UNIT 7

Chapter 1&2

7-1. what is meant by data and the term *overhead?*

Answer:- *Data can be generally defined as information that is stored in digital format, usually in the form of binary digits. Data may be alphabetic, numeric, or symbolic in nature. Data added to the original information is called overhead, and sometimes a message contains more overhead than user information.*

7-2. what are some of the other names for *data communications codes? E*xplain why the *Morse code* is inadequate for modern-day data communications network.

Answer:- *Data communications codes* are often used to represent characters and symbols, such as letters, digits, and punctuation marks. Therefore, these types of data communications codes are called *character codes, character sets, symbol codes,* or *character languages.* In essence, there are only three types of characters used with character codes: data-link control characters, alphanumeric characters, and graphic control characters.

Morse Code:- The Morse code is inadequate for use in modern digital equipment because all characters do not have the same number of symbols or take the same length of time to send, and each Morse code operator transmits code at a different rate. It literally requires the reasoning ability of a human brain to decode Morse code. Morse code also has an insufficient selection of graphic and data-link control characters to facilitate the transmission and presentation of the data used in contemporary computer applications.

7-3. what is the purpose of the *figure shift* and le*tter shift* in the Baudot code?

The *Baudot code* (sometimes called the *Telex code)* was the first *fixed-length character code* developed for machines rather than for people. With fixed-length source codes, all characters are represented in binary and have the same number of symbols (bits). The Baudot code is a five-bit character code that was used primarily for low- speed teletype equipment, such as the TWX/Telex system and radio teletype (RTTY). With a five-bit code, there are only 2, or 32, combinations possible, which is insufficient to represent the 26 letters of the alphabet, 10 digits, and the various punctuation marks and control characters. Therefore, the Baudot code uses two special control characters called figure *shift* (FS) and *letter shift* (LS) to expand its capabilities to 58 characters. Characters that follow a letter shift are interpreted from the letter column, and characters that follow the figure shift are interpreted from the figure column. For example, the letter shift followed by 1 00 00 represents the letter E, whereas the figure shift followed by 1 0000 represents the digit 3. Each time you switch from the letter column to the figure column and vice versa, you must insert either a letter shift or a figure shift character.

7-4. what is a *bar code,* and when is it commonly used? Describe what is meant by *discrete bar code, continuous bar code,* and *2D bar code.*

Answer:- *Bar codes* are those omnipresent black and white striped stickers that seem to a - every consumer item found in every store in the United States and most of the rest world. A bar code is a series of vertical black bars separated vertical white bars (called spaces). The widths of the bars and spaces, along with their reflective abilities, represent binary 1's and 0's that identify a specific item. In addition, bar codes may contain information regarding cost, inventory management and cost security access, shipping and receiving, production counting, document and order processing, automatic billing, and many other applications.

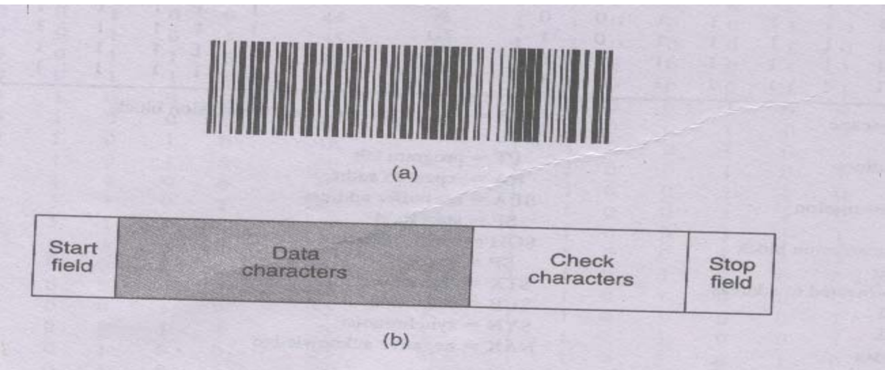

FIGURE 13-1 (a) Bar code; (b) bar code layout

Figure 13-lb shows the layout of the fields found on a typical bar code. The field consists of a unique sequence of bars and spaces used to identify the beginning the data field. The data characters correspond to the bar code symbology or format used. Serial data encoded in the data character field is extracted from the card with an optical scanner. The scanner reproduces logic conditions that correspond to the difference in reflectivity of the printed bars and underlying white spaces. To read the information, simply scan over the printed bar with a smooth, uniform motion. A photo detector in the scar senses the reflected light and converts it to electrical signals for decoding.

There are several standard bar code formats used today in industry. The format is selected on the basis of the type of data being stored, how the data is being stored, system performance, and which format is most popular with business and industry. Bar codes are generally classified as being discrete, continuous, and 2D.

Discrete code:- A discrete bar code has spaces or gaps between characters. Therefore, each character within the bar code is independent of every other character. Code 39 is an example of a discrete bar code.

Continuous code:- A continuous bar code does not include spaces between characters. An example of a Continuous bar code is the Universal Product Code (UPC).

2D code:- A 2D (two-dimensional) bar code stores data in two dimensions instead of in conventional linear bar codes, which store data along only one axis. A 2D bar code has a larger storage capacity than one-dimensional bar codes (typically 1 kilobyte a more per data symbol).

7-5. Describe what is meant by *error control and detection.*

Answer:-

Error Control :-A data communications circuit can be as short as a few feet or as long as several thousand miles, and the transmission medium can be as simple as a pair of wires or as complex as microwave, satellite, or optical fiber communications system. Therefore, because of non ideal transmission characteristics associated with any communications system, it is inevitable that errors will occur, and it is necessary to develop and implement procedures for error control. Transmission errors are caused by electrical interference from natural sources, such as lightning, as well as from man-made sources, such as motors, generators, power lines, and fluorescent lights.

Data communications errors can be generally classified as *single bit, multiple bit, or burst.* Single-bit errors are when only one bit within a given data string is in error. Single bit errors affect only one character within a message. A multiple-bit error is when two or nonconsecutive bits within a given data string are in error. Multiple-bit errors can affect one or more characters within a message. A burst error is when two or more consecutive bits w a given data string are in error. Burst errors can affect one or more characters within a message.

Error Detection:- *Error detection* is the process of monitoring data and determining when transmission errors have occurred. Error-detection techniques neither correct errors nor identify which bits are in error: they indicate only when an error has occurred. The purpose of error detection is not to prevent errors from occurring but to prevent undetected errors from occurring. How data communications systems react to transmission errors is system dependent and varies considerably.

7-6. Briefly describe *redundancy error detection and echoplex.*

Answer:- The most common error-detection techniques used for data communications networks are redundancy, echoplex, exact-count coding, and redundancy checking, which includes vertical redundancy checking, checksum, longitudinal redundancy checking, and cyclic redundancy checking. *Redundancy* is a form of error detection where each data unit is sent multiple times, usually twice. At the receive end, the two units are compared, and if they are the same, it is assumed that no transmission errors have occurred. When the data unit is a single character, it is called *character redundancy,* whereas if the data unit is the entire message, it is called *message redundancy.* Character redundancy is the most common form of redundancy. If the exact same character is not received twice in succession, a transmission error must have occurred. With message redundancy, if the exact same sequence of characters is not received twice in succession, in exactly the same order, a transmission error must have occurred.
Echoplex (sometimes called *echo checking)* is a relatively simple form of error-detection scheme used almost exclusively with data communications systems involving human operators working in real time at computer terminals or PCs. With echoplex, receiving devices retransmit received data back to the transmitting device; therefore, echoplex requires full- duplex operation. Each character is transmitted immediately after it has been typed on the key board. At the receive end, once a character has been received, it is immediately transmitted back to the originating terminal, where it appears on that terminal's screen. When the re character appears on the screen, the operator has verification that the character has been

received at the destination terminal, if a transmission error occurs, the wrong character will be displayed on the transmit terminal's screen. When this happens, the operator can send a back space and remove the erroneous character and then type and resend the correct character.

7-7. Briefly describe the following error-detection schemes: *checksum, check character checksum, single-precision checksum, double-precision checksum, Honeywell checksum,* and *residue checksum.*

Answer:-

Checksum:- *Checksum* is another relatively simple form of redundancy error checking where the data within a message is summed together to produce an error- checking character (checksum). The checksum is appended to the end of the message. The receiver replicates the summing operation and determines its own sum and checksum character for the message. The receiver's checksum is compared to the checksum appended to the message, and if they are the same, it is assumed that no transmission errors have occurred. If the two checksums are different, a transmission error has definitely occurred. There are five primary ways of calculating a checksum: *check character, single precision, double precision, Honeywell,* and *residue.*
Check character checksum:- With a check character checksum, a decimal value is assigned to each character. The decimal values for each character of the message are added together (summed) to produce the checksum character, which is app ended to the end of the message as redundant bits and transmitted. The Code 39 and POSTNET bar codes use modified forms of check characters to determine a checksum.

Single-precision checksum:- Single-precision checksum is probably the most common method of calculating checksums. With single precision, the checksum is calculated by simply performing binary addition of the data within the message. However, with n-bit characters (where *n* equals the number of bits in each character), if the sum of the data exceeds 2^n -1, a carryout occurs. The carry bit is ignored, and only the n-bit checksum is appended to the message. Therefore, the checksum with single-precision addition is the LSB of the arithmetic sum of the binary data being transmitted.

Double-precision checksum:- A double-precision checksum is computed in the same manner as with single-precision except the checksum is 2n bits long. For *exa*mple, if the data is comprised of eight-bit characters, the checksum would contain 16 bits, thereby reducing the probability of producing an erroneous checksum.

Honeywell checksum:- The Honeywell checksum is another form of double-precision checksum. The Honeywell checksum is *2n* bits long however, the checksum is based on interleaving consecutive data words to form double-length words. The double length words are summed together to produce a double-precision checksum.

Residue checksum:- The residue checksum is virtually identical to the single-precision checksum except for the way the carry bit is handled. With the residue checksum, carry bit is wrapped around and added to the LSB of the sum, adding complexity.

7-8. Briefly describe *cyclic redundancy checking.*

Answer:-

With CRC generation, the division is not accomplished with standard arithmetic vision. Instead, modulo-2 division is used, where the remainder is derived from an exclusive OR (XOR) operation. In the receiver, the data stream, including the CRC code, is divided by the same generating function *P(x).* If no transmission errors have occurred, the remainder will be zero. In the receiver, the message and CRC character pass through a block check register. After the entire message has passed through the register, its contents should be zero if the receive message contains no errors.

Mathematically, CRC can be expressed as G(x)/P(x)=Q(x)+R(x)

where *G(x)* = message polynominal
P(x) = generator polynominal
Q(x) = quotient
R(x) = remainder

Example:- Determine the BCS for the following data- and CRC-generating polynomials:

Data G(x)= $x^7 + x^5 + x^4 + x^2 + x^1 + x^0$

= 10110111

CRC P(x)= $x^5+x^4+x^1+x^0$ =110011

Solution First, $G(x)$ is multiplied by the number of bits in the CRC code, which is 5.

$$x^5(x^7 + x^5 + x^4 + x^2 + x^1 + x^0) = x^{12} + x^{10} + x^9 + x^7 + x^6 + x^5 = 1011011100000$$

Then divide the result by $P(x)$:

```
                      1 1 0 1 0 1 1 1
1 1 0 0 1 1  |  1 0 1 1 0 1 1 1 0 0 0 0 0
                1 1 0 0 1 1
                  1 1 1 1 0 1
                  1 1 0 0 1 1
                    1 1 1 0 1 0
                    1 1 0 0 1 1
                      1 0 0 1 0 0
                      1 1 0 0 1 1
                        1 0 1 1 1 0
                        1 1 0 0 1 1
                          1 1 1 0 1 0
                          1 1 0 0 1 1
                            0 1 0 0 1  =  CRC
```

The CRC is appended to the data to give the following data stream:

```
            G(x)                CRC
1 0 1 1 0 1 1 1 1 0 1 0 0 1
```

At the receiver, the data is again divided by $P(x)$:

```
                      1 1 0 1 0 1 1 1
1 1 0 0 1 1  |  1 0 1 1 0 1 1 1 1 0 1 0 0 1
                1 1 0 0 1 1
                  1 1 1 1 0 1
                  1 1 0 0 1 1
                    1 1 1 0 1 0
                    1 1 0 0 1 1
                      1 0 0 1 1 0
                      1 1 0 0 1 1
                        1 0 1 0 1 0
                        1 1 0 0 1 1
                          1 1 0 0 1 1
                          1 1 0 0 1 1
                          0 0 0 0 0 0   Remainder = 0,
```

which means there were no transmission errors

7-9. Give a brief explanation of the *Hamming code with an example.*

Answer:-

Hamming bits (sometimes called *error bits)* are inserted into a character at random locations. The combination of the data bits and the Hamming bits is called the Hamming code. The only stipulation on the placement of the Hamming bits is that both the sender and the receiver must agree on where they are placed. To calculate the number of redundant Hamming bits necessary for a given character length, a relationship between the character bits and the Hamming bits must be established. As shown in Figure 13-10, a data unit contains *m* character bits and *n* Hamming bits.

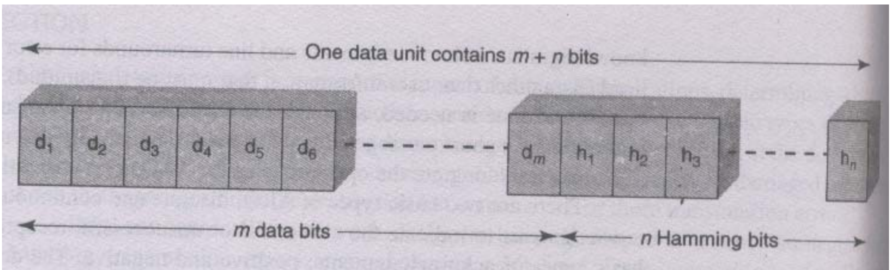

FIGURE 13-10 Data unit comprised of *m* character bits and *n* Hamming bits

Therefore, the total number of bits in one data unit is m+n. Since the Hamming bits must be able to identify which bit is in error, *n* Hamming bits must be able to indicate at least *m* + *n* + 1 different codes. Of the *m* + *n* codes, one code indicates that no errors have occurred, and the remaining *m* + *n* codes indicate the bit position where an error has occurred. Therefore, m + *n* bit positions must be identified with *n* bits. Since *n* bits can produce 2^ndifferent codes, 2^n must be equal to or greater than m+n+1. Therefore, the number of Hamming bits is determined by the following expression:

$2^n >= m + n + 1$
where m = number of Hamming bits
n = number of bits in each data character

The Hamming code uses parity to determine the logic condition of the Hamming bits. Each Hamming bit equates to the even-parity bit for a different combination of data bits. For example, the data unit representing ASCII character A shown in Figure 13.11a uses four Hamming (parity) bits. The seven data bits are placed in bit positions 3, *5, 6, 7,9,* l0,and 11, and the four Hamming bits are placed in bit positions 1,2,4, and 8 (all powers of 2) and designated n_1, n_2, n_4, and n_8 respectively. The data bits included in the calculation of each Hamming bit are shown next. Also shown in the figure are the logic conditions for the data bits for ASCII character A and the logic condition of each of the Hamming bits.

	Data bits					Hamming bit (even parity)
bit positions	3	5	7	9	11	n_1
logic conditions	1	0	0	0	1	0
bit positions	3	6	7	10	11	n_2
logic conditions	1	0	0	0	1	0
bit positions	5	6	7			n_4
logic conditions	0	0	0			0
bit positions	9	10	11			n_8
logic conditions	0	0	1			1

Figure 13-11 b shows ASCII character A after the Hamming bits have been added.

ASCII code for upper case letter A = 1000001

Bit #	1	2	3	4	5	6	7	8	9	10	11
logic condition	n_1	n_2	1	n_4	0	0	0	n_8	0	0	1

Hamming bits n_1, n_2, n_4, and n_8

(a) Before determining logic condition of Hamming bits

Bit #	1	2	3	4	5	6	7	8	9	10	11
logic condition	0	0	1	0	0	0	0	1	0	0	1

Hamming bits 0, 0, 0, and 1

(b) After determining logic condition of Hamming bits

FIGURE 13-11 (a) Before determining logic condition of Hamming bits; (b) after determining logic condition of Hamming bits

if an occurs in one data bit, one or more of the Hamming bits will indicate a parity error. To determine the data bit in error, simply add the numbers of the parity bits that failed. For example, if bit 6 were received in error, the received bit sequence would be 00 1 00101001. Parity checks for n_1 and n_8 would pass, but parity checks for n_2 and n_4 would fail. To determine the bit position in error (called the *svndrome)* , simply add the positions of the Hamming bits that are in error. In this case, $n_2 + n_4$ equates to 2 + 4= 6. Thus, bit 6 is in error.

An alternate method of determining the Hamming bits is shown in Example l3-9

Example 13-9

For a 12-bit data string of 101100010010, determine the number of Hamming bits required, arbitrarily place the Hamming bits into the data string, determine the logic condition of each Hamming bit, assume an arbitrary single-bit transmission error, and prove that the Hamming code will successfully detect the error.

Solution Substituting $m = 12$ into Equation 13-2, the number of Hamming bits is

$$\text{for } n = 4 \qquad 2^4 = 16 \geq 12 + 4 + 1 = 17$$

16 < 17; therefore, four Hamming bits are insufficient:

$$\text{for } n = 5 \qquad 2^5 = 32 \geq 12 + 5 + 1 = 18$$

32 > 18; therefore, five Hamming bits are sufficient, and a total of 17 bits make up the data stream (12 data plus 5 Hamming).

Arbitrarily place five Hamming bits into bit positions 4, 8, 9, 13, and 17:

bit position	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	H	1	0	1	H	1	0	0	H	H	0	1	0	H	0	1	0

To determine the logic condition of the Hamming bits, express all bit positions that contain a logic 1 as a five-bit binary number and XOR them together:

Bit position	Binary number
2	00010
6	00110
XOR	00100
12	01100
XOR	01000
14	01110
XOR	00110
16	10000
XOR	10110 = Hamming bits

$b_{17} = 1, \quad b_{13} = 0, \quad b_9 = 1, \quad b_8 = 1, \quad b_4 = 0$

The 17-bit Hamming code is

```
   H        H             H  H          H
   1  1  0  1  0  1  0  0  1  1  0  1  0  0  0  1  0
```

Assume that during transmission, an error occurs in bit position 14. The received data stream is

```
1  1  0  0  0  1  0  0  1  1  0  1  0  0  0  1  0
         ‿
       error
```

At the receiver, to determine the bit position in error, extract the Hamming bits, and XOR them with the binary code for each data bit position that contains a logic 1:

Bit position	Binary number
Hamming bits	10110
2	00010
XOR	10100
6	00110
XOR	10010
12	01100
XOR	11110
16	10000
XOR	01110 = 14

Therefore, bit position 14 contains an error.

7-10. Describe *data communications modems* and tell where they are used in data communications circuits.

Answer:-

Data communications equipment (DCE) describes the hardware that allows *digital terminal equipment* (DTE) to access a transmission facility, such as a metallic or optical fiber cable. Because DCEs are used to terminate the digital portion of a data communications circuit, they are sometimes called *data circuit-terminating equipment* (DCTE).

Digital terminal equipment are always some type of digital device; however, the transmission facility they connect to may have been designed for either digital or analog signals. Therefore, there are two basic types of data communications equipment. The first type of DCE is called a *modem*. Modems allow digital terminal equipment to access and interface to analog transmission facilities. In essence, the purpose of a modern is to convert digital signals to analog signals and vice versa. Therefore, modems include both an *analog- to-digital converter* (ADC) and a *digital-to-analog converter* (DAC).

The ADC is used in the modem's receiver, and the DAC is used in the modem's transmitter. The second type of DCE actually involves two devices that allow digital equipment to access and interface with digital transmission facilities. The two devices are called *channel service units* (CSUs) and *digital service units* (DSUs). Although CSUs and DSUs perform different functions, they are often combined into one unit.

7-11.Describe the basic functions of a *channel service unit.*

Answer *:-*

Digital service units (DSUs) and *channel service units* (CSUs) are *customer premise equipment* (CPE) used to terminate a digital circuit at a subscriber's location and allow the subscriber to connect to a local central telephone office.

Digital Service Unit :- At the transmit end, a digital service unit (DSU) converts unipolar digital signals (such as TIL) from a local area network's digital terminal equipment into self-clocking bipolar digital signals that are capable of being transmitted more efficiently over a telecommunications line. At the receive end, a DSU removes any special codes inserted by the transmitting DSU and converts the bipolar digital signals back to unipolar. A DSU may also provide timing (clock) recovery, control signaling, and synchronous sampling.

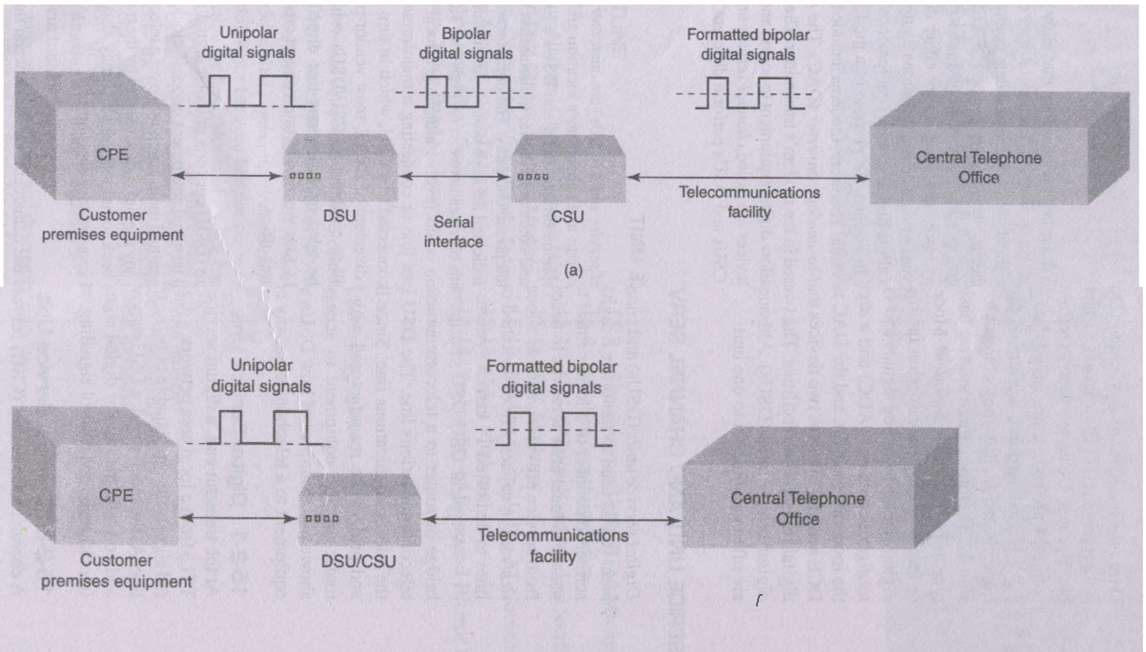

FIGURE 15-1 Channel service units and digital service units: (a) separate DSU and CSU; (b) combined DSU/CSU

Channel Service Unit :-A channel service unit (CSU) serves as the demarcation point between the digital Station equipment and the telecommunications line. A CSU physically terminates the telecommunications line, performs signal regeneration and reshaping, performs zero substitution, and converts digital signals to a format more suitable for transmission over the digital transmission facility, such as AMI,2B1Q encoding. CSU s may also perform other functions, such as channel multiplexing and line conditioning (equalization); execute certain carrier-controlled tests, such as local and remote loop backs; and provide performance measurement capabilities and statistical compilations.

7-12.What is meant by the term *voice-band data communications modem?*

Answer:- The most common type of data communications equipment (DCE) is the *data communications modem.* Alternate names include *datasets, data phones,* or simply *modems.* The word *modem* is a contraction derived from the words *modulator* and *demodulator*. Data communications modems designed to operate over the limited bandwidth of the public telephone network are called *voice-band modems.*

Because digital information cannot be transported directly over analog transmission media (at least not in digital form), the primary purpose of a *data communications modem* is to interface computers, computer networks, and other digital terminal equipment to analog communications facilities. Modems are also used when computers are too far apart to be directly interconnected using standard computer cables. In the transmitter (modulator) section of a modem, digital signals are encoded onto an analog carrier signal. The digital signals modulate the carrier, producing digitally modulated analog signals that are capable of being transported through the analog communications media. Therefore, the output of a modem is an analog signal that is carrying digital information. In the receiver section of a modem, digitally modulated analog signals are demodulated. Demodulation is the reverse process of modulation. Therefore, modem receivers (demodulators) simply extract digital information from digitally modulated analog carriers.

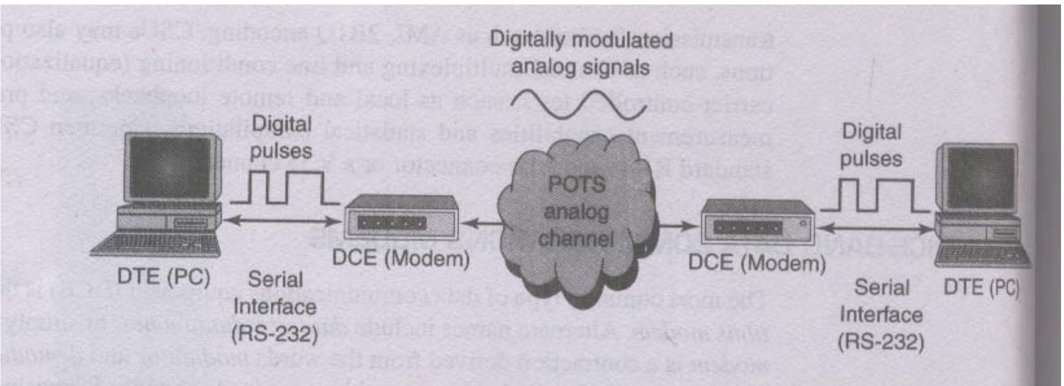

FIGURE 15-2 Data communications modems—POTS analog channel

The most common (and simplest) modems available are those intended to be used to interface DTEs through a serial interface to standard voice-band telephone lines and provide reliable data transmission rates between 300 bps and 56 kbps. These types of modems are sometimes called *telephone-loop modems* or *POTS modems,* as they are connected to the telephone company through the same local loops used for standard voice telephone circuits. More sophisticated modems (sometimes called *broadband modems* or *cable modems)* are also available that are capable of transporting data at much higher bit rates over wide- band communications channels, such as those available with optical fiber, coaxial cable, microwave radio, and satellite communications systems. Broadband modems operate using a different set of standards and protocols than telephone loop modems.

7-13.List and describe the basic blocks of a voice-band modem.

Answer:- The primary blocks of a modem are described here:

Serial interface circuit:- This interfaces the modem transmitter and receiver to the serial interface. The transmit section accepts digital information from the serial interface, converts it to the appropriate voltage levels, and then directs the information to the modulator. The receive section receives digital information from the demodulator circuit, converts it to the appropriate voltage levels, and then directs the information to the serial interface. In addition, the serial interface circuit manages the flow of control, timing, and data information transferred between the DTE and the modem, which includes handshaking signals and clocking information.

Modulator circuit:- This receives digital information from the serial interface circuit. The digital information modulates an analog carrier producing a digitally modulated analog signal. In essence, the modulator converts digital changes in the information to analog changes in the carrier. The output from the modulator is directed to the transmit band- pass filter and equalizer circuit.

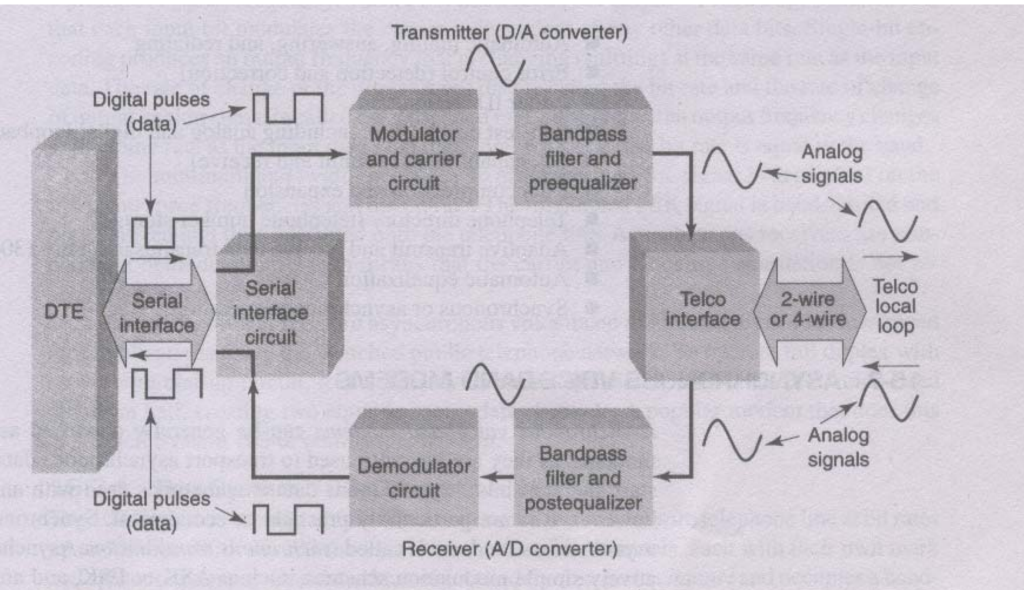

FIGURE 15-3 Simplified block diagram for a modem

Band pass filter and equalizer circuit:- There are band pass filter and equalizer circuits in both the transmitter and the receiver sections of the modem. The transmit band pass filter limits the bandwidth of the digitally modulated analog signals to a bandwidth appropriate for transmission over a standard telephone circuit. The receive band pass filter limits the bandwidth of the signals allowed to reach the demodulator circuit, thus reducing noise and improving system performance. Equalizer circuits compensate for bandwidth and gain imperfections typically experienced on voice-band telephone lines.

Telco interface circuit:- The primary functions of the Telco interface circuit match the impedance of the modem to the impedance of the telephone line and regu1a amplitude of the transmit signal. The interface also provides electrical isolation and protection and serves as the demarcation (separation) point between subscriber equipment and telephone company provided equipment. The Telco line can be two wire or four wire, and the modem can operate half or full duplex. When the telephone line is two wire, the Telco interface circuit would have to perform four-wire-to-two-wire and two-wire-to-four-wire conversions.

Demodulator circuit:- This receives modulated signals from the band pass filter and equalizer circuit and converts the digitally modulated analog signals to digital signals. The output from the demodulator is directed to the serial interface circuit, where it is passed on to the serial interface.

*Carrier and clock generation circuit:-*The carrier generation circuit produces the analog carriers necessary for the modulation and demodulation processes. The clock generation circuit generates the appropriate clock and timing signals required for performing transmit and receive functions in an orderly and timely fashion.

7-14.Ddescribe the characteristics and basic blocks of asynchronous voice-band modems.

Answer:- ***Asynchronous voice band modems*** can be generally classified as low-speed voice band modems, as they are typically used to transport asynchronous data (i.e., data framed with start and stop bits). Synchronous data is sometimes used with an asynchronous modem; however, it is not particularly practical or economical. Synchronous data transported by asynchronous modems is called ***isochronous transmission.*** Asynchronous modems use relatively simple modulation schemes, such as ASK or FSK, and are restricted to relatively low-speed applications (generally less than 2400 bps), such as telemetry and caller ID.

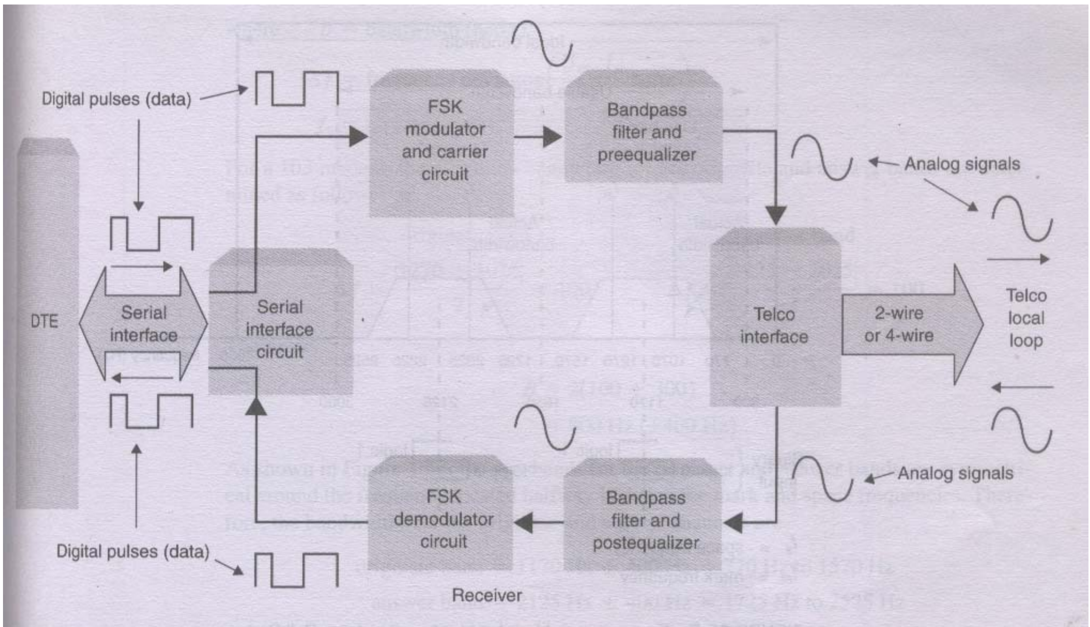

FIGURE 15-4 Simplified block diagram for an asynchronous FSK modem

Figure *15-4* shows a simplified block diagram for an asynchronous voice-band FSK modem. In the transmitter, serial data received from the DTE is applied directly to the FSK modulator.

Clocking information is not required because FSK modulators are typically voltage-controlled oscillators, which react to voltage levels independent of any timing reference. The voltage for a binary 1 produces a mark frequency, and the voltage for a binary 0 produces a space frequency. Thus, FSK modulators use single-bit encoding, which means that each input bit modulates the carrier independent of any other data bits. Single-bit encoding produces an output frequency that is changing (shifting) at the same rate as the input data. The rate of change of the digital input data is called the bit rate and the rate of change of output analog signal is called baud (or baud rate). With FSK, the output frequency changes at the same rate as the input data rate; therefore, with FSK the bit rate is equal to the baud.

The minimum bandwidth necessary to propagate an FSK signal is dependent on the mark and space frequencies and the bit rate. The modulated FSK signal is band-limited and preequalized and then outputted onto the telephone line. Asynchronous receivers use non-coherent demodulation, which means that the carrier and clocking information is not recovered in the receiver.
There are several standard asynchronous voice-band modems designed for low-speed data applications using the switched public telephone network. To operate full duplex with a two-wire dial-up circuit, it is necessary to divide the usable bandwidth of a voice-band circuit in half, creating two equal-capacity data channels. A popular modem that does this is the Bell System 103 or compatible modem.

7-15. What is *modem synchronization?* Define *modem synchronization* and list its functions.

Answer:- During the (RTS/CTS) delay, a transmit modem outputs a special, internally generated bit pattern called a *training sequence.* This bit pattern is used to synchronize (train) the receive modem at the distant end of the communications channel. Depending on the type *of* modulation, transmission bit rate, and modem complexity, the training sequence accomplishes one or more of the following functions:

1. Initializes the communications channel, which includes disabling echo and establishing the gain of automatic gain control (AGC) devices
2. Verifies continuity (activates RLSD in the receive modem)
3. Initializes descrambler circuits in the receive modem
4. Initializes automatic equalizers in the receive modem
5. Synchronizes the receive modem's carrier to the transmit modem's carrier
6. Synchronizes the receive modem's clock to the transmit modem's clock

Modem Equalizers:-

Equalization is the compensation for phase delay distortion and amplitude distortion inherently present on telephone communications channels. One form of equalization provided by the telephone company is C-type conditioning, which is available only on private line circuits. Additional equalization may be performed by the modems themselves *Compromise equalizers* are located in the transmit section of a modem, and they provide *pre equalization-they* shape the transmitted signal by altering its delay and gain characteristics before the signal reaches the telephone line. It is an attempt by the modem to compensate for impairments anticipated in the bandwidth parameters of the communication line. When a modem is installed, the compromise equalizers are manually adjusted to provide the best error performance. Typically, compromise equalizers affect the following:

1. Amplitude only
2. Delay only
3. Amplitude and delay
4. Neither amplitude nor delay

Compromise equalizer settings may be applied to either the high- or the low-voice-band frequencies or symmetrically to both at the same time. Once a compromise equalizer setting has been selected, it can only be changed manually. The setting that achieves the best error performance is dependent on the electrical length of the circuit and the type of facilities that make it up.

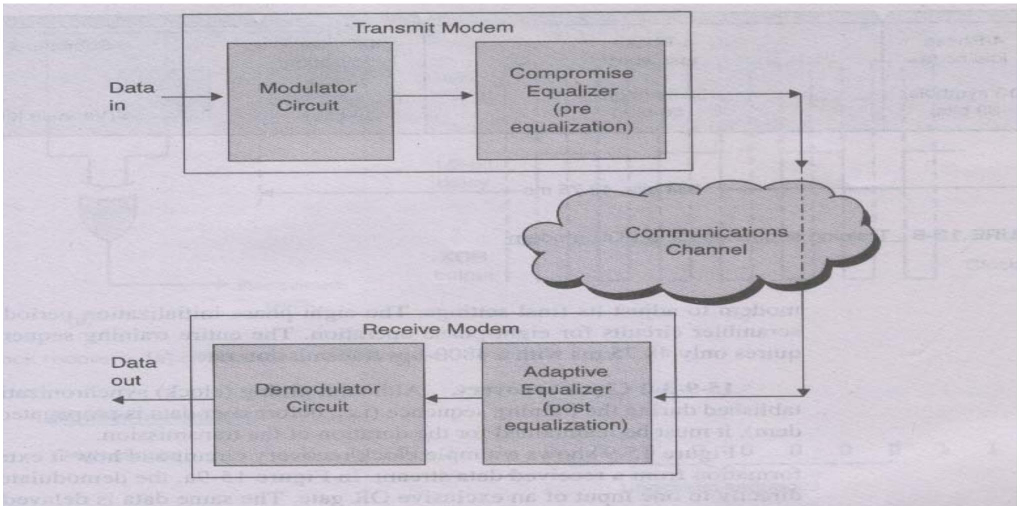

FIGURE 15-7 Compromise and adaptive equalizers

Adaptive equalizers:-They are located in the receiver section of a modem, where they provide post equalization to the received signals. Adaptive equalizers automatically adjust their gain and delay characteristics to compensate for phase and amplitude impairments encountered on the communications channel. Adaptive equalizers may determine the quality of the received signal within its own circuitry, or it may acquire this information from the demodulator or descrambler circuits. Whatever the case, the adaptive equalizer may continuously vary its settings to achieve the best overall bandwidth characteristics for the circuit.

7.16. What are the purposes of *scrambler* and *descrambler circuits?*

Answer:-

Scrambler and descrambler circuits:- The purpose of a scrambler circuit is to detect undesirable sequences of 1s and 0s and convert them to a sequence more conducive to clock recovery. The job of a descramble is to detect scrambled data and convert it back to its original sequence. If a scrambler circuit simply randomized data, it would be impossible to convert the data back to its original sequence in the receiver. Therefore, scrambler circuits pseudo randomize data and alter it in a logical manner, allowing it to be descrambled in the receiver. For a scrambler circuit to be effective, the descrambler must contain the appropriate descrambling algorithm to recover the original bit sequence before data is sent to the DTE. The purpose of the scrambler is not simply to randomize the bit sequence

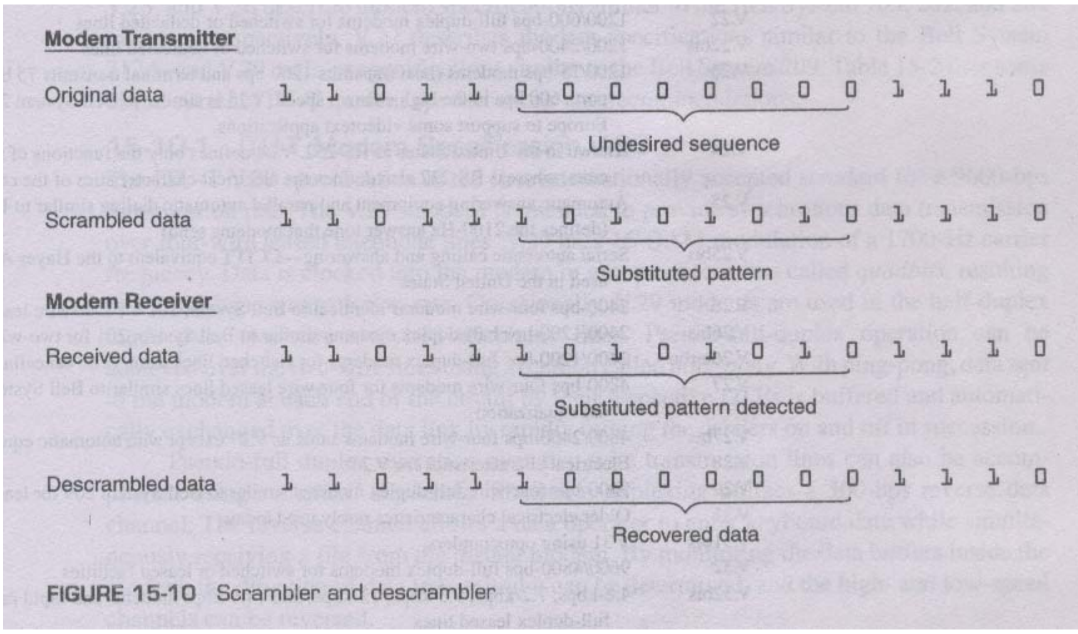

FIGURE 15-10 Scrambler and descrambler

but also to detect the occurrence of an undesirable bit sequence and convert it to a more acceptable pattern (i.e., one Containing transitions).

Figure 15-10 illustrates the basic idea behind scrambler and descrambler circuits. The scrambler shown detects eight consecutive logic 0s and converts them to an alternating 1/0 pattern, which is more conducive to clock recovery. The descrambler detects the alternating 1/0 pattern and converts the sequence back to the original eight consecutive Os. Actual scrambler and descrambler circuits obviously use more complex scrambling and descrambling algorithms.

7-17. Explain the difference between the terms *probability of error* and *bit error* .

Answer:- *Probability of error (P[e])* and *bit error rate* (BER) are often used interchangeably, although in practice they do have slightly different meanings. *P(e)* is a theoretical (mathematical) expectation of the bit error rate for a given system. BER is an empirical (historical) record of a system's actual bit error performance. For example, if a system has a *P(e)* of 10^{-5}, this means that mathematically you can expect one bit error in every 100,000 bits transmitted ($1/10^{-5}$= 1/100,000). If a system has a BER of 10^{-5}, this means that in past performance there was one bit error for every 100,000 bits transmitted. A bit error rate is measured and then compared with the expected probability of error to evaluate a system's performance.

7-18. Describe the differences between *cable modems* and *standard voice-band modems.*

Anwer:-

Cable modems are similar to standard voice-band modems, except cable modems operate at higher frequencies, operate at higher bit rates, use more sophisticated modulation and demodulation schemes, and require more bandwidth than conventional voice-band modems. Cable modems connect subscribers to cable TV (CATV) facilities, such as coaxial cables and optical fibers, and provide high-speed Internet access and video services. A single CATV channel can support multiple individual subscribers or a local area network using a shared network protocol capable of supporting many users, such as Ethernet.

Cable modems are broad band modems, which simply means that they require wider bandwidths than standard voice-band moderns. Another example of a broadband modem is an Asymmetric Digital Subscriber Line (ADSL) modem. Subscribers are connected through a cable modem over a TV cable to a CATV network *headend,* which is the originating point for the CATV audio, video, and data signals. With cable modems, the upstream (subscriber to headend) and downstream (headend to subscriber) frequency spectrums and transmission rates are not the same (asymmetrical transmission). For obvious reasons, the bandwidths are considerably wider and transmission rates considerably higher on the downstream connection. Cable modem frequency assignments and transmission rates are the following:

Upstream:

Carrier frequency: 5 MHz to 40 MHz
Transmission rate: 19.2 kbps to 3 Mbps

Downstream:

Carrier frequency: 250 MHz to *850* MHz
Transmission rate: 10 Mbps to 30 Mbps

Individual data channels are assigned frequency slots in 250-kHz increments with a maximum bandwidth of 6 MHz