Unit 5
Chapter 2

5-11. Explain what *loading coils* and *bridge taps* are and when they can be detrimental to the performance of a telephone circuit. What is meant by the term L*oop resistance?*

Answer:-

Loading Coils:-

Loading coils placed in a cable decrease the attenuation, increase the line impedance and improve transmission levels for circuits longer than 18,000 feet. Loading coils allowed local loops to extend three to four times their previous length. A loading coil is simply a passive conductor wrapped around a core and placed in series with a cable creating a small electromagnet. Loading coils can be placed on telephone poles, in manholes, or on cross-connect boxes. Loading coils increase the effective distance that a signal must travel between two locations and cancels the capacitance that inherently builds up between wires with distance.

Loading coils cause a sharp drop in frequency response at approximately 3400 Hz, this is undesirable for high-speed data transmission. Therefore, for high-performance data transmission, loading coils should be removed from the cables. The low-pass characteristics of a cable also affect the phase distortion versus frequency characteristics of a signal. The amount of *phase distortion* is proportional to the length and gauge of the wire. Loading a cable also affects the phase characteristics of a cable. The telephone company must often add gain and delay equalizers to a circuit to achieve the minimum requirements. Equalizers introduce discontinuities or ripples in the band pass characteristics of a circuit. Automatic equalizers in data modems are sensitive to this condition, and very often an overequalized circuit causes as many problems to a data signal as an underequalized circuit.

Bridge Taps:-

A *bridge tap* is an irregularity frequently found in cables serving subscriber locations. Bridge taps are unused sections of cable that are connected in shunt to a working cable pair, such as a local loop. Bridge taps can be placed at any point along a cable’s length. Bridge taps were used for party lines to connect more than one subscriber to the same local loop. Bridge taps also increase the flexibility of a local loop by allowing the cable to go to more than one junction box, although it is unlikely that more than one of the cable pairs leaving a bridging point will be used at any given time. Bridge taps may or may not be used at some future time, depending on service demands. Bridge taps increase the flexibility of a cable by making it easier to reassign a cable to a different subscriber without requiring a person working in the field to cross connect sections of cable.

Bridge taps introduce a loss called *bridging loss.* They also allow signals to split and propagate down more than one wire. Signals that propagate down unterminated (open circuited) cables reflect back from the open end of the cable, often causing interference with the original signal. Bridge taps that are short and closer to the originating or terminating ends often produce the most interference. Bridge taps and loading coils are not generally harmful to voice transmissions, but if improperly used, they can literally destroy the integrity of a data signal. Therefore, bridge taps and loading coils should be removed from a cable pair that is used for data transmission. This can be a problem because it is sometimes difficult to locate a bridge tap. It is estimated that the average local loop can have as many as 16 bridge taps.

Loop Resistance:-

The dc resistance of a subscriber local loop is called loop resistance. It depends primarily on the type of wire and wire size. Most local loops use 18- to 26-gauge, twisted-pair copper wire. The dc loop resistance for copper conductors is approximated by

$$R_d = 0.1095/\mathbf{d}^2$$

where ***Rd*** = dc loop resistance (ohms per mile)

d = wire diameter (inches)

5-12. What *are* the three categories of *transmission parameters?* Describe *attenuation distortion* and *envelope delay distortion.*

Answer:-

Transmission parameters are divided into three broad categories:

Bandwidth parameters:- attenuation distortion and envelope delay distortion;

Interface parameters:- terminal impedance, in-band and out-of-band signal power, test signal power, and ground isolation;

Facility parameters:- noise measurements, frequency distortion, phase distortion, amplitude distortion, and nonlinear distortion.

Attenuation distortion is the difference in circuit gain experienced at a particular frequency with respect to the circuit gain of a reference frequency. This characteristic is sometimes referred to as *frequency response, differential gain,* and *1004-Hz deviation.*

Envelope delay distortion is an indirect method of evaluating the phase delay characteristics of a circuit. To reduce attenuation and envelope delay distortion and improve the performance of data modems operating over standard message channels, it is often necessary to improve the quality of the channel. The process used to improve a basic telephone channel is called *line conditioning.*

5-13. What is meant by *line conditioning?* Briefly describe the types of line conditioning are available?

Answer:-

To reduce attenuation and envelope delay distortion and improve the performance of data modems operating over standard message channels, it is often necessary to improve the quality of the channel. The process used to improve a basic telephone channel is called *line conditioning.* Line conditioning improves the high- frequency response of a message channel and reduces power loss. The attenuation and delay characteristics of a circuit are artificially altered to meet limits prescribed by the *line conditioning* requirements. Line conditioning is available only to private-line subscribers at an additional charge. The *basic voice-band channel* (sometimes called a *basic 3002 channel)* satisfies the minimum line conditioning requirements. Telephone companies offer two types of special line conditioning for subscriber loops: C-type and D-type.

C-type Line conditioning:- *C-type conditioning* specifies the maximum limits for attenuation distortion and envelope delay distortion. C-type conditioning pertains to line impairments for which compensation can be made with filters and equalizers. There are five classifications or levels of C-type conditioning available. The grade of conditioning a subscriber selects depends on the bit rate, modulation technique and desired performance of the data modems used on the line. The five classifications of C-type conditioning are the following:

Cl and C2 conditioning pertain to two-point and multipoint circuits.

C3 conditioning is for access lines and trunk circuits associated with private switched networks.

C4 conditioning pertains to two-point and multipoint circuits with a maximum of four stations.

C5 conditioning pertains only to two-point circuits.

D-type Line conditioning:- *D-type conditioning* neither reduces the noise on f a circuit nor improves the signal-to-noise ratio. It simply sets the minimum requirements for *signal-to-noise* (S/N) *ratio* and *nonlinear distortion.* D-type conditioning is sometimes referred to as *high-performance conditioning* and can be applied to private-line data circuits in addition to either basic or C-conditioned requirements. There are two categories for D-type conditioning: Dl and D2. Limits imposed by Dl and D2 are virtually identical. The only difference between the two categories is the circuit arrangement to which they apply. Dl conditioning specifies requirements for two-point circuits and D2 conditioning specifies requirements for multipoint circuits. D-type conditioning is mandatory when the data transmission rate is 9600 bps because without D-type conditioning, it is highly unlikely that the circuit can meet the minimum performance requirements guaranteed by the telephone company. D-type conditioned circuits must meet the following specifications:

Signal-to-C-notched noise ratio: $\geq$28 dB

Nonlinear distortion

Signal-to-second-order distortion: $\geq$35 dB

Signal-to-third-order distortion: $\geq$40 dB

The signal-to-notched noise ratio requirement for standard circuits is only 24 dB, and they have no requirements for nonlinear distortion.

5-14. Briefly describe the following parameters: 1004-Hz variation. C-message noise, impulse noise, gain hits and dropouts, phase hits, phase jitter. Single-frequency interference, frequency shift, phase intercept distortion, and peak-to-average ratio.

Answer:-

lOO4-Hz variation:- The telephone industry has established 1004 Hz as the standard test-tone frequency; 1000 Hz was originally selected because of its relative location in the pass band of a standard voice-band circuit. The frequency was changed to 1004 Hz with the advent of digital carriers because 1000 Hz is an exact sub multiple of the 8-kHz sample rate used with T carriers. Sampling a continuous 1000-Hz signal at an 8000-Hz rate produced repetitive patterns in the PCM codes, which could cause the system to lose frame synchronization.

The purpose of the 1004-Hz test tone is to simulate the combined signal power of a standard voice-band data transmission. The 1004-Hz channel loss for a private-line data circuit is typically 16 dB. A

1004-Hz test tone applied at the transmit end of a circuit should be received at the output of the circuit at -16 dBm. Long-term variations in the gain of the transmission facility are called *1004-Hz variation* and should not exceed ±4 dB. Thus, the received signal power must be within the limits of -12 dBm to -20 dBm.

C-message noise:- C-message noise measurements determine the average weighted rms noise power. Unwanted electrical signals are produced from the random movement of electrons in conductors. This type of noise is commonly called *thermal noise* because its magnitude is directly proportional to temperature. Because the electron movement is completely random and travels in all directions, thermal noise is also called *random noise,* and because it contains all frequencies, it is sometimes referred to as *white noise.* Thermal noise is inherently present in a circuit because of its electrical makeup. Because thermal noise is additive, its magnitude is dependent, in part, on the electrical length of the circuit.

C-message noise measurements are the terminated rms power readings at the receive end of a circuit with the transmit end terminated in the characteristic impedance of the telephone line. Impulse noise:- *Impulse noise* is characterized by high-amplitude peaks (impulses) of short duration having an approximately flat frequency spectrum. Impulse noise can saturate a message channel. Impulse noise is the primary source of transmission errors in data circuits. There are numerous sources of impulse noise—some are controllable, but most are not. The primary cause of impulse noise is man-made sources, such as interference from ac power lines, transients from switching machines, motors, solenoids, relays, electric trains, and so on. Impulse noise can also result from lightning and other adverse atmospheric conditions.

Gain hits and dropouts:- A *gain hit* is a sudden, random change in the gain of a circuit resulting in a temporary change in the signal level. A *dropout* is a decrease in circuit gain (i.e., signal level) of more than 12 dB lasting longer than *4* ms. Gain hits and dropouts are depicted in Figure 9-15.

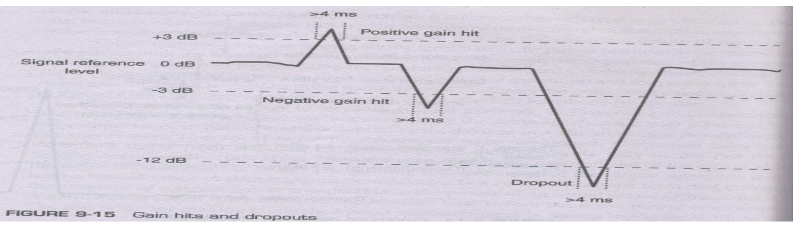


FIGURE 9-15 Gain hits and dropouts

Phase hits:- *Phase hits* (slips) are sudden, random changes in the phase of a signal. Phase hits are shown in Figure 9-16.

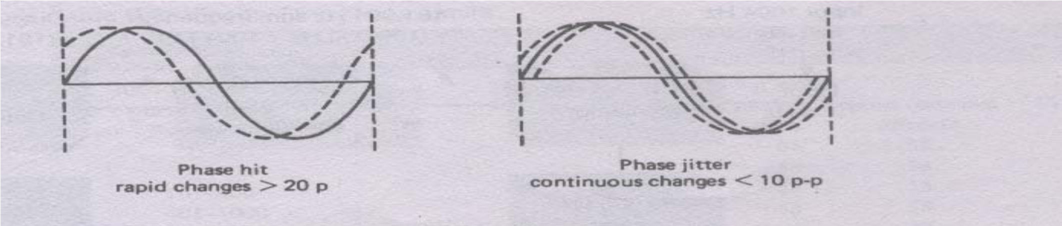


FIGURE 9-16 Phase hits and phase jitter

Phase jitter:- *Phase jitter* is a form of incidental phase modulation-a continuous, uncontrolled variation in the zero crossings of a signal. Generally, phase jitter occurs at a 300-Hz rate or lower, and its primary cause is low-frequency ac ripple in power supplies.

Single-frequency interference:- *Single-frequency interference* is the presence of one or more Continuous, unwanted tones within a message channel. The tones are called *spurious tones* and are often caused by crosstalk or cross modulation between adjacent channels in a transmission system due to system nonlinearities. Spurious tones are measured by terminating the transmit end of a circuit and then observing the channel frequency band. Spurious tones can cause the same undesired circuit behavior as thermal noise. Single-frequency interference is shown in Figure 9-17.

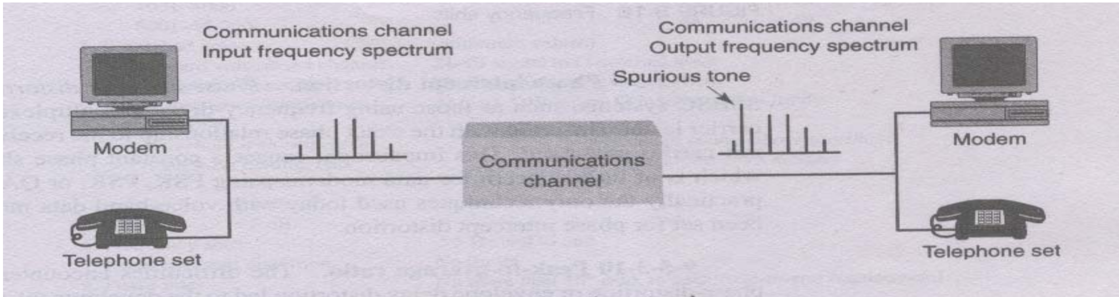


FIGURE 9-17 Single-frequency interference (spurious tone)

Frequency shift:- *Frequency shift* is when the frequency of a signal changes during transmission.

Frequency shift is shown in Figure 9-18.

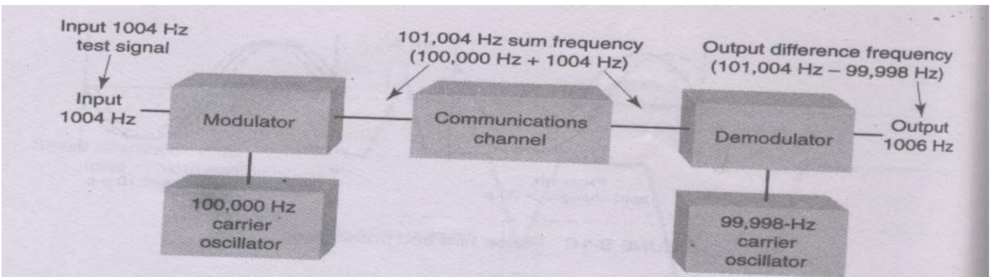


FIGURE 9-18 Frequency shift

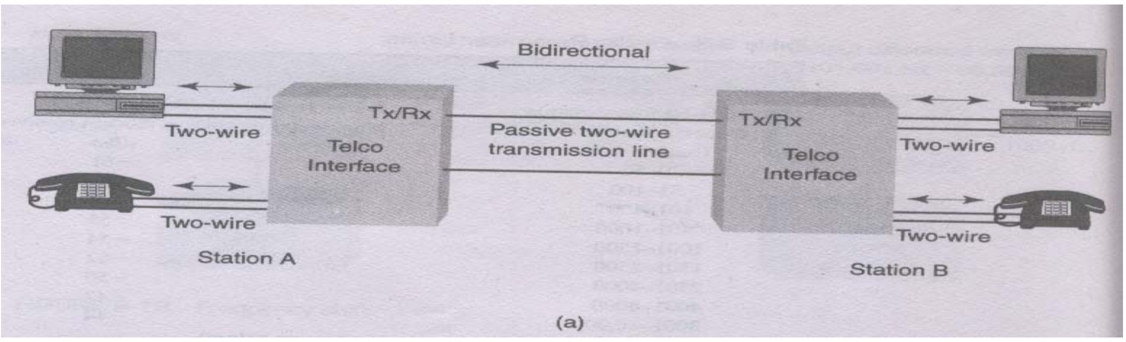
Phase intercept distortion:- *Phase intercept distortion* occurs in coherent SSBSC systems, such as those using frequency division multiplexing When the received carrier is not reinserted with the exact phase relationship to the received signal as the transmit carrier possessed. Peak-to-average ratio:- The difficulties encountered in measuring true phase distortion or envelope delay distortion led to the development *of peak-to-average ratio* (PAR) tests.

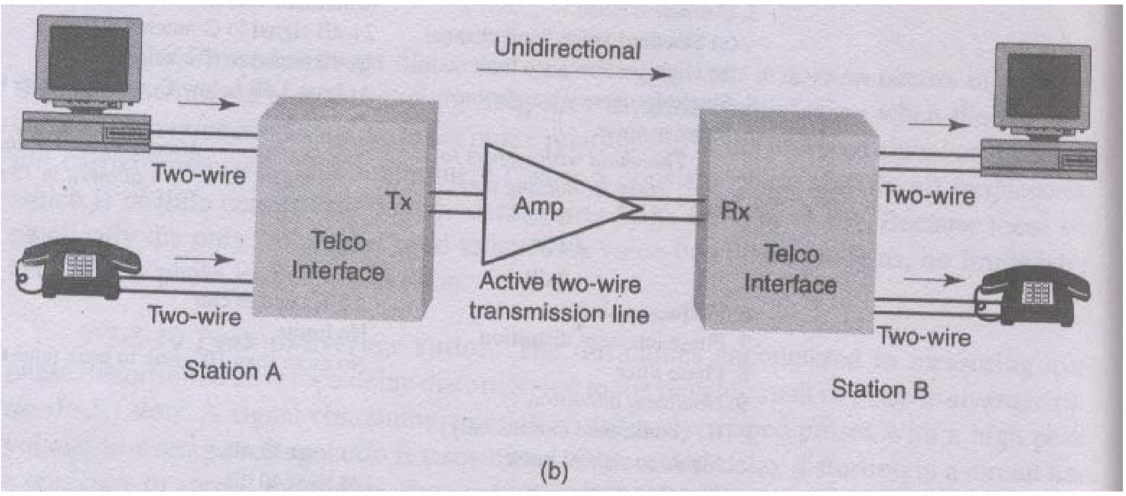
5-15. Describe what is meant by a *two-wire circuit* and *a four-wire circuit?*

Two-Wire Voice-Frequency Circuits:-

As the name implies, *two-wire transmission* involves two Wires (one for the signal and one for a reference or ground) or a circuit configuration that is equivalent to using only two wires. Two-wire circuits are ideally suited to simplex transmission, although they are often used for half- and full-duplex transmission

Figure 9-19 shows the block diagrams for four possible two-wire circuit configurations.





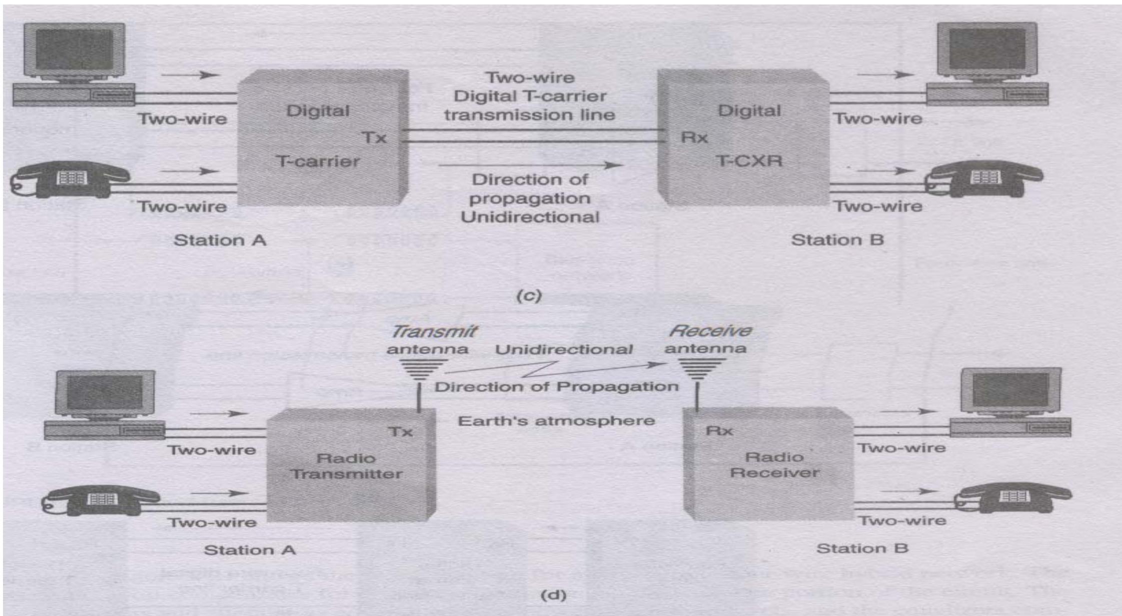
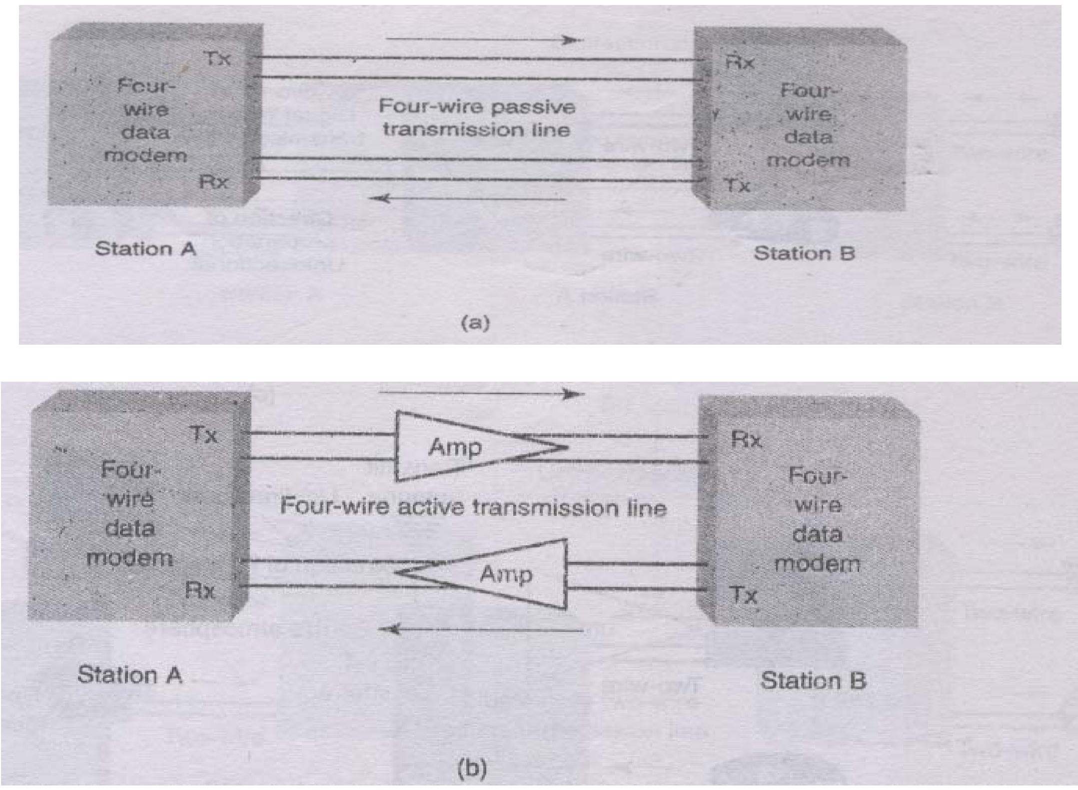


FIGURE 9-19 (Continued) (c) digital T carrier system; (d) wireless radio carrier system

Four-Wire Voice-Frequency Circuits:-

As the name *implies, four-wire transmission* involves four wires (two for each direction-a signal and a reference) or a circuit configuration that is equivalent to using four wires. Four-wire circuits are ideally suited to full-duplex transmission, although they can (and very often do) operate in the half-duplex mode. As with two-wire transmission, there are two forms of four-wire transmission systems: *physical four wires* and *equivalent four wire.*

Figure 9-20 shows the block diagrams for four possible four-wire circuit configurations.



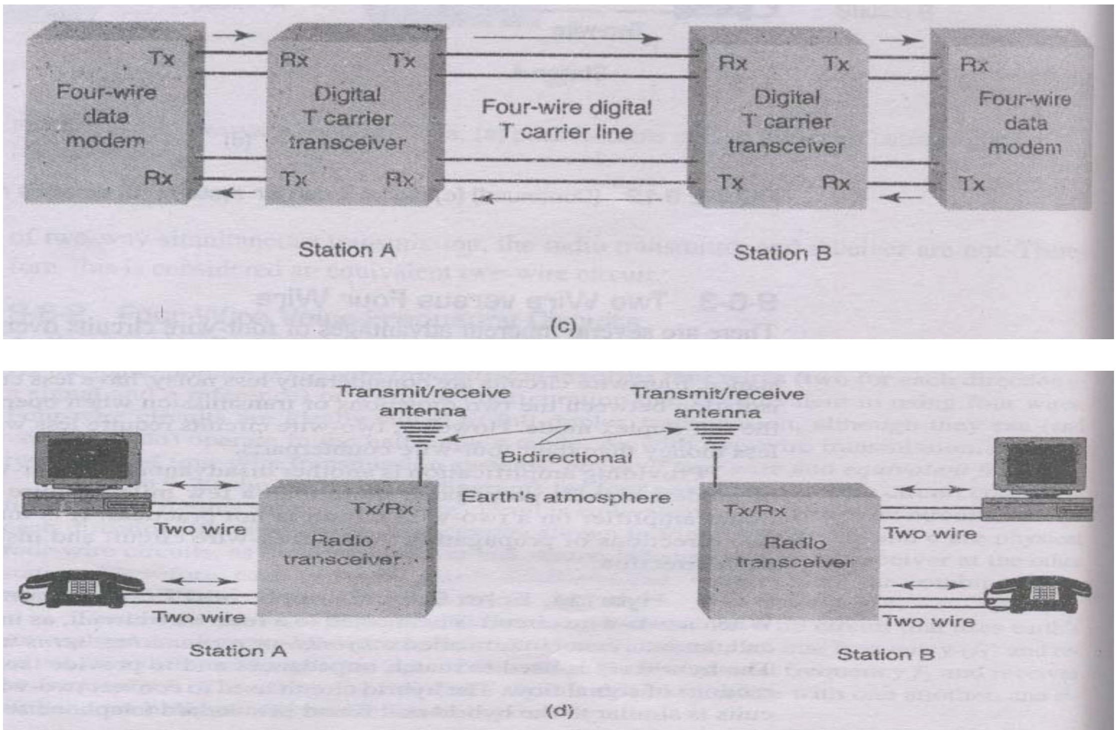


FIGURE 9-20 Four-wire configurations: (a) passive cable circuit; (b) active cable circuit; (c) digital T carrier system; (d) wireless radio carrier system

5-16. Briefly describe the function of a two-wire-to-four-wire *hybrid set.*

Answer:-

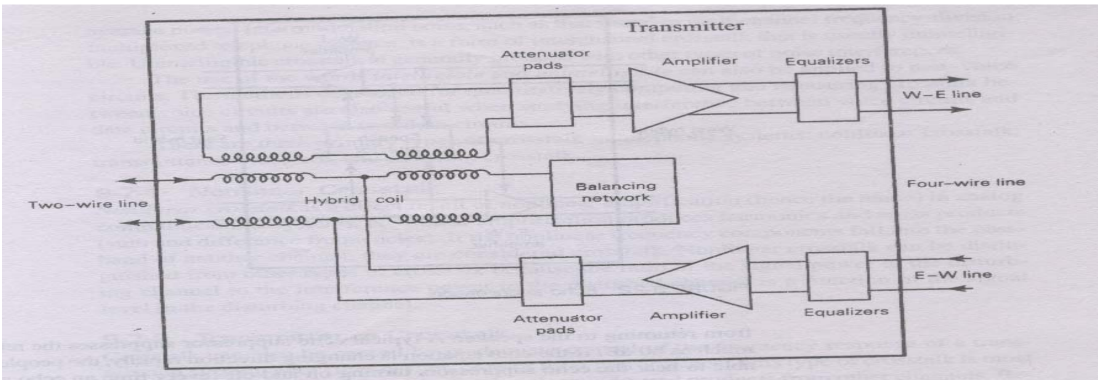


FIGURE 9-21 Hybrid (terminating) sets

Figure 9-21 shows the block diagram for a two-wire to *four-wire* hybrid network. The hybrid coil compensates for impedance variations in the two-wire portion of the circuit. The amplifiers and attenuators adjust the signal power to required levels, and the equalizers compensate for impairments in the transmission line that affect the frequency response of the transmitted signal, such as line inductance, capacitance, and resistance. Signals traveling west to east (W-E) enter the terminating set from the two-wire line, where they are inductively coupled into the west-to-east transmitter section of the four-wire circuit. Signals received from the four-wire side of the hybrid propagate through the receiver in the east-to-west (E-W) section of the four- wire circuit, where they are applied to the center taps of the hybrid coils. If the impedances of the two-wire line and the balancing network are properly matched, all currents produced in the upper half of the hybrid by the E-W signals will be equal in magnitude but opposite in polarity. Therefore, the voltages induced in the secondary's will be 1800 out of phase with each other and, thus, cancel. This prevents any of the signals from being retransmitted to the sender as an echo. If the impedances of the two-wire line and the balancing network are not matched, voltages induced in the secondary's of the hybrid coil will not completely cancel. This imbalance causes a portion of the received signal to be returned to the sender on the W-E port ion of the four-wire circuit.

5-17. What is the purpose of an *echo suppressor* and an *echo canceler?*

Answer:-

Balancing networks can never completely match a hybrid to the subscriber Loop because of long-term temperature variations and degradation of transmission lines. The talker hears the returned portion of the signal as an echo, and if the round-trip delay exceeds approximately 45 ms, the echo can become quite annoying. To eliminate this echo, devices called *echo suppressors* are inserted at one end of the four-wire circuit.

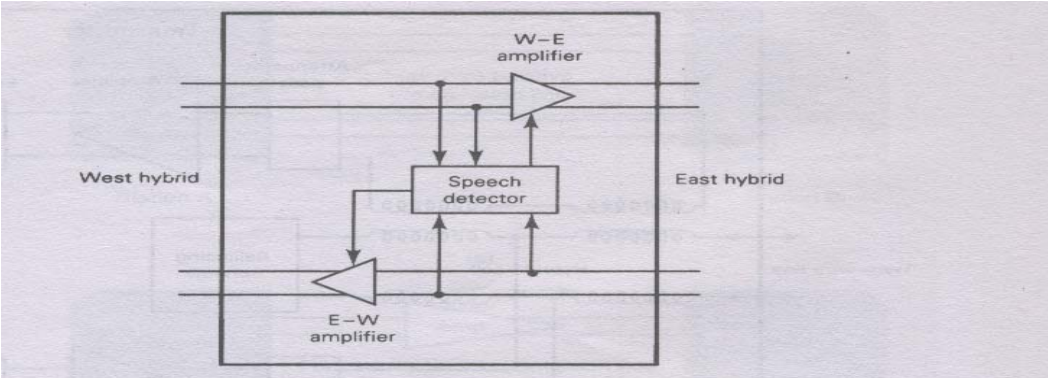


FIGURE 9-22 Echo suppressor

Figure 9-22 shows a simplified block diagram of an echo suppressor. The speech detector senses the presence and direction of the signal. It then enables the amplifier in the appropriate direction and disables the amplifier in the opposite direction, thus preventing the echo from returning to the speaker. A typical echo suppressor suppresses the returned echo by as much as 60 dB. If the conversation is changing direction rapidly, the people listening may be able to hear the echo suppressors turning on and off (every time an echo suppressor detects speech and is activated, the first instant of sound is removed from the message, giving the speech a choppy sound). If both parties talk at the same time, neither person is heard by the other.

With an echo suppressor in the circuit, transmissions cannot occur in both directions at the same time, thus limiting the circuit to half-duplex operation. Long-distance carriers, such as AT&T, generally place echo suppressors in four-wire circuits that exceed 1500 electrical miles in length (the longer the circuit, the longer the round-trip delay time). Echo suppressors are automatically disabled when they receive a tone between 2020 Hz and 2240 Hz, thus allowing full-duplex data transmission over a circuit with an echo suppressor. Full- duplex operation can also be achieved by replacing the echo suppressors with *echo cancelers.* Echo cancelers eliminate the echo by electrically subtracting it from the original signal rather than disabling the amplifier in the return circuit.

5.18. Briefly describe *crosstalk*. List and describe three types of crosstalk.

Answer:-

Crosstalk can be defined as any disturbance created in a communications channel by signals in other communications channels (i.e., unwanted coupling from one signal path into another). Crosstalk can originate in telephone offices, at a subscriber's location, or on the facilities used to interconnect subscriber locations to telephone offices.

Nonlinear crosstalk:- It is a direct result of nonlinear amplification (hence the name) in analog communications systems. Nonlinear amplification produces harmonics and cross products (sum and difference frequencies). If the nonlinear frequency components fall into the pass- band of another channel, they are considered crosstalk. Nonlinear crosstalk can be distinguished from other types of crosstalk because the ratio of the signal power in the disturbing channel to the interference power in the disturbed channel is a function of the signal level in the disturbing channel.

Transmittance Crosstalk:-

Crosstalk can also be caused by inadequate control of the frequency response of a transmission system, poor filter design, or poor filter performance. This type of crosstalk is most the prevalent when filters do not adequately reject undesired products from other channels.

Coupling Crosstalk:-

Electromagnetic coupling between two or more physically isolated transmission media is called *coupling crosstalk.* The most common coupling is due to the effects of near-field mutual induction between cables from physically isolated circuits (i.e., when energy radiates from a wire in one circuit to a wire in a different circuit). To reduce coupling crosstalk due to mutual induction, wires are twisted together (hence the name *twisted pair).* Twisting the wires causes a canceling effect that helps eliminate crosstalk.