CHAPTER 2.--COMMUNICATION SYSTEMS

2.1 Introduction

Any communication system requires at least three elements in order to function: a transmitting device, a receiving device, and a transmission line or propagation medium. Even the device children use, tin cans connected with string, consists or these three elements. One speaks into one can (transmitter), which vibrates at the same frequencies as the voice. The string (transmission path) picks up the vibrations of the can and carries them along its entire length. The other can (receiver) detects the vibration and reproduces the original sounds to a lesser extent depending on distance, tightness of string, type of string, etc. All communication systems depend on these three elements: transmitter, transmission path, and receiver.

Communication systems can be divided into three fundamental categories: wired phone systems, radio systems, and carrier current systems. Sections 2.2, 2.3, and 2.4, respectively, describe these systems and explain the basic principles of how each works.

Hybrid systems are those systems that use various combinations of the three basic communication methods. Hybrid systems are described in section 2.5.

There are some other methods of signaling (stench warning, bell signaling, etc.) that can be used in underground mines to transmit or convey information. These systems, although they cannot be considered true communication systems since they do not provide voice or even two-way communication, are briefly described in section 2.6.

2.2 Wired Phone Systems

Wired phone systems are all those that depend on a wire connection between phones with the wire carrying the voice signals. Figure 2-1 is a diagram of two typical wired phone systems. The top panel shows a simple single pair party line system. In this system each phone is connected to a common pair of wires, and a person speaking into one phone will be heard at all the other phones on the line. The bottom panel shows a multipair private line phone system. In this type of system, each phone is connected by its own individual pair of wires to a central switch or telephone exchange. To establish a call between two phones in this system, the lines between the two phones must be connected (switched together) within the telephone exchange.

In early exchanges, the connections were made manually by an operator. These exchanges are called Private Branch Exchanges (PBX's). Today, equipment within the exchange can automatically connect each phone to any other phone in the system. These exchanges are called Private Automatic Branch Exchanges (PABX's). There are many different types of automatic exchanges. Some utilize switches to physically make each connection according to the number dialed. Other, more advanced exchanges are completely solid state and may even be computer controlled.

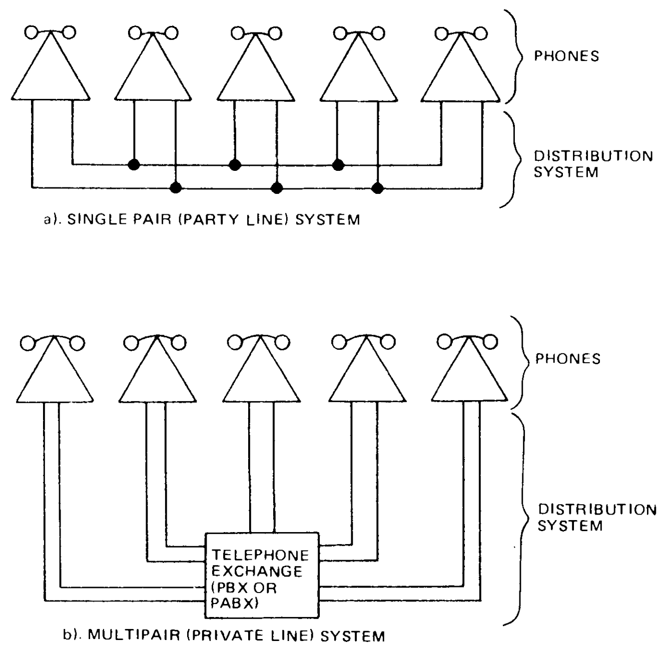

FIGURE 2-1. - Wired phone systems.

Telephone exchanges are described in section 2.2.3. The various types of phones in use today and a description of how they operate is given in section 2.2.1. Distribution systems are described in section 2.2.2.

2.2.1 General Telephone Theory

There are many different types of phones in use today, including

Magneto type

Sound-powered

Paging

Dial

Dial-and-page

These phones and the basic principles of how they operate are described in the following paragraphs.

2.2.1a Magneto-Type Telephones

One of the earliest types of underground communication instruments was the magneto phone, also known as the crank ringer phone. These phones consisted of a transmitter, receiver, hookswitch, ringer, battery, and hand generator (magneto). As the spindle handle was turned, 80 to 100 volts at 15 to 18 cycles per second was produced by the magneto. This current caused the other phones to ring. Once the called phone was answered, talking power was supplied by battery voltage.

Magneto phones were connected in party line fashion with a code of short and long rings to identify the called station. Some mines still use this type of system. However, as mines expanded in size, the system proved to lack adequate signal strength to power a large number of phones.

2.2.1b Sound-Powered Telephones

A sound-powered set is one that provides a means of voice communications with the use of no energy except that furnished by the speaker's voice. These phones have highly efficient transmitters and receivers for converting voice into electrical signals.

The sound-powered handset is comparable in size and appearance to the familiar battery-powered handset. Two of these phones were usually connected by a single line to constitute an intercom circuit. Such a circuit will reproduce speech with reasonable good quality for short distances in quiet surroundings.

For special communication applications requiring exceptionally rugged and durable sets for private communication purposes, and particularly when the line loops are short, sound-powered sets are well adapted.

Sound-powered sets find their principal application in mines, as independent intercom systems. The simplicity and convenience of operating without batteries and the service reliability and ruggedness of the sound-powered telephone when used in adverse surroundings are points in their favor.

2.2.1c Paging Telephones

The most common type of communication system used in underground mines is a paging telephone system. These phones are sometimes referred to as squawk phones or squawk boxes because of the harsh sound of the speaker. Each phone in the system is usually connected to a twisted pair cable in party line fashion. Each pager phone has internal batteries that power audio amplifiers to boost signal level for normal communication. A paging amplifier allows each phone to broadcast a page call on a loudspeaker that is also housed within each phone (fig. 2-2).

The paging telephone has gained widespread use for two reasons. First, it permits persons and station areas to be paged by name and thus does not require the miners to learn ringing codes or telephone numbers. Second, the use of page amplifiers in each phone makes the

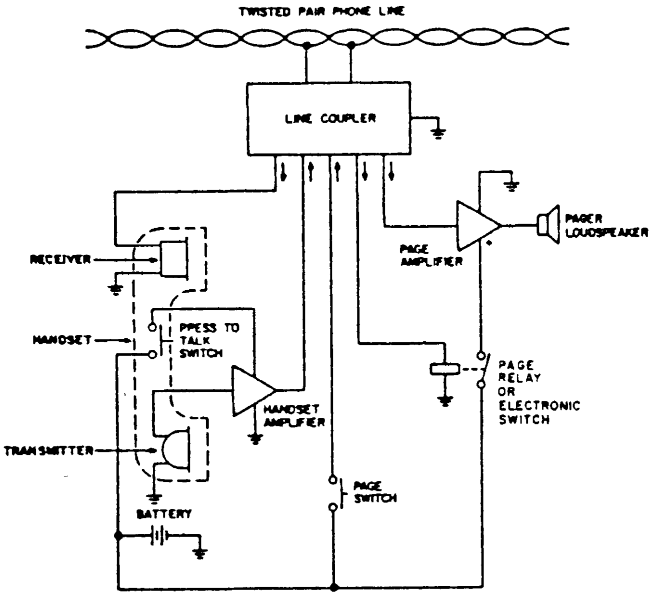

FIGURE 2-2. - Generalized two-wire pager phone.

system less affected by poor line splices and induced noise. The loudspeaker also yields a higher sound level at the receiver, which is important in the vicinity of noisy machinery. The primary disadvantage of paging telephone systems is that the telephone line must be used in a party line arrangement. This prevents simultaneous conversations in the system and reduces its usefulness for discussing maintenance problems or other uses which can tie up the system for long periods of time.

In a large mine there may be 30 to 40 phones on a single twisted pair cable. However, as the mine develops and the miles of twisted wire pair increase, a limit is reached. The limiting factor is the power available to signal the paging amplifier in other phones to turn on. The application of an electronic switch, in place of the low-voltage "page relay," has extended the operating range of newer paging phones.

A schematic of a generalized two-wire pager phone is shown in figure 2-2. When the ("Page") switch on the page phone is pressed, a dc voltage from the battery is placed on the line. All telephones connected to the line are energized through their "page relay," and the paging amplifier at each station is turned on. The person making the call then squeezes the press-to-talk button on his handset and makes an announcement. The handset signal is amplified and then transmitted over the two-wire network to all other phones. After completing the page, the caller releases the "Page" switch. The individual paged can respond by squeezing the press-to-talk button and talking into the handset. Because the two-wire line is common to all phones, any conversation on the party line may be heard at all stations.

Most of the pager phones that are available are directly interchangeable within a system or can easily be modified to be interchangeable. Two major areas of difference among available equipment are the battery voltage used for the page-call function, and the characteristics of the internal relay that responds to the dc page signal. The two choices of battery voltage are presently 12 volts and 24 volts. The 24-volt system was the standard for several years. Most installations also used electromechanical relays to "switch in" the paging amplifiers.

In recent years, new designs using solid state switching circuits that operate at 12 volts have become popular. Besides being more reliable, solid state systems have a high impedance and thus present a minimum load to the paging circuit. In a large complex multiphone system, with several miles of interconnecting cable, the minimum loading caused by these phones means that more phones can be installed.

Options included by the manufacturers of some paging phones include a battery-test button, an improve-hearing button, and a flashing light to help attract attention in noisy areas. The battery-test button, when pressed, lights a lamp on the front panel to indicate that the battery is in good condition. When the improve-hearing button is pressed, the gain of the receiver amplifier in the handset is increased. To assist the loudspeaker in attracting a miner's attention, the flashing light is turned on when the page is initiated.

2.2.1d Dial-and-Page Telephones

The use of normal surface-type telephones in underground mines has two disadvantages: The potential hazard, in a methane atmosphere, from the 120-volt 20-hertz bell-ringing voltage; and the inability to locate a person who is not in his immediate work area. Surface-type telephones also have two advantages, however: The selective call feature and the multiple private lines.

A unique system combines the dial telephone with the page phone. A surface interface is provided to isolate the potentially hazardous voltages from the underground line, and a converter changes ring voltage into the low-voltage direct current required to turn on the paging speaker in the dial-selected pager phone. The handset switch eliminates the need for a hook switch. Pressing the handset switch accomplishes all functions normally accomplished by lifting the handset of a conventional phone from the cradle. When a call is dialed, the interface modifies signaling to interface another underground phone or a conventional telephone on the surface.

Figure 2-3 is a diagram of a dial-and-page phone. The telephone consists of a handset, containing a transmitter in the mouthpiece and a receiver in the earpiece, and a main housing. The main housing contains a speech dialer network, which isolates the outgoing and incoming signals, a pulsing switch that is actuated by the rotary dial to signal a number to the surface interface, and the paging speaker. The speech network filters noise and processes the talker's voice. A common-page button permits paging all phones, as is required when searching for a roving miner or for making a general announcement.

Automatic dial systems are used at several mines that operate their own Private Automatic Branch Exchange (PABX) for

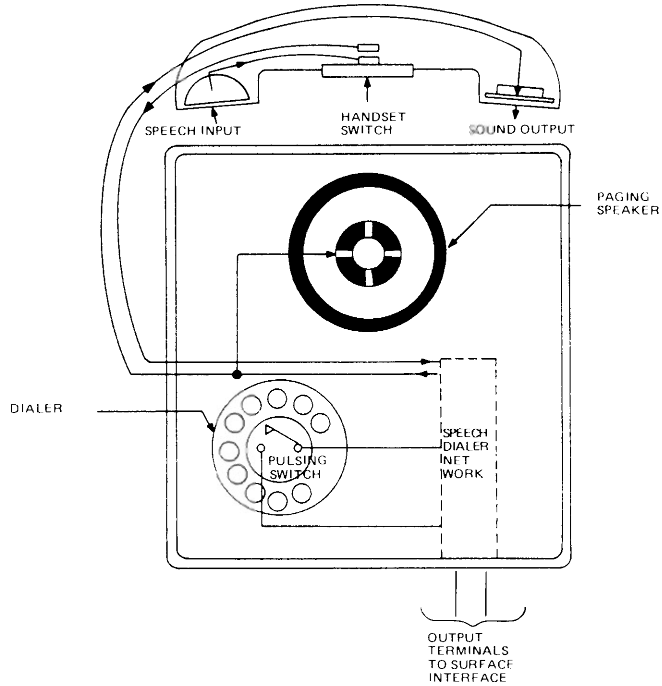

FIGURE 2-3. - Mine dial phone.

both inside and outside telephone service. Dial systems provide for many simultaneous conversations, but do need to use some form of signal multiplexing or multiconductor cables. These problems can be minimized by using multiconductor cables only in the main haulageway where few roof falls or line breaks are likely to occur and by taking conventional two-wire cable up to each section. However, this means all telephones in one area must be on a party line.

2.2.2 Distribution Systems

The distribution system for wired phones is the equivalent of the string between the two tin cans described in the introduction. This is the propagation medium that carries the voice signal. For wired phones, the distribution system may be single pair, multipair, or a multiplex system.

All wired systems used in mines are inherently unreliable. That is, if a telephone line is broken or shorted by a roof fall, for example, all telephones beyond that point are severed from communication to the outside. If the line is shorted, communications in the entire system may be severely affected or lost completely.

2.2.2a Single Pair

A single pair of wires is the minimum requirement for wired communications. A single twisted pair is used for magneto phones, paging phones, and intercom phones, connected in party line fashion. Single-pair wires are generally 14 AWG (0.06408-inch diameter). This relatively heavy gage wire is used in order to minimize signal loss over long distance.

The signal loss per mile, or attenuation as it is called, is dependent upon the frequency of the signal and the size of wire gage as shown in table 2-1. This table shows that as wire size increases and gage decreases, the signal loss (attenuation) decreases.

Each attenuation of 3 dB means that the signal power has decreased by one-half. For example, if the output of a communication device was 4 mW, the -3 dB attenuated value of this signal is one-half the output, or 2 mW. A 6-dB attenuation of a 4-mW signal results in a 1-mW (4 × 1/2 × 1/2) signal level.

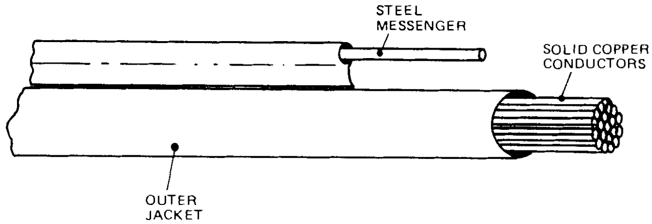

FIGURE 2-4. - Figure-8 multipair cable.

2.2.2b Figure-8 Multipair Cable

Figure-8 aerial distribution wire is shown in figure 2-4. In cross section, the wire looks like a figure-8 with a steel support wire, called the messenger, in the top half and a core of twisted pairs in the lower half. The outer jacket covering the messenger cable and twisted pair bundle is highly resistant to abrasion, moisture, and environmental stress cracking. Each wire is solid, commercially pure, annealed copper. One conductor of each pair is usually color coded by a solid body color with a contrasting spiraling color strip. The other conductor has the complementary color combination. Figure-8 cable is recommended for mine applications because the messenger cable adds considerable strength to the cable and the installation is similar to that of trolley wire.

TABLE 2-1. - Cable attenuations

Frequency (kHz)	Wire size					
	13 gage		16 gage		19 gage	
	Decibels per mile	Percent of signal power remaining	Decibels per mile	Percent of signal power remaining	Decibels per mile	Percent of signal power remaining
10	0.80	83	1.32	74	2.43	57
20	1.04	79	1.55	70	2.77	53
30	1.27	75	1.78	66	3.02	50
50	1.75	67	2.24	60	3.53	44
100	2.72	54	3.31	47	4.80	33
150	3.60	44	4.27	37	6.00	25

2.2.2c Coaxial Cable

Coaxial cable consists of an inner conductor and an outer conductor, as shown in figure 2-5. This type of cable has two main advantages over twisted pair for transmission. First, the coax usually has lower attenuation. Second, the shield over the central conductor keeps the electrostatic and electromagnetic fields contained within the coax, thereby minimizing crosstalk and interference problems.

2.2.2d Multiplex Systems

The term "multiplex" is applied to any system in which a single wire or wire pair is used for the transmission of more than one simultaneous signal. In this type of system, a means must be provided for inserting the individual signals onto the common transmission line and then separating these individual signals at the output of the line. There are two principal methods of multiplexing signals. One is based on frequency translations and is called frequency-division multiplexing, or FDM. The other is based on time-sharing the transmission line and is called time-division multiplexing, or TDM.

2.2.2d.i Frequency Division Multiplexing

Frequency division multiplexing is a process by which two or more signals are sent over the same line by transmitting each signal at a different frequency. The FDM concept can be illustrated by considering how the commercial radio broadcasting systems operate. Each radio station transmits at a specific frequency that has been assigned by the Federal Communications Commission (FCC). The signal from each radio station is transmitted by a common path (the atmosphere), with many stations being on the air at the same time. To receive a particular station, a person merely tunes his radio (receiver) to the frequency of the desired radio station.

This same principle, transmitting more than one voice signal, each at a different frequency, over a common path (in this case a single pair of wires), can be employed in underground communication systems.

Figure 2-6 illustrates the FDM concept. At the transmitting terminal, each of the voice channels (CH 1 through CH n) is applied to a modulator. Each modulator shifts that voice signal to an assigned frequency (f_1 through f_n) and transmits the resulting signal over the common line to the receiving terminal.

At the receiving terminal, a bank of filters separates the signals according to frequency. Individual demodulators recover the original voice signal. Note that the multiplexing system shown in figure 2-6 operates in only one direction. Most communication systems require two-way voice transmission. This is accomplished by a complete duplication of

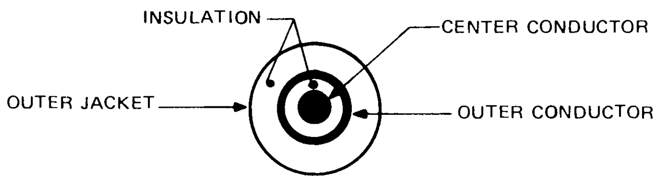

FIGURE 2-5. - Coaxial cable, cross-sectional view.

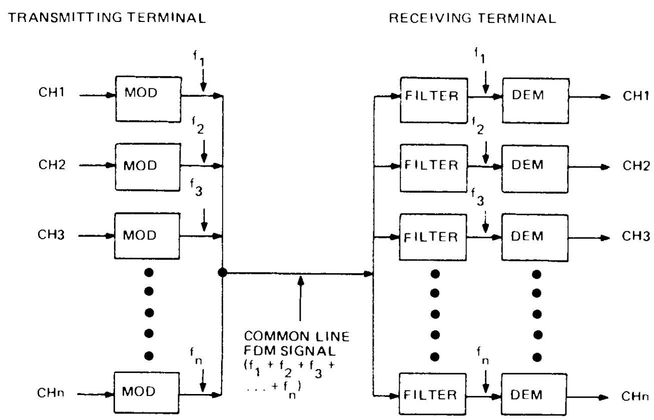

FIGURE 2-6. - Frequency division multiplex (FDM).

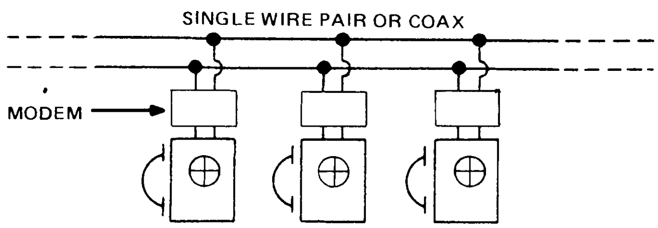

FIGURE 2-7. - Multiplex phone system.

multiplexing facilities, with the components in reverse order and with the signal waves traveling from right to left. Each terminal has a transmitting modulator and a receiving filter and demodulator combined to form a "modem."

A block diagram of the multiplexing principle is shown in figure 2-7. Each phone is connected to a subscriber terminal unit or modem. The transmission line is a twisted pair or coaxial cable whose gage depends on the system size. Repeaters can be inserted in the line to compensate for attenuation.

2.2.2d.ii Time Division Multiplexing

Time division multiplexing is a process by which two or more signals are transmitted over the same line by allocating a different time interval for the transmission of each signal. The time available is divided up into small slots, and each of these is occupied by a piece of one of the signals to be sent. The multiplexing equipment scans the input signals in a sequential round-robin fashion so that only one signal occupies the TDM line at any one time.

The basic concept, showing two signals (A and B) being time division multiplexed together, is illustrated in figure 2-8. During time slot 1, signal B

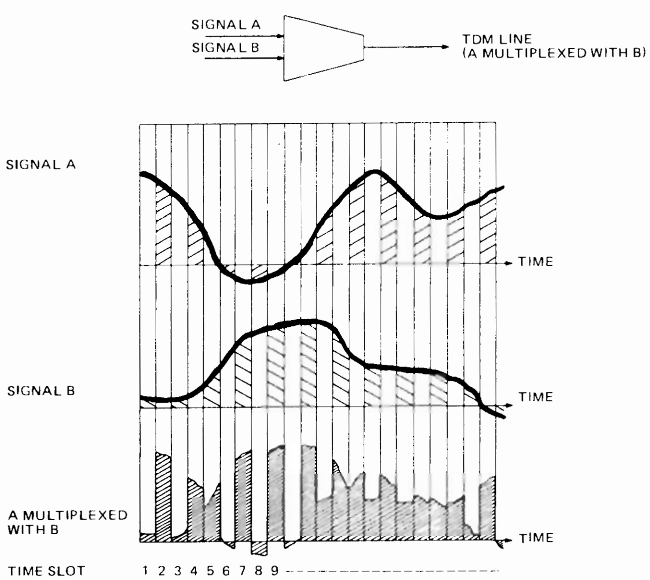

FIGURE 2-8. - Time multiplexing two signals.

is connected to the TDM line. During time slot 2, signal B is removed and signal A is placed on the TEM line. This process is repeated with each signal alternately occupying a time slot on the TDM line. The bottom waveform in figure 2-8 shows the resulting time division multiplexed signal. The TDM signal consists of signal A during the even-numbered time slots and signal B during the odd-numbered time slots. To separate the signals, when they are received at the other end of the TDM line, a demultiplexer must be used. The demultiplexer is similar to a multiplexer except that the input and output are reversed. The demultiplexer reconstructs the original signals (A and B) from the multiplexed signal.

In order to illustrate the TDM concept, the preceding discussion considered multiplexing only two signals together. This concept can be extended to multiplex many signals together onto a single TDM line. For instance, if eight different signals are to be multiplexed, then each signal would be placed onto the TDM line each eighth time slot. Figures 2-9 and 2-10 show eight switches at one location and eight lamps at another which must be controlled by those switches.

The system shown in figure 2-9 is simple and easy to understand; however, eight separate wires must be strung between the switches and the lamps. This can be quite costly and impractical when the switches and lamps are separated by large distances. Figure 2-10 shows how each lamp can still be controlled by its associated switch using a single wire (TDM line) between the switches and lamps. With the wiper on each of the multipole switches synchronized, this system would sample the status of the first input switch (S1) at the transmitting end and communicate that information to the receiving end. At the next interval of time, both multipole switches would step to position 2. Control of the second lamp would be accomplished by sampling the status of the S2 input switch at the transmitting end. At the next time interval, both scanner switches would step to position 3 and a similar

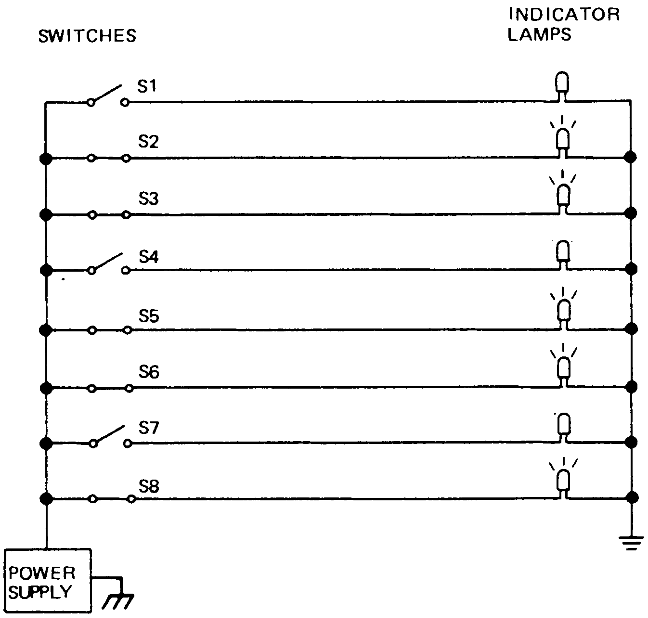

FIGURE 2-9. - No multiplexing (eight wires required).

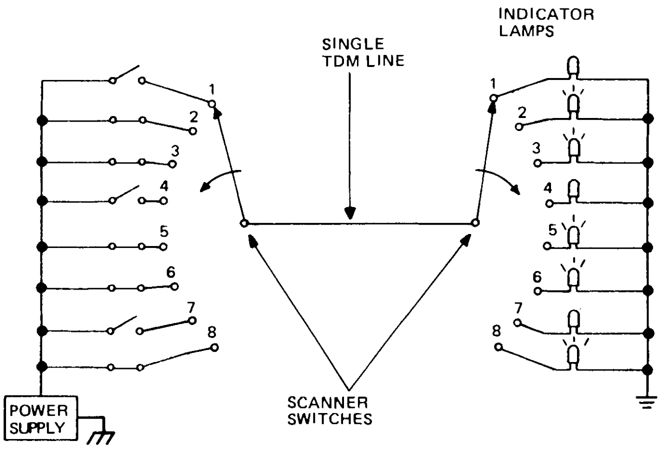

FIGURE 2-10. - Time division multiplexing (one wire).

control action would result for the third lamp. After all eight positions had been scanned, the scanner switch would return to position 1 and start the sequence over again. If the scanning were fast enough the lights would appear to glow steady and not blink. In a like manner, if this were a voice system, it would not sound chopped.

2.2.3 Telephone Exchanges

The function of any telephone exchange is to connect a calling phone to a called phone. The earliest method of connection was the manual switchboard located within a private branch exchange (PBX). As the number of phones in use increased, the size and complexity of manual switchboards also increased. This led to the development of an automatic switching system called a private automatic branch exchange (PABX). Since telephone lines are currently used as data links for computers, teletypwriters, and various other data equipment, faster, more reliable exchanges were needed. To fill this need, the computer is presently used to control large solid state exchanges and perform many other central office (CO) functions.

2.2.3a Manual Switchboard

The earliest switchboards allowed the operator to manually patch two circuits together. When the central office received ringing current, the operator inserted the answering plug into the jack of the caller. After verbally receiving the called number, the operator inserted the calling plug of the same circuit into the called party's jack and applied ringing voltage on the ringer of the called party. After the conversation has been concluded, both parties would ring off, informing the operator that the plugs could be disconnected.

2.2.3b Private Automatic Branch Exchange

The private automatic branch exchange performs the same end function as the operator at the old manual switchboard. It makes a connection between the phone line of a caller to the line of the phone being called. Connections through PABX's can be made using electromechanical devices (rotary switches, relays, etc.) or solid state electronic circuits.

In rotary dial phone system, the phone loop, which includes the two speech wires and the telephone set, is momentarily interrupted by the dial switch as the dial runs down. The number of loop interruption electrical pulses thus generated corresponds to the number dialed. In pushbutton-type phone systems, the numerical information (each digit dialed) is transmitted to the switching equipment in the form of coded frequency or voltage signals. In either case, the PABX switching equipment must receive and decode the "number dialed" signals from the calling phone to determine what phone is being called.

2.2.3c Computer-Controlled Switches

Modern solid state exchanges under computer control can efficiently handle thousands of phone lines. In addition to being faster and more reliable, computer-controlled equipment occupies only a fraction of the space required by systems using mechanical relays or rotary switches.

Alterations to these systems no longer require a lot of time and hardware since the switching is under control of a computer program. Changes such as adding phones, deleting phones, changing a phone number, etc., can be made by simply changing the program. The computer also can keep track of billing functions and special events. Special features, such as conference calls, automatic call forwarding, and abbreviated dialing, can be incorporated into computer-controlled exchanges by making changes to the computer program.

System maintenance can also be handled by computer program. Instead of many labor hours spent in attempting to locate and correct a fault, the computer can cycle through all parts of the system and locate a trouble spot within a matter of minutes. Because computer operations are very fast, they can be performing maintenance functions even while handling the switching function for thousands of calls.

2.3 Radio Systems

Radio systems do not depend on a wire connection between transmitter and receiver. There are many types of systems in this category: one-way voice, one-way signal, and two-way voice. In one-way operations, the transmitter sends a code or voice signal to the receiver. Two-way voice utilizes a device called a transceiver (combined form of transmitter and receiver).

2.3.1 General Radio System Theory

Voice frequency (VF) signals could be transmitted directly from one antenna to another; however, because of the low frequencies (and therefore long wavelengths) involved, the antennas required would be very large. For this reason, VF signals are combined with higher frequency RF (radio frequency) carrier signals which can be effectively transmitted and received by antennas of reasonable size. The two primary methods of combining VF signals and RF carriers are amplitude modulation (AM) and frequency modulation (FM).

2.3.1a Amplitude Modulation

In amplitude modulation the height, or amplitude, of the RF carrier is made to vary with the VF signal. This principle is illustrated in figure 2-11. The top waveform shown in figure 2-11 is a typical VF signal. The middle waveform of figure 2-11 represents an RF carrier that will easily propagate between antennas of convenient size. The bottom waveform shows the result of "amplitude modulating" the RF carrier with the VF signal. This signal retains the basic shape of the original VF signal but will also easily propagate between antennas because it is being transmitted at the RF carrier frequency. The original voice signal is regenerated by demodulation circuits in the receiver.

2.3.1b Frequency Modulation

A voice signal may also be superimposed on a carrier frequency through the use of frequency modulation techniques. In FM, the frequency of the RF carrier is made to vary at the VF signal rate. As the amplitude of the VF signal changes, the frequency of the RF carrier (instead of the amplitude) changes.

Figure 2-12 shows the principles of frequency modulation. The voice signal

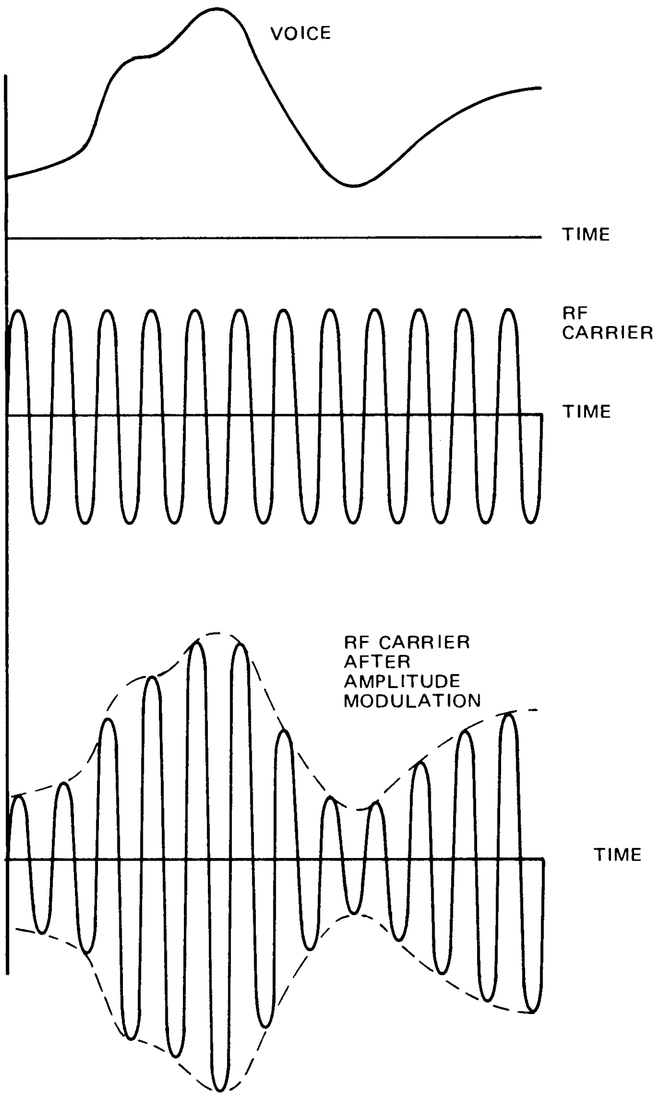

FIGURE 2-11. - Amplitude modulation (AM).

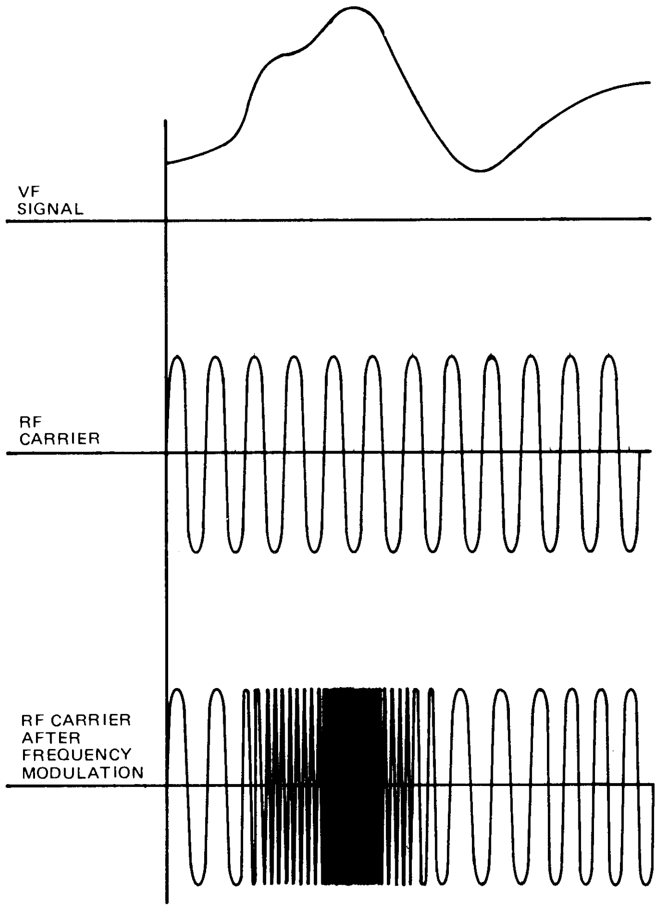

FIGURE 2-12. - Frequency modulation (FM).

is shown by the top waveform and the RF carrier by the middle waveform. The bottom waveform shows the resultant frequency-modulated RF carrier. As the voice signal increases to its maximum value, the carrier frequency increases (the waves bunch up). As the voice signal decreases to its minimum value, the carrier frequency decreases (the wave spreads out). The amount of carrier frequency change is referred to as frequency deviation or carrier deviation. The unmodulated carrier frequency is referred to as the center frequency. The amount of carrier deviation is proportional to the amplitude of the voice signal, with maximum carrier deviation occurring at the peaks of the voice signal.

FM receivers are less susceptible to noise when receiving a signal of only moderate strength or when the background electromagnetic (EM) noise is almost as "loud" as the signal. This advantage of FM over AM can become an important consideration in underground mining operations where electrical equipment is being operated and the amount of EM noise being generated is large.

2.3.2 Distribution Systems

For the most part, the distribution system or propagating medium for radio transmission is not hardwired but takes the form of electromagnetic (radio) waves in the air. (Radio waves at certain frequencies will also propagate directly through the earth.) Electromagnetic energy (radio waves) in empty space travel at the speed of light. Because the speed of any traveling wave is its wavelength times its frequency, we have a formula of propagation ($f\lambda$ = speed of light) where λ is the wavelength and f is the frequency. λ and f are thus inversely proportional (as f increases, λ decreases), as shown in figure 2-13. Commonly used units are λ in meters and f in hertz (Hz) (cycles per second). If the wave is traveling through anything other than empty space, its speed is reduced depending upon the electrical properties of the medium through which it is passing. Radio waves are slowed down only slightly by the earth's atmosphere. In solid insulating materials the speed is generally much slower; for example, in distilled water (which is a good insulator) the waves travel only one-ninth as fast as they do in free space. In good conductors such as metals the speed is so low that opposing fields induced in the conductor by the wave almost cancel the wave itself. This is the reason why thin metal enclosures make good shields for electrical fields at radio frequencies.

2.3.2a Antenna Theory

In normal electronic circuits the physical size of a circuit is small compared with the wavelength of the frequencies being used. When this is the case, most of the electromagnetic energy stays in the circuit itself or is converted into heat. However, when the physical dimensions of wiring or components approach the size of the wavelength being used, some of the energy escapes by radiation in the form of electromagnetic, or radio, waves. Antennas can be considered as special circuits intentionally designed so that a large part of the energy input to the antenna will be radiated as electromagnetic energy.

Usually an antenna is a straight section of conductor, either a wire or hollow metal tubing, which is suspended in space. When a radio transmitter is connected to the antenna, rapidly varying electrical currents are set up in the antenna. These currents cause electromagnetic waves to radiate from the antenna and travel through the atmosphere or other surrounding medium. When these waves strike another antenna they induce electrical currents in it similar to the current flowing in the transmitting antenna. These currents, although they may be very small if the antennas are far apart or if they are transmitting through the earth, can be amplified by electronic circuits (receivers) to reproduce the original signal. The range of radio distribution systems can be extended by leaky feeder cable (special coaxial cable designed to allow radio waves to "leak" from the cable to the surrounding atmosphere and/or radio repeater stations.

2.3.2a.i Half-Wave Dipole Antenna

The strength of the electromagnetic field radiated from an antenna is proportional to the amount of current flowing in the antenna. It is, therefore, desirable to make the current as large as possible. This can be accomplished by adjusting the length of the antenna so that it resonates at the operating frequency.

If a straight wire, or antenna element, were to be suspended in space, the lowest frequency at which it would resonate has a wavelength of twice the length of the wire. When used to transmit or receive RF energy that has a wavelength of twice the length of the wire,

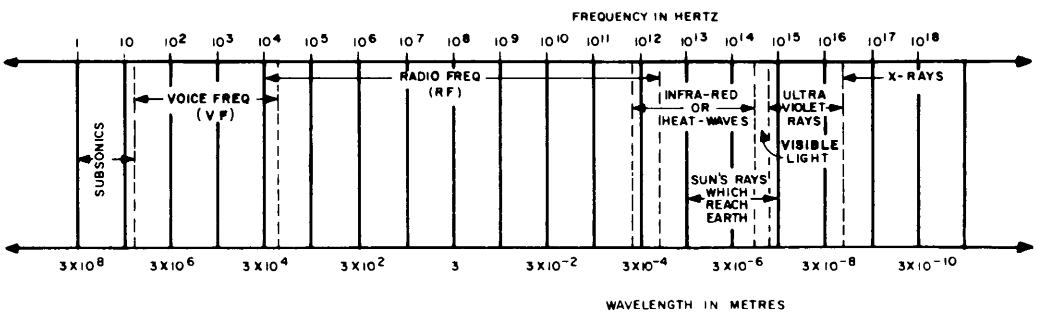

FIGURE 2-13. - Electromagnetic energy spectrum.

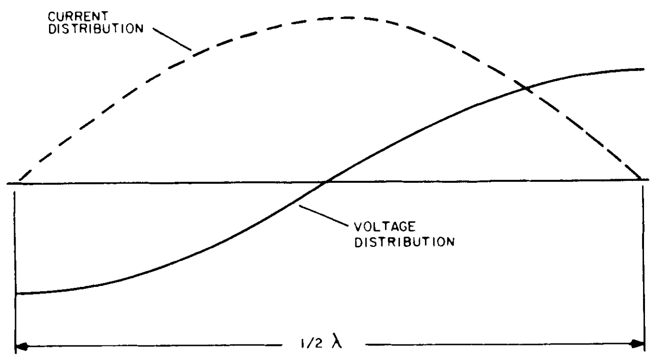

FIGURE 2-14. - Half-wave antenna, voltage and current distribution.

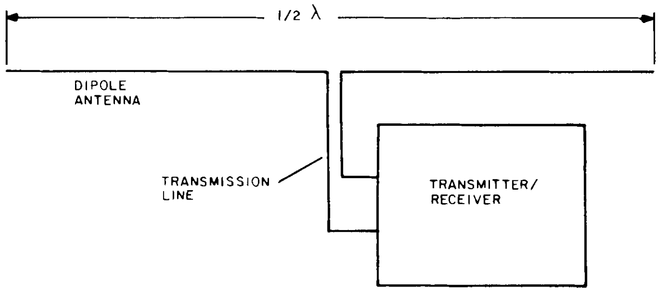

FIGURE 2-15. - Dipole antenna.

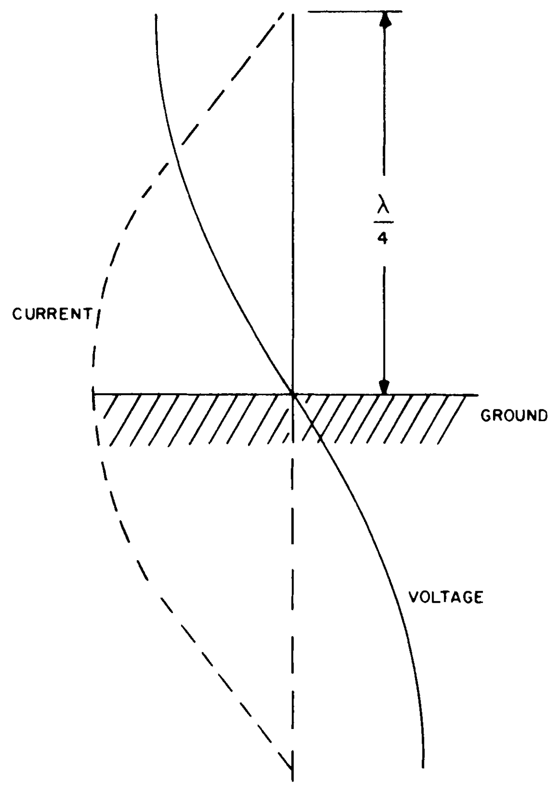

FIGURE 2-16. - Quarter-wave antenna, voltage and current distribution.

the wire is known as a half-wave antenna. The current and voltage distributions along such a wire are shown in figure 2-14. Such an antenna, when connected to a receiver as shown in figure 2-15, is called a dipole.

2.3.2a.ii Quarter-Wave Antenna

An antenna may also be a quarter wave in length. This is possible because of its connection to ground, which electrically acts as the other quarter-wavelength. Refer to figure 2-16. The ground plane reflects the quarter-wave antenna so it has electrical characteristics similar to those of a half-wave antenna.

An antenna of this sort may be any odd multiple of a quarter-wavelength: 1/4λ, 3/4λ, 5/4λ, 7/4λ, etc. These antennas are commonly used for low- and medium-frequency applications. If a quarter-wave whip antenna is installed on a vehicle, the vehicle becomes the ground plane. A modified quarter-wave antenna is commonly used for citizens' band (CB) radios on vehicles.

2.3.2a.iii Long-Wire Antenna

A long-wire antenna is one that is long with respect to the wavelength of the incoming and outgoing signals. The length should be an integral number of half-wavelengths (2λ, 2-1/2λ, 3λ, 3-1/2λ, etc.) to radiate effectively. A 1/2λ (dipole antenna) is said to operate on the fundamental frequency, λ operates on the second harmonic, 1-1/2λ operates on the third harmonic, 2λ operates on the fourth harmonic, and so on.

2.3.2a.iv Loop Antenna

Loop antennas can be utilized for through-the-earth radio transmissions or as receiving antennas in direction-finding systems. These antennas can be composed of one or more turns of wire on a round or square form, or the loop can be established by simply laying the wire in a loop on the ground or floor of a mine tunnel.

2.3.2b Leaky Feeder Systems

Figure 2-17 shows a cross-section view of a standard coaxial cable and the lateral variation of its associated fields. In such cables, the bulk of the radio frequency electromagnetic energy is transported down the cable between the center conductor and the shield. However, the shields of most coaxial cables do not provide perfect containment of the internal electromagnetic fields or isolation from external fields. As shown in figure 2-17, a small fraction of the cable's internal field is leaked to the external space. External fields also leak into the cable in a similar manner.

The leaky feeder system is based on the use of semiflexible cable with specially designed shielding that has a greater coupling to the external space. Therefore, this cable easily leaks radiated signals and saturates the area around the cable with these signals. One type of leaky feeder cable is shown in figure 2-18. The cable has a solid copper shield in which holes have been machined to increase the amount of leakage to and from external space. In large mines, repeaters may also be used to amplify and retransmit incoming and outgoing signals to roving miners carrying portable radios. The spacing of these repeaters along the cable is governed primarily by the receiver sensitivity, the longitudinal attenuation rate of the cable, the coupling loss from the cable to the portable units, and the transmitter power. Since the portable unit's transmitter power is generally lower than that available for fixed repeater or base stations, the portable units set the coverage limits for two-way communications.

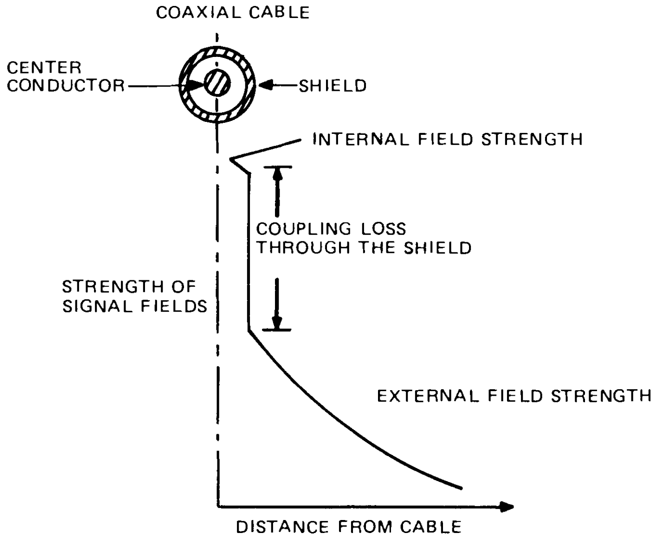

FIGURE 2-17. - Coaxial cable, field strength.

2.3.2c. Waveguide Propagation

A waveguide is a hollow conductor, through which electromagnetic waves (radio waves) may propagate. Such a waveguide may be made of copper (the ideal), or other materials, such as coal or shale (nonideal). Hence, a mine entry is a waveguide. In order for a wave to efficiently propagate in a rectangular waveguide (mine entry or haulageway), the wavelength must be equal to or less than two times the greater dimension (a or b of figure 2-19). Table 2-2 shows the frequency spectrum designations with their wavelength ranges. The dimension of "a" that would be common in underground communications is 3 meters. This limits the lowest frequency range of signals that will effectively propagate within mine tunnels to the upper VHF and the UHF range. A communication device such as a CB radio has no application since it operates at approximately 27 MHz, a frequency which is too low.

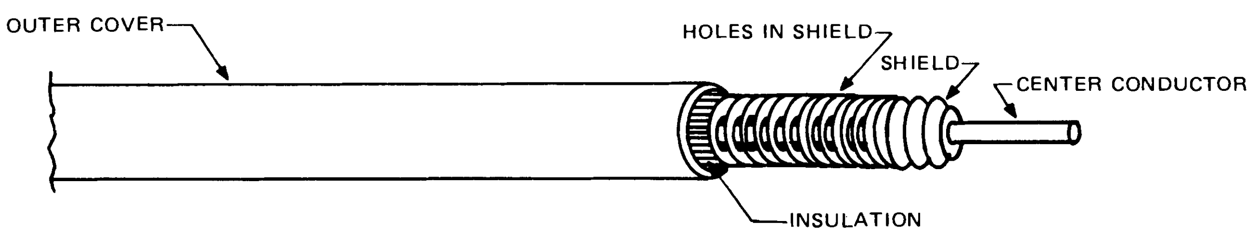

FIGURE 2-18. - Cutaway view of leaky feeder cable.

TABLE 2-2. - Frequency spectrum designation

Abreviation	Description	Frequency	Wavelength range
VF.........	Voice frequencies...........	300-3,000 Hz............	10^6-10^5 m
VLF........	Very low frequencies........	3-30 kHz................	10^5-10^4 m
LF.........	Low frequencies.............	30-300 kHz..............	10^4-10^3 m
MF.........	Medium frequencies..........	300-3,000 kHz...........	10^3-10^2 m
HF.........	High frequencies............	3,000-30,000 kHz........	100 -10 m
VHF........	Very high frequencies.......	30-300 MHz..............	10 - 1 m
UHF........	Ultra high frequencies......	300-3,000 MHz...........	1 - 0.1 m
SHF........	Super high frequencies......	3,000-30,000 MHz........	10 - 1 cm
EHF........	Extremely high frequencies..	30-300 GHz..............	1 - 0.1 cm

Other factors that influence waveguide propagation are wall texture (the smoother the wall, the better the propagation) and tunnel straightness, and electrical properties of the roof, walls, and floor.

2.3.2d. Repeaters

Two general types of repeaters will be considered for application in the mine environment: Single-frequency (F1-F1) repeaters and frequency translation (F1-F2) repeaters. In its simplest form a repeater consists of two basic elements, a receiver unit and a transmitter unit, as shown in figure 2-20.

2.3.2d.i F1-F1 Repeater

Single-frequency repeaters are used in most wired systems such as coaxial systems where the transmission energy is confined within the coax. These repeaters function as signal amplifiers. The attenuated input signal is detected, amplified, and retransmitted. Since the signals are confined to a separate coax, isolation between transmitter and receiver is maintained.

Single-frequency repeaters are also used in some wireless repeater systems, but extreme caution must be used to prevent feedback between repeater transmitter and receiver. Isolation must be maintained between the transmitter output and receiver input to prevent the transmitted signal from being received and amplified by the same unit. This

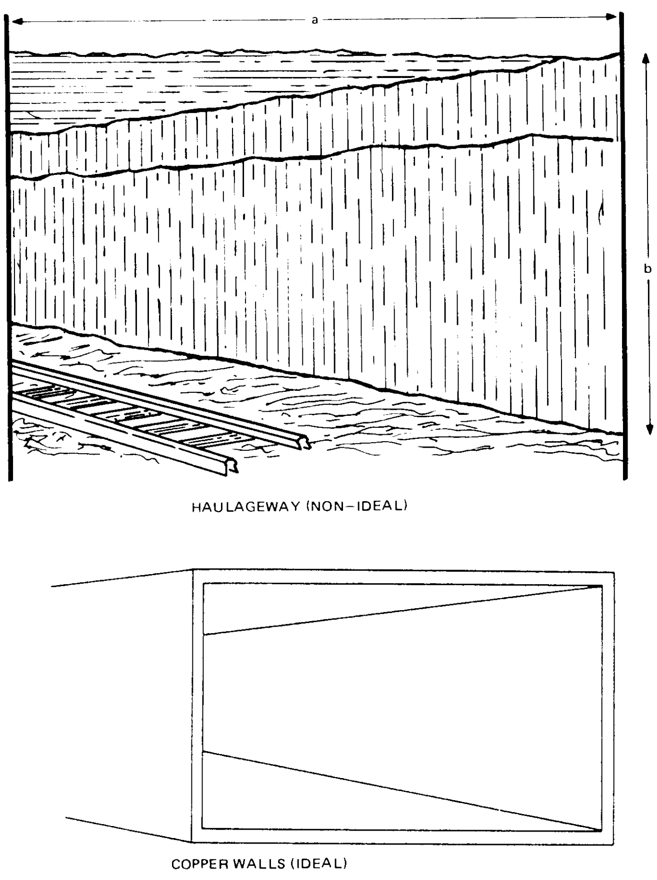

FIGURE 2-19. - Waveguides.

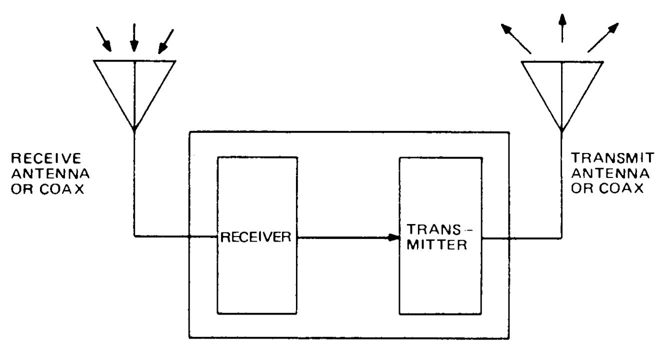

FIGURE 2-20. - Basic repeater block diagram.

feedback can cause an oscillation or squealing problem very similar to that caused by placing a microphone in front of its own speaker. Directional antennas can be used to minimize this feedback problem; however, the use of high-gain directional antennas is not considered practical in the mine environment owing to installation problems and their susceptibility to mechanical damage.

Another method of overcoming these problems is to use special repeaters that do not depend on directional antennas. In general terms, these units function by separating the transmit and receive signals with time division multiplexing. The repeaters transmit pulses of RF energy and receive between these pulses. In this type of system all repeaters must be phase-locked with each other to synchronize the time division process.

2.3.2d.ii F1-F2 Repeater

F1-F2 repeaters receive signals from a portable unit on one frequency (F1) and retransmit these signals on another frequency (F2) to another portable unit. The mobile radios transmit on F1 and receive on F2. In this mode, all information goes to the repeaters, then back to the portable units. Some portable units are also capable of transmitting on F2 and, therefore, are able to talk to one another without the repeaters on a local simplex basis. With these systems, the receive and transmit antennas at the repeater are often covering the same general frequency bands and they can be combined so that only one antenna is required.

Thus far, repeaters have been discussed only as a means to permit communication over greater distances than would be possible using direct transmission between portable radios. However, the audio link between the transmitter and receiver in the repeaters allows radio access to and from other types of audio circuits, such as specialized paging consoles or the telephone system.

One possible system configuration which includes both a telephone link and talk-through capability is shown in figure 2-21. This configuration allows for two modes of communications: F1-F2 would be used for a local mode, that is, miner to miner within the working section through the repeater; and the second mode could support communications between a miner located in a working section with a second miner located somewhere else in the mine. The audio link (fig. 2-21) between the receiver and transmitter of a repeater can be used to customize repeaters to fit a variety of applications. An audio wireline can also be used to link a number of repeaters together to provide complete radio coverage of the mine on a party line basis as shown in figure 2-22.

2.3.3 Through-the-Earth Radio

VF (0.3- to 3-kHz) radio waves will penatrate, to some extent, directly through the earth. Although signal strength is greatly attenuated, experiments have shown that up to 1,000 feet

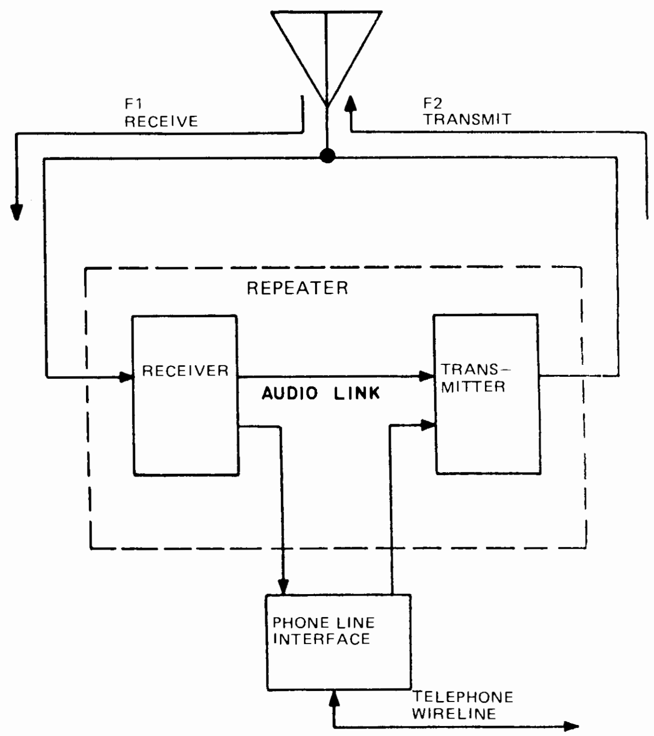

FIGURE 2-21. - Repeater linked to telephone system.

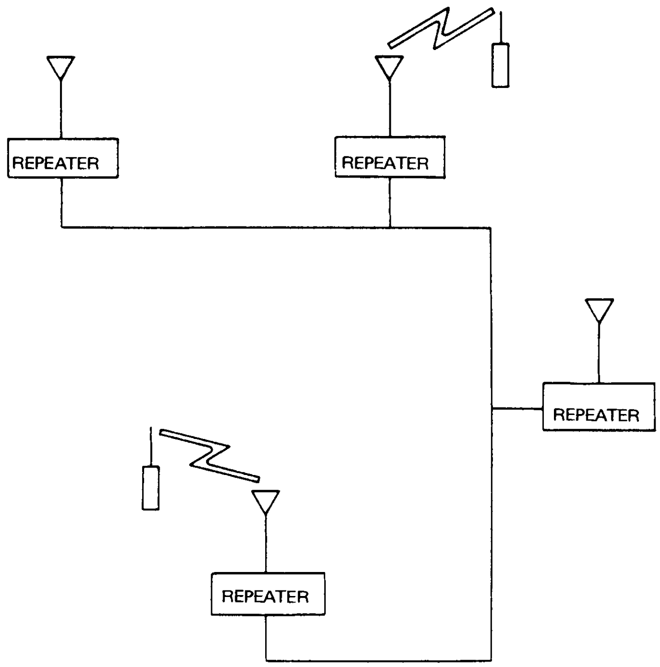

FIGURE 2-22. - Minewide repeater system linked by audio pair.

(305 meters) of overburden may be penetrated.

The transmitter may be a simple generator with a loop or grounded wire antenna. The receiver may be a loop antenna connected to a power amplifier with a set of earphones or a meter. When the transmitter is activated, it sets up a magnetic field directly through the earth (the overburden).

These characteristics of through-the-earth radio can be utilized in emergency situations to detect, locate, and even communicate with miners trapped underground. Once the position of an underground transmitting antenna has been determined using direction-finding techniques, a loop antenna can be positioned on the surface directly above the underground position. The trapped miner has a method of pulsing his transmitter off and on, such that a coded message may be sent to the surface. A high-power transmitter attached to the surface loop may also be utilized to establish down-link voice communications with the underground location.

2.3.4 Radio Pagers

Radio pagers are usually small FM radio receivers. The simplest type of radio pager is a one-way signal detector or "beeper." These devices emit an audible tone and/or blink a small light on and off. The miner must then go to the nearest phone to receive the message.

Another type of radio pager is a one-way voice pager. These devices are similar to the simple beeper-type pagers except that the caller can deliver a short verbal message to the person being paged. A common type of one-way voice pager sounds a tone to alert the miner that a message will follow, and then broadcasts the verbal message. A disadvantage of these pagers is that, although it is possible to transmit instructions, such as "turn off the power to number 4 left," it is not possible for the caller to know for sure that the instruction was even received, let alone carried out. For this reason, one-way voice pagers should not be used to instruct personnel to perform specific tasks that may affect safety.

Some one-way voice, and even beeper, pager systems allow the caller to selectively page a specific section or an individual miner. The heart of these systems is an encoder, which translates the number of each pocket pager to a specific frequency or code that activates only the designated pager.

2.4 Carrier Current Systems

Any underground wire or cable, when fed an RF signal, tends to distribute that signal throughout its length. Carrier current systems utilize this fact to establish communication paths using existing mine wiring. The wire used may be ac or dc power lines, neutral lines such as the hoist rope, existing phone lines, or other wiring.

Carrier current devices are basically FM radio transceivers that transmit and receive over existing mine wiring instead of using an antenna system. The LF (low-frequency) and MF (medium-frequency) RF ranges propagate best in carrier current systems. A common example of a carrier current system is the trolley carrier phone systems presently used in many mines using trolley or rail haulage. Another example is the shaft communication systems that utilize the hoist rope itself to establish communications to and from the cage. The most modern system, based on MF, promises to be the most effective of all.

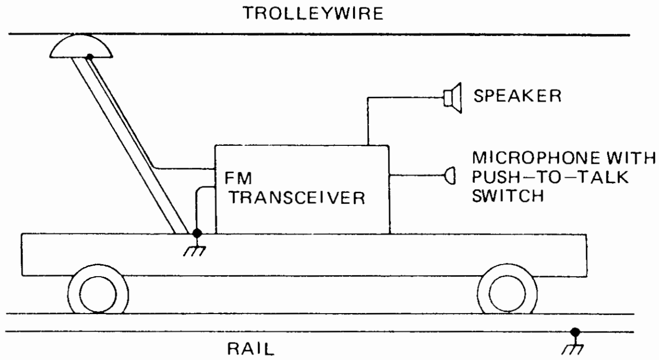

FIGURE 2-23. - Trolley carrier phone, block diagram.

2.4.1 Trolley Carrier Phone

A simplified block diagram of a typical trolley carrier phone is shown in figure 2-23. As mentioned earlier, the basic elements of any carrier current phone are the FM receiver and transmitter.

In a trolley carrier current phone system, the receiver and transmitter are connected to the trolley wire through a coupler capacitor. The coupler capacitor acts as a short circuit at the frequency of the FM voice signals, but as an open circuit to the trolley wire dc power voltage. The high voltage levels on the trolley wire are thus blocked from entering the receiver and transmitter sections of the carrier phone, while the FM voice signals pass freely through the coupler capacitor.

The FM transceiver shown in figure 2-23 contains a power supply that converts trolley wire high voltage down to low voltage levels to provide power to the carrier phone circuits. The power supply may also contain a battery for backup power in case power on the trolley wire is lost. Such a system operates in the push-to-talk, release-to-listen mode.

2.4.2 Hoist Rope Radio

Figure 2-24 shows a block diagram of a hoist rope carrier current system. The system consists of two signal couplers and two transceivers. Each unit is

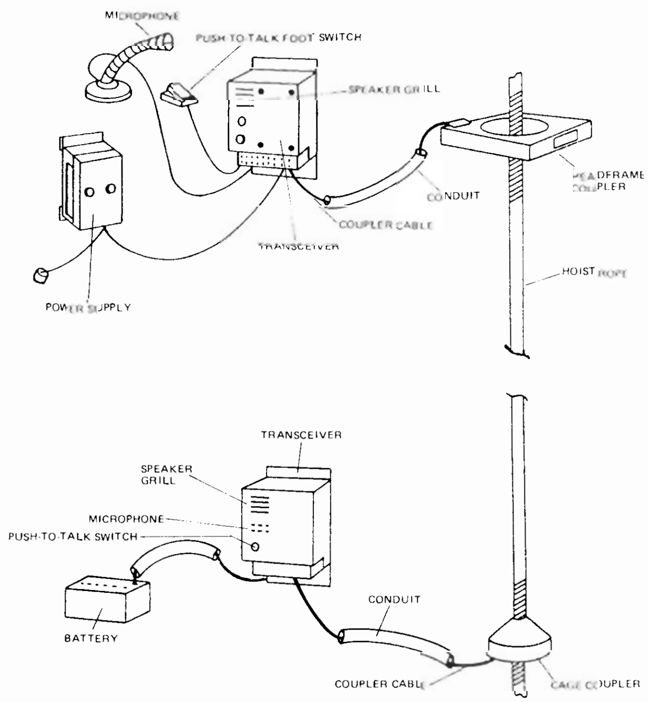

FIGURE 2-24. - Hoist radio hardware.

of the push-to-talk, release-to-listen design. During transmission, the sending unit feeds its coupler with a frequency-modulated (FM) carrier. The coupler induces a signal in the hoist rope, which is then picked up by the coupler of the second unit. Both couplers are electrically identical, and each operates both as a transmitting and as a receiving element. Operation of the hoist radio is the same as for a trolley carrier phone, except that the hoist radio signal is inductively coupled to the propagation medium (hoist rope). Some hoist phones are simply modified trolley carrier phones. Other hoist phone systems have been specifically designed for operation in a vertical shaft and usually provide better coverage.

The transceivers of the hoist room and cage are identical, except for the battery required in the cage. The hoist room power supply provides the power for the surface equipment. Surface equipment also may include a boom-type microphone and a foot-actuated push-to-talk switch to facilitate hands-free operation.

2.4.3 Medium Frequency (MF) Radio

Although radio transmission on the surface of the earth is well understood, transmission in an underground environment generally is not. Complex interactions occur between the radio wave and the environment. Characteristics of the geology (stratified layering, boundary effects, conductivity, etc.) and the mine complex (entry dimension, conductors, electromagnetic interferences, etc.) had to be measured and understood before a practical mine radio system could be built. To this end, considerable research has been directed.

In a confined area such as a mine, radio waves can propagate useful distances only if the environment has the necessary electrical and physical properties. The "environment" takes into account the natural geology and manmade perturbations such as the mine complex itself. As an example, if the wavelength (λ) of a radio wave is small compared with the entry dimensions, a waveguide mode of propagation is possible. Attenuation depends primarily upon the physical properties of the entry such as cross-sectional area, wall roughness, entry tilts, and obstacles in the propagation path. Secondary effects such as the dielectric constants and earth conductivity also influence attenuation.

Mine radio systems based upon this effect are available commercially. These are UHF systems operating around 450 MHz which provide useful but limited coverage. In high coal (6.5 feet), line-of-sight ranges of 1,000 feet are often possible. Range is reduced severely in non-line-of-sight, such as when going around a coal pillar. In lower coal, or when obstacles exist in the propagation path, range is reduced even more. For this reason, conventional UHF radio systems require an extensive network of leaky feeder transmission cables and repeaters to become useful. Even so, range from the cable is not usually in excess of 30 to 50 feet, and equipment cost is very high. Clearly another approach is desirable.

An important contribution to underground radio communications was made by the Chamber of Mines of South Africa. As early as 1948, programs were in place to develop radio systems for deep mines, primarily gold mines. The result was that by 1973, an advanced 1-watt single sideband (SSB) portable radio system had been developed that apparently worked well. The Bureau of Mines procured several of these units for evaluation. Performance in U.S. coal mines was not satisfactory. There were several reasons for this. First, U.S. mines are highly electrified, producing considerable electromagnetic interference (EMI) not normally found in the South African mines, which completely desensitized SSB radios. Second, 1 watt was not enough power. U.S. mines are mostly room and pillar, which means that any radio system would have to have reasonable range from local conductors. Third, geological electrical parameters were less favorable in the United States. For these reasons, the South African system was not acceptable.

The Bureau's approach was to first determine the actual propagation characteristics of MF in U.S. mines, and then to relate the propagation to the underground environment such as the geology, entry size, existing conductors, and EMI. Several exhaustive in-mine measurement and analysis programs were conducted. These programs formed the foundation for the first true understanding of how MF propagates in a stratified medium of various electrical parameters, which are often interlaced by manmade conducting structures (rails and power lines) and artificial voids (entryways).

Figure 2-25 is a simplified geometry of an in-mine site that illustrates one of the most important findings of the measurement program, the "coal seam mode." For this mode to exist, the coal seam conductivity (σ_c) must be several orders of magnitude less than that of the rock (σ_r). A loop antenna that is at least partially vertically oriented produces a vertical electric field (E_z) and a horizontal magnetic field ($H\phi$). In the rock, the fields diminish exponentially in the Z-direction. In the coal seam, the fields diminish exponentially at a rate determined by the attenuation constant (α), which in turn depends upon the electrical properties of the coal. An inverse square-root factor also exists because of spreading. The effect is that the wave propagates between the highly conducting rock layers bounding the lower conductivity coal seam. The fact that the coal may have entries and crosscuts is of minor consequence.

In the presence of conductors, the picture changes considerably. In this case, the effects of these conductors can totally dominate the effects of the geology. In general, the presence of conductors (rails, trolley lines, water pipes, air lines, phone lines) is always of advantage.

MF can couple into, and reradiate from, continuous conductors in such a way that these conductors become not only the transmission lines, but also the antenna system, for the signals. The most favorable frequency depends to some extent on the relationship between the geology and

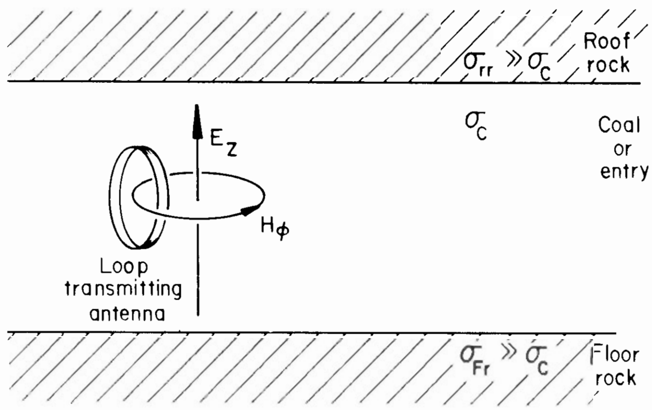

FIGURE 2-25. - The coal seam mode.

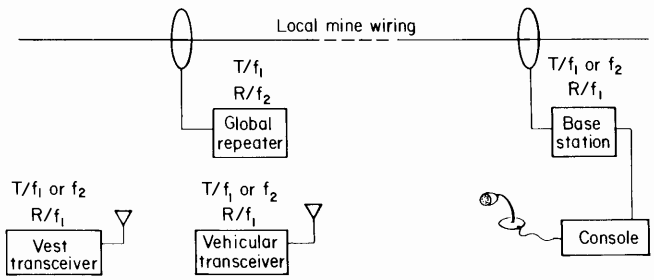

FIGURE 2-26. - Global repeater concept.

existing conductors. The frequency effects are quite broad. Anything from 400 kHz to 800 kHz will usually be adequate.

The MF system described here is based upon vehicular and personnel transceiver units, base stations, and repeaters. It applies prior fundamental research in the area of MF and utilizes the existing mine wiring network (power cables, trolley line, etc.) to achieve whole-mine coverage. The basic system configuration is shown in figures 2-26 and 2-27.

Figure 2-26 illustrates a minewide repeater-base station concept known as the global maintenance net. In this configuration, mobile units (persons using transceiver vests and/or vehicular transceivers) can maintain local communications by operating at frequency f_1. The range of communications in this case is solely dependent on point-to-point radio propagation, aided by parasitic coupling. A transmission on f_2 causes repeater action to occur, permitting the two mobile units to be separated very large distances. To achieve this repeater action, it is only necessary for the transmitting unit to reach the repeater, either directly or by parasitic effects to the repeater line coupler. Communications with a base station are also possible.

Figure 2-27 illustrates a local repeater concept constituting a local cellular net. This local repeater is known as a "cellular repeater" because it illuminates a "cell" or area of the mine, such as a working section, only. The antenna for the cellular repeater is a dual wire loop attached to timbers or the rib. An interface to the mine telephone system permits communications "off section."

The system design is distributed in the sense that each net can be operated independently of the other. In practice, a net can be easily installed by coupling a base station (at the portal) to electrical conductors in the wire plant (phone lines, power lines, etc.). Mobile transceivers operating on the assigned net frequency communicate with each other and the base. Other nets use different frequencies and are installed in the same way.

Two types of mobile transceivers have been developed for the system. These transceivers consist of vest units for individuals and vehicular units for rolling stock. Functionally the two are equivalent, differing only in power levels and physical configuration. These transceivers are shown in figures 2-28 and 2-29.

An important human factor problem was solved by the vest design. By placing the radio circuit modules in pockets on the vest, the weight and bulk of the transceiver have been evenly distributed. The loop antenna is sewn into the back of the vest. The pockets are located where medical records show less frequency of injury. Sound is directed toward the

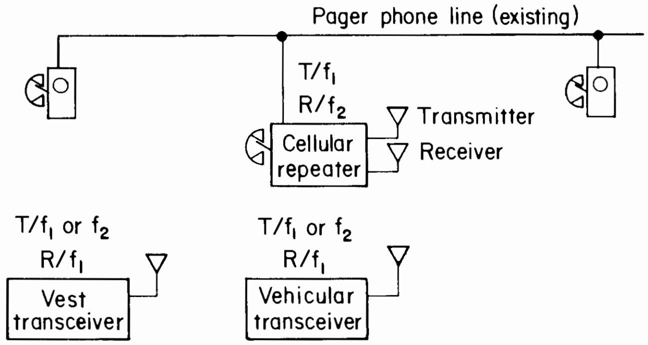

FIGURE 2-27. - Cellular repeater concept.

FIGURE 2-28. - Vest transceiver.

FIGURE 2-29. - Vehicular transceiver.

ears from epaulet speakers. A hinged control head is conveniently located on the front. The design allows the miners to maneuver in tight quarters and perform normal mining tasks without catching the radio on obstructions.

The vehicular unit can be conveniently placed on any mine vehicle. It is used in conjunction with a special loop antenna of advanced design that produces high magnetic moment. Mechanically, the antenna is enclosed in high strength lexan and is attached to the vehicle via special brackets. The lexan will not break even if severely flexed by impact.

Besides the mobile transceivers discussed above, the system also consists of fixed transceivers such as repeaters and base stations. (See figures 2-26 and 2-27.) For proper system operation it is necessary that these fixed transceivers have very efficient antennas so that the local wire plant can be properly illuminated and signals on the wire plant are properly received. This efficiency is paramount for whole-mine coverage.

The cellular repeaters use dual-loop antennas (for transmit and receiver) attached to the rib or posts in such a way that there is little danger of damage in normal mine activities. The transmit antenna produces a large magnetic moment that provides the signal for local cellular coverage, which is usually aided by parasitic coupling and reradiation effects. The receive antenna is similar.

The global repeater and base station use a newly designed RF line coupler (see fig. 2-30) that permits very efficient coupling to the mine wire plant. Like a current probe, the coupler can be easily clamped around local conductors. MF signal current flowing through the wire plant conductors produces a coupler output signal (V_O), which is applied to the input of the base station or repeater.

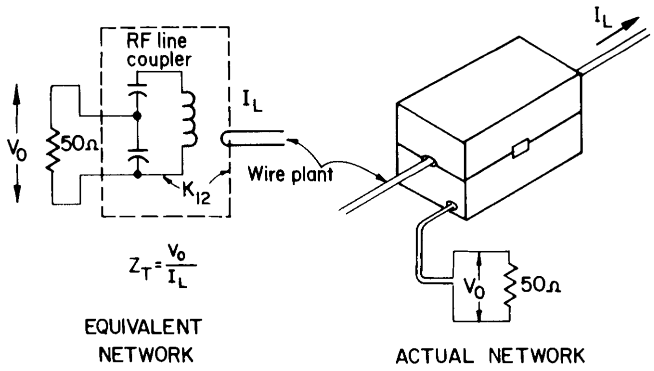

FIGURE 2-30. - RF line coupler for base stations and repeaters.

The base station is intended to be placed where mine management finds it most advantageous, usually in the surface office complex or with the dispatcher. If desired, the base station can be controlled remotely via signal lines that allow the control console to be placed in a surface building for convenience, while the actual base transceiver is placed in the mine where it can more efficiently couple into the local wiring. Both the global repeater and the base station utilize the RF line coupler for maximum efficiency. The cellular repeater is generally located in a working section. It enables the vest to operate as a mobile pager telephone by switching voice signals between the local pager telephone network and the vest. Vehicular radios can also operate in this mode.

The system was developed around an interchangeable set of plug-in radio circuit modules. The same receiver, synthesizer, and transmitter modules are used in the vehicular transceiver, base station, and repeaters. Servicing the equipment only requires troubleshooting to the board level. Since the equipment uses the same radio circuit modules, the performance specifications of all transceivers are similar. The signaling used depends upon the specific network requirements. All receivers are designed with an adaptive noise-operated squelch network that allows every transceiver on the net to hear the same message (party line).

The transmitters are designed with both subaudible (100 Hz) and in-band (1,000 Hz) tone oscillators. A subaudible tone is used in the vest transceiver to cause the cellular repeater to switch the message (page) to the pager telephone network. The repeater includes both a noise-operated squelch and a subaudible tone squelch for use in telephone switching. Subaudible tone signaling is useful in identifying "stuck on" transmitters that can block the communications net. In-band signaling is useful in emergency situations.

2.5 Hybrid Systems

Each of the communications systems already discussed has some individual shortcomings. However, one system may complement another system to alleviate certain problem areas. A hybrid is an interconnection of two or more subsystems, taking advantage of the benefits of each.

2.5.1 Improvements in System Versatility

As mines have grown and mining technology has improved, needs have arisen for new and improved communication capabilities that cannot adequately be provided by the traditional mine pager-type phones or trolley wire carrier phones. These needs include the following:

1. Ability to communicate when the phone line or the trolley wire breaks.

2. Ability to communicate with personnel not in the vicinity of a telephone.

3. Ability to communicate over private channels.

4. Ability to deliver important messages during periods of heavy communications traffic during emergencies.

5. Ability to communicate with surface public phones.

The following techniques are capable of satisfying the foregoing needs using hybrid systems:

1. Underground phones with manual trunking or automatic switching can provide privacy and an interconnection to the public telephone system on the surface. Also, a larger number of simultaneous communications can take place with multipair or multiplexed phone systems.

2. Low-frequency radio offers a means of paging and communicating directly using the mine structure within a working section, and through the mine overburden in times of emergency.

3. Medium-frequency radio can be used with power cables, trolley wires, and roof bolts to provide haulageway and section paging throughout the mine to key mining personnel carrying pocket pagers.

4. Very-high-frequency radio can be used with leaky feeder cable or coaxial cable and antennas, as a technique for guiding radio waves throughout the mine haulageways and entries. This technique can be used to provide whole-mine communications with hand-held radios carried by key mining personnel.

5. Ultra-high-frequency radio can provide wireless communication between key roving miners carrying radios within a working section, without the aid of additional wiring.

2.5.2 Dial Phone-Pager Phone Systems

Interconnect devices are avilable that permit mine paging telephones to be interconnected with the public phone system on a selective or temporary basis. The intent of these systems is to provide greater emergency communication capability during off-hours. These systems enable a person at a mine pager phone to gain access to the public phone system, or permit access to the mine page or phone system from any public phone.

Figure 2-31 shows one system in which the interconnect between public phone and mine phone is made automatically. In this type of system small hand-held tone-generators are required to activate the automatic interconnect at the mine office.

If a person in the mine wants to reach a prearranged public telephone from his mine phone, he sends a tone via the tone generator and mine phone to a telephone interconnect unit of the surface. At this surface interconnect, the tone is detected and activates a relay which, in turn, automatically dials the preset telephone number.

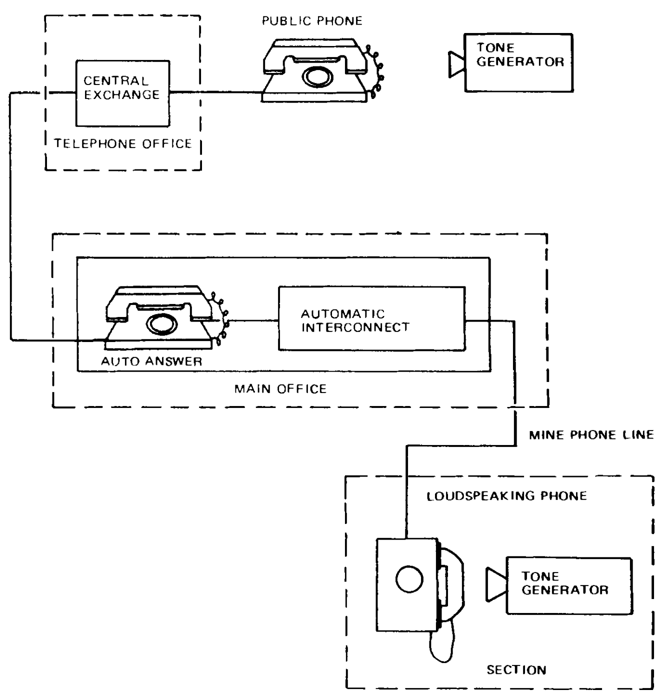

FIGURE 2-31. - Dial phone to pager phone hybrid.

When a person calls the "auto answer" telephone number from a public phone, the interconnect unit automatically answers the phone, and upon reception of the audio tone from the outside party, connects the incoming call directly to the mine pager phone line, thereby enabling the calling person to page and talk to the desired person in the mine.

Systems also exist where the interconnection between the mine phone system and the public telephone system is made manually, such as by a person on the surface.

2.6 Other Systems

2.6.1 Seismic Systems

A seismic system can be used for trapped miner location. If a miner strikes a roof bolt, floor, or rib of the mine with a heavy object, the vibrations travel through the earth to the surface and can be converted into electric signals by seismic transducers called geophones. These signals can be amplified, filtered, and recorded. Because the shock waves reach individual geophones at different times, the seismic recordings can be analyzed and the location of the miner can be determined. Analysis of seismic signals is a highly specialized field and beyond the scope of this manual. This method requires the assistance of an individual trained in seismic methods. However, the seismic system is the only trapped-miner system presently in operation and accepted by MSHA. Every miner should have a sticker (fig. 2-32) affixed to the inside of his helmet that he can refer to if entrapment should ever occur.

FIGURE 2-32. - MSHA signaling sticker.

2.6.2 Stench System

Stench is used primarily as an evacuation warning. It should be introduced into the underground system at as many locations as possible, with the intake air and the compressed air as priority. Wherever miners may be in the mine, driven air is required and eventually the driven air and stench will arrive at their location. Stench may be any clearly distinguishable odor.

The delay time in a stench warning system is one of its most important drawbacks. Another very important negative point is that stench warning cannot inform the miner what has happened, where it has happened, or what he should do. Many times this type of information can be worse than no information at all.

2.6.3 Hoist Bell Signaling

Much of the communication between the various levels of a mine and the hoist room consists of hoist bell signaling. This is a one-way communication system by which miners can request a cage and/or desired level.

In the hoist room, there is a power source for the system and a buzzer. Each shaft station has a buzzer and a pull bottle. The bottle, when pulled, closes a switch that sounds the buzzer in the hoist room and at all other levels (fig. 2-33). The number of times the bottle is pulled corresponds to a command code.

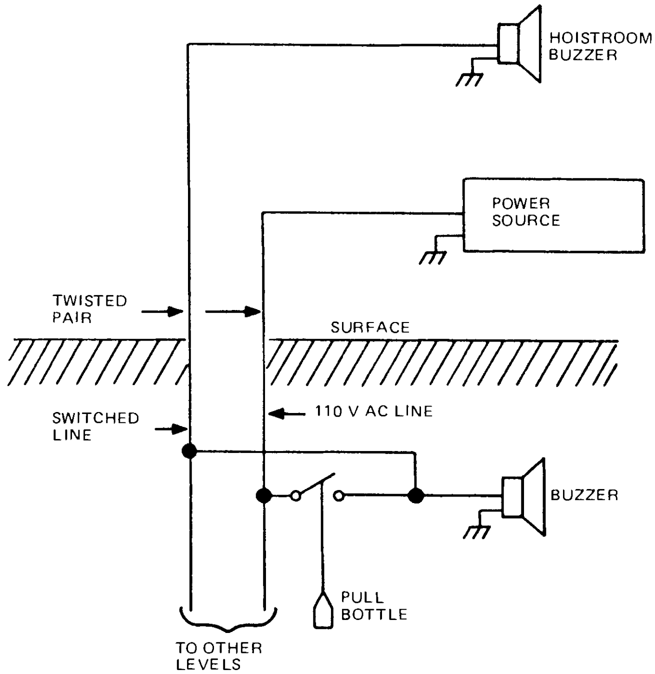

FIGURE 2-33. - Hoist bell operation.

2.6.4 Visual Pagers

One of the most common type of mine communication devices is the pager phone. However, with these systems, many calls are lost because the phone is too far from a working face or the page is not heard owing to high ambient noise. Visual pager systems are being developed that may eventually alleviate this problem.

The most common type of visual pager system consists of strobe lights located at strategic locations in the mine. These lights are controlled by a dispatcher who can set or reset them as required. They are usually used in conjunction with pager phones. Some modern multichannel phones have a light on the face of the phone that provides the visual paging function.

2.7 Summary

There are three basic types of communication systems used in underground mines: wired phone systems, radio system, and carrier current systems. Wired phone systems include common dial telephones, pager phones, dial-type pager phones, magneto phones, intercoms, and sound-powered phones. These may be connected in party line fashion using a two-wire pair, or in selective calling fashion using multipair or multiplex techniques. Wired phone systems may have no switchboard (party line) for small systems, a manual switchboard, an automatic exchange, or a more sophisticated computer-controlled switch. A major disadvantage of any wired phone system is that a roof fall could disrupt communications between miners and the surface.

Radio systems include all wireless communication systems. Coverage is limited in radio systems because of poor propagation of radio waves underground. Voice frequency ranges can be used for through-the-earth radio. Ultra-high-frequency radio can be used when it is combined with leaky feeder cables, antennas, and repeaters to extend coverage. Personal radio pagers can be used to summon an individual to a wired phone.

Carrier current systems utilize existing mine wiring to propagate RF signals. An RF signal from a carrier phone is induced onto a cable and transmitted throughout the length of that cable. A transceiver, inductive or capacitive coupled to the carrier cable, receives the RF signal, strips off the carrier, and lets the electromagnetic voice signal activate a speaker or earphone.

Modern MF radio systems are being developed that combine the best features of radio systems and carrier current systems. In these systems, no physical contact to existing mine wiring is required.

Since one system cannot usually satisfy all the communication requirements in a mine, interfaces have been developed to make hybrid systems. Hybrids (two or more systems interconnected) take advantage of the beneficial qualities of one system to alleviate the deficiencies of another system.

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