through the use of a Motorola Community Repeater. A community repeater allows a number of users to share a repeater system. This allows users to buy only a small local control station and the number of mobile or portable units desired instead of purchasing an entire repeater system. The users then rent space on the community repeater and pay only a nominal monthly fee.

Telephone Interconnect

Many two-way radio systems can be enhanced by a telephone interconnect option. As the name implies, telephone interconnect allows the mobile or portable radio user to place and receive standard telephone calls. In order for this to work, a special piece of equipment called a patch is required. It is this device that connects the telephone lines to the base station or repeater. Designated mobile users can then use Touch-Code microphones which provide both two-way radio capability as well as simplex car telephone service. Portables users have a special keypad on the portables that allow them to use the telephone interconnect feature.



SUMMARY

This booklet has provided you with an introduction to the basics of two-way communications. The two-way radio systems available today are extremely sophisticated and provide the user with a wide range of communications capabilities. It is important that you understand these capabilities, and how and when they should be used. There are also many additional aspects of two-way radio that have not been covered. However, by understanding the information presented here, you will have built a strong foundation with which you can better help your customers meet their communications needs.

The glossary which follows contains two-way radio terms, abbreviations and acronyms which you can use as a helpful reference tool for better understanding two-way radio.

REVIEW QUIZ

Take another few minutes to check your understanding of two-way radio. Answer the questions that follow, the check your answers with the Answer key on the pages that follow.

1. What are the frequency bands we deal with in the Land Mobile Services?

   _____
   _____
   _____
   _____

2. Why is spectrum allocation important?

   _____
   _____

3. What governing body in the United States controls frequency allocation, rules, and regulations?

   _____

4. Which of the following is **not** a characteristic of the UHF band?

   a. Least susceptible to noise.
   b. Limited range.
   c. Good metropolitan signal penetration.
   d. Not affected by terrain and foliage.

5. Which of the following is **not** a characteristic of the Low band?

   a. Greatest range.
   b. Good penetration in urban areas.
   c. Best vehicle to vehicle coverage.
   d. Highest noise level.

6. A _____ antenna can improve reception in fringe areas.

7. Which of the following is a consideration in determining range and coverage?

   a. Frequency band.
   b. Antenna type.
   c. Antenna location.
   d. All of the above.
   e. Only a and b above.

8. Range can be increased by increasing antenna height and/or base station power.

   _____ True _____ False

9. The distance from a transmitting antenna is called the range.

   _____ True _____ False

10. Terrain variations do not affect communications.

    _____ True _____ False

11. In a simlex system, vehicles can talk and listen at the same time.

    _____ True _____ False

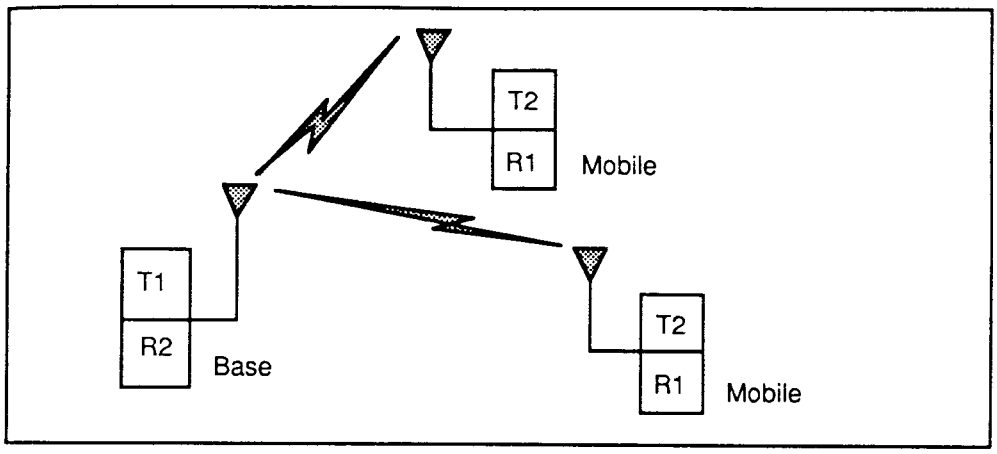
12. In a simplex system, vehicles can communicate with each other if they are within range.

    _____ True _____ False

13. Potential radio system users must be _____ prior to operating a radio system.

14. Hills and valleys create _____ in a coverage area.

15. Repeaters are used to extend the _____ of a communications system.

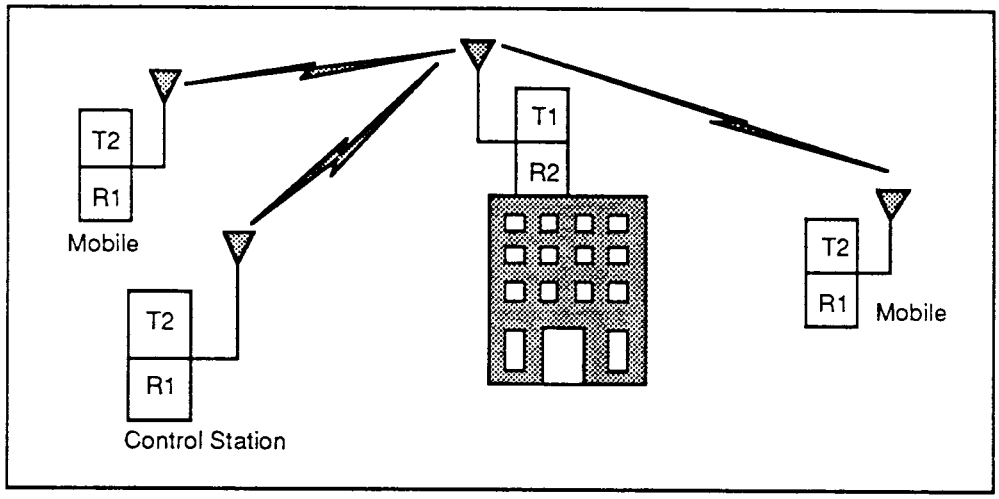


16. In the above diagram, which type of system is shown.

    a. Simplex
    b. Two-frequency simplex
    c. Repeater
    d. Telephone interconnect

17. In the above system, the mobile units can communicate with each other.

    _____ True _____ False



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    a. Simplex
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19. In the above system, the mobile units can communicate with each other.

_____ True _____ False

20. An economical means of obtaining the benefits of a repeater system is through the use of a _____ _____ system.

REVIEW QUIZ ANSWER KEY

Check your answers to the Review Quiz with the answers on the pages that follow.

1. What are the frequency bands we deal with in the Land Mobile Services?

   Low Band
   High Band
   UHF
   800 MHz

2. Why is spectrum allocation important?

   Ensures all users an effective radio system.

3. What governing body in the United States controls frequency allocation, rules, and regulations?

   Federal Communications Commission (FCC)

4. Which of the following is **not** a characteristic of the UHF band?

   a. Least susceptible to noise.
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8. Range can be increased by increasing antenna height and/or base station power.

   __✔__ True _____ False

9. The distance from a transmitting antenna is called the range.

   __✔__ True _____ False

10. Terrain variations do not affect communications.

    _____ True __✔__ False

11. In a simplex system, vehicles can talk and listen at the same time.

    _____ True __✔__ False

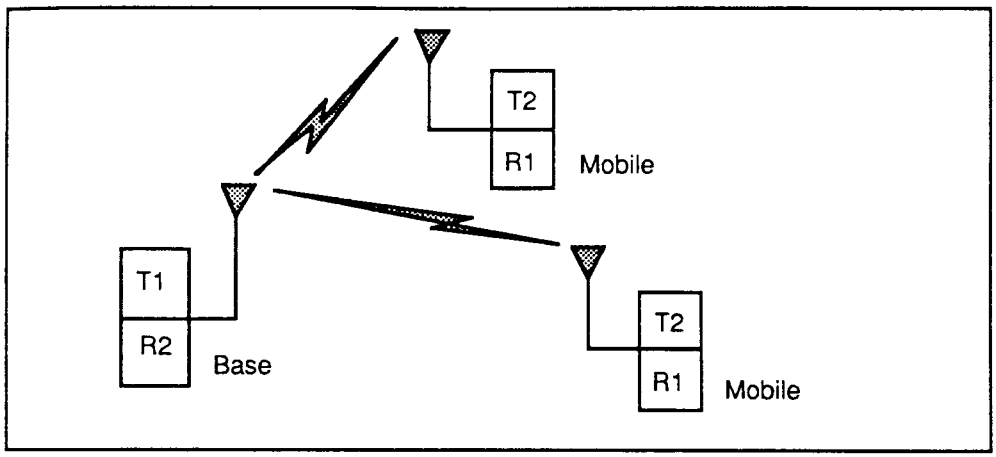
12. In a simplex system, vehicles can communicate with each other if they are within range.

    __✔__ True _____ False

13. Potential radio system users must be ___*Licensed*_____ prior to operating a radio system.

14. Hills and valleys create ____*Shadows*___ in a coverage area.

15. Repeaters are used to extend the _____*Range*_____ of a communications system.



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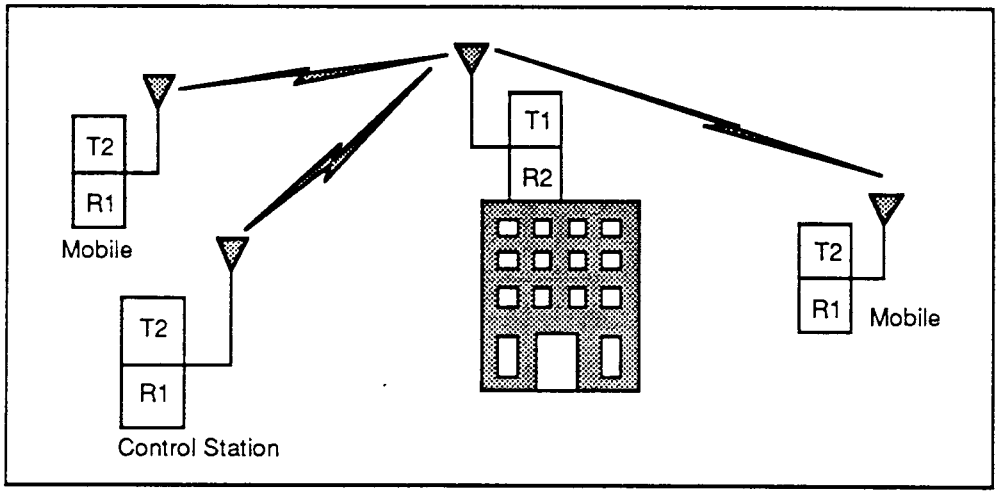

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    a. Simplex
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    c. Repeater
    d. Telephone interconnect

19. Repeaters can be used to extend the range of a system.

✔ True _____ False

20. An economical means of obtaining the benefits of a repeater system is through the use of a ***community*** ***repeater*** system.