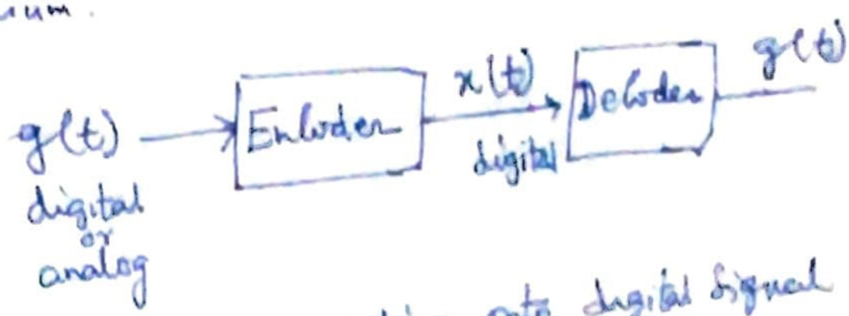
Signal encoding Techniques -

Both analog and digital data can be encoded as either analog or digital signal. The particular encoding that is chosen depends on the specific requirements to be met and the transmission medium.

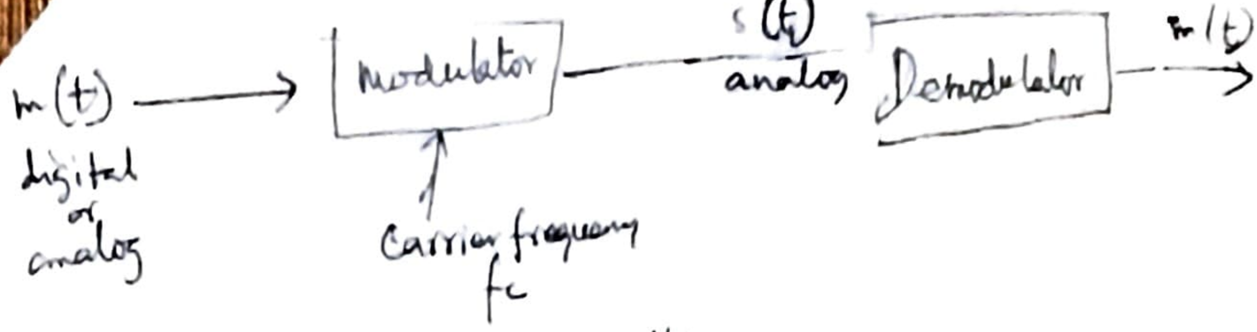
Digital signaling

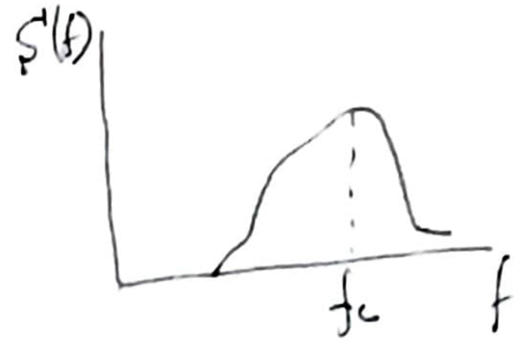


encoding onto digital signal

data source g(t) either digital or analog, is encoded onto digital signal x(t). The actual form of x(t) depends on encoding technique which is chosen to optimize the use of transmission medium (for some application to conserve bandwidth, whereas in some other application to minimize errors).

Analog signaling - The basis for analog signaling is a continuous constant-frequency signal known as carrier signal. The frequency of carrier signal is chosen to be compatible with the transmission medium being used. Data will then be transmitted using the carrier signal by modulation. The modulation is the process of encoding source data onto carrier signal with frequency fc. All modulation techniques involve operations on one or more of the three fundamental frequency domain parameters - amplitude, frequency, and phase. So, the input signal m(t) [analog or digital] (modulating signal or baseband signal) will be passed to the modulator to produce the modulated signal s(t) which is bandlimited and often centred on fc.





modulation onto analog signal

1. Digital data → digital signal :- A digital signal is a sequence of discrete, discontinuous voltage pulse. Each pulse is a signal elements. Binary data are transmitted by encoding each data bit into signal elements. Thus, an encoding scheme is nothing but a mapping between data bits and signal elements.

To interpreate digital signals at the receiver, the receiver must know the timing of each bit (when a bit begins and ~~ends~~ ends) with some accuracy. And, the receiver ~~also~~ must be able to distinguish the binary 1 and 0 based on their signal level. This can be done by sampling each bit position in the middle of the interval and comparing the value to a threshold. Because of noise and other impairments there may be errors.

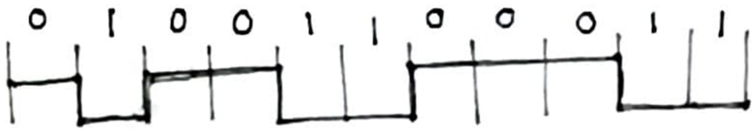
What are the factors that determine how successful the receiver will be able to interpreate the incoming signal?

1. signal-to-~~interference~~ noise ratio (an increase in SNR decreases bit error rate (BER))
2. the data rate (increase in data rate increases BER)
3. the bandwidth (increase in bandwidth increases data rate)

The other factor that can be used to improve the performance is the encoding scheme. There are many encoding scheme. The most commons are —

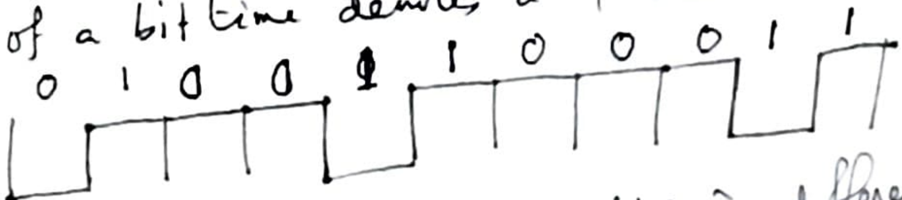
A - Nonreturn to Zero (NRZ) — In this scheme, digital signal is transmitted by using two defferent voltage levels corresponding to two binary bits. Codes that follow this strategy have the property that the voltage level is constant during a bit interval, i.e, there is no transition (No return to 0 level) in between the intervals.

— Nonreturn to zero - Level:- negative voltage level represent binary 1 and positive voltage level represents binary 0.



NRZ-L

— Nonreturn to zero - Inverted:- As with NRZ-L, NRZ-I maintains constant voltage pulse for the duration of a bit time. The data themselves are encoded as the presence or absence of a signal transition at the begining of the bit time. A transition (low ↔ high) at the begining of a bit time denotes a 1 and no transition denotes 0.



NRZ-I

NRZ-I is a type of differencial encoding. In differencial encodings, the information to be transmitted is represented in terms of the changes between successive signal elements rather than the signal elements themselves. If the current bit is a 0, the current bit is encoded with same signal as the preceding bit, if the current bit is a 1, the current bit is encoded with a different signal than the preceding bit.

...efit of differencial encoding is that it may be more reliable to detect a transition in the presence of noise than to compare a value to a threshold.

The NRZ Codes are easiest to ~~engineer~~ implement and make use of bandwidth efficiently. The limitations are presence of dc component and lack of synchronization (long string of 0 or 1 in NRZ-L and long string of 0 in NRZ-I, constant voltage over a long period of time).

NRZ codes are commonly used for digital magnetic recording but not that much of attractive for signal transmission application.

B. multilevel Binary - these codes use more than two signal levels.

- bipolar AMI :- a binary 0 is represented by no line signal and a binary 1 is represented by a positive ~~or~~ negative pulse. The binary 1 pulses must alternate in polarity. [unipolar - if the signal elements all have same sign (+ or -).
  polar :- one state is represented by positive, the other by negative]
- ~~pse~~ pseudoternary :- a binary 1 is represented by no line signal, and a binary 0 is represented by alternative positive and negative pulses.

[there is no particular advantage of one over the other but each is the basis of some application]

Advantages of multilevel binary are 1) no loss of synchronization of a long string of 0 (pseudoternary) or long string of ~~1~~ (bipolar AMI) introduces a transition, and each 1 (Bipolar AMI) or 0 (pseudoternary) introduces a transition. However, a the receiver can resynchronize on that transition.

of string of 0 (bipolar AMI) or 1 (pseudoternary) would still be a problem.

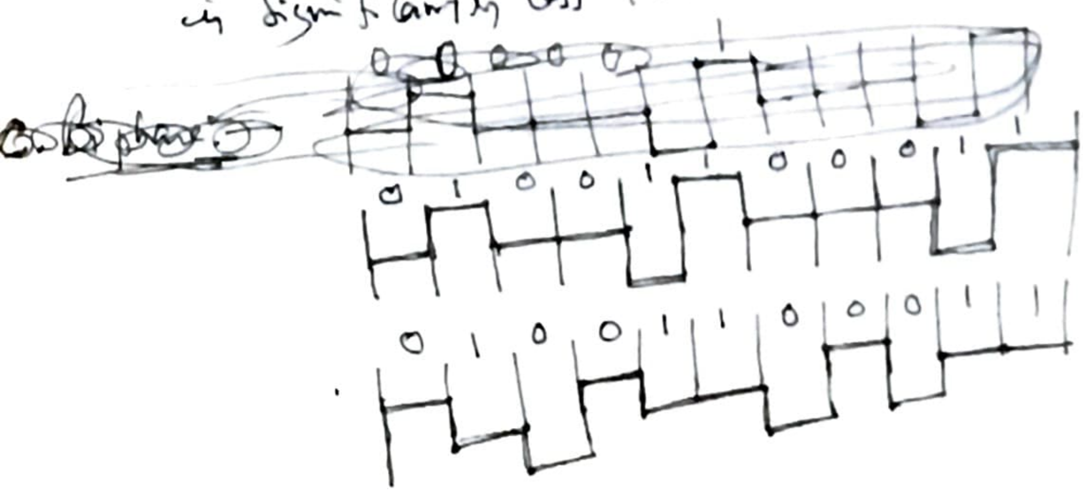
2) Because the 1 signals (or, 0 signals) alternate in voltage from positive to negative, there is no dc component.

3) the bandwidth of resulting signals is considerably less than the bandwidth of for NRZ.

4) pulse alternation property provides a simple means of error detection

Disadvantages - 1) long string of 0 (AMI) or 1 (pseudoternary) still a problem
(2) To overcome this, one can insert additional bits to force transitions. This approach (used in ISDN - Integrated Services digital network) may be good for low data rate but at high data rate, this scheme is expensive because it results in an increase in an already high signal transmission rate.

2) the receiver has to distinguish between (+, −, 0) three levels instead of just two level in NRZ. Because of this, the multilevel binary signal requires approximately 3 dB more signal power than (3) two-valued signal for the same probability of bit error. In other words, the bit error rate for NRZ codes, at a given SNR, is significantly less than that for multilevel binary.



bipolar-AMI

pseudoternary

Biphase - <u>manchester encoding</u> :- there is a transition at the middle of each bit. The midbit transition serves as a clocking mechanism and also data - a low to high transition represents a 1 and a high to low transition represents a 0.

<u>Differential manchester encoding</u> - The midbit transition is used only to provide clocking. The encoding of 0 is represented by the presence of a transition at the begining of a bit, and a 1 is represented by the absence of a transition at the begining of a bit.

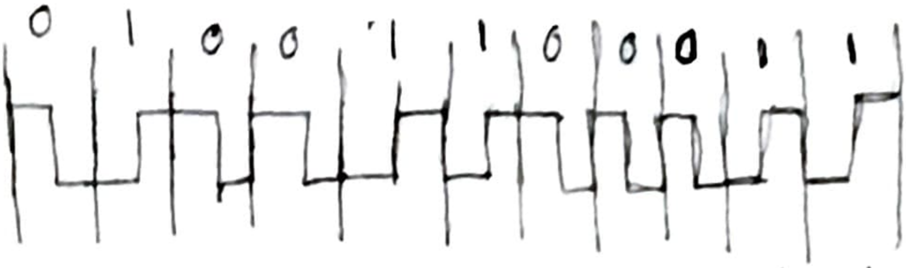
All biphase techniques require at least one transition per bit and may have as many as two transitions. Thus the maximum modulation rate is twice that for NRZ. This means that bandwidth required is correspondingly greater than NRZ. On the other hand, the biphase have several advantages -

1.) Synchronization - Since there is a predictable transition during each bit, the receiver can synchronize on that transition (Self-clocking code).

2) No dc component - biphase codes have no dc component.

3) Error detection - The absence of an expected transition can be used to detect errors. Noise has to invert both the signal before and after the expected transition to cause undetected error.

Biphase codes are popular for data transmission and used in IEEE 802.3 (Ethernet).



manchester

Differential manchester.

Data rate – bits per second (bps) = $\frac{1}{T_b}$ when T_b = bit duration
modulation rate – the rate at which signal elements are generated and represented in ~~baud~~ baud.

Manchester – the minimum size signal element is a pulse of one half of a bit duration. Thus maximum modulation rate there is $2/T_b$, for a string of all 0s and all 1s.

In general, $D = \frac{R}{L}$

R = data rate
D = modulation rate
L = number of bits per signal element.

Baud rate = 2 × Bit rate for manchester, $L=\frac{1}{2}$

One way of computing modulation rate is to determine the average number of transition per bit time. This will depend on the exact sequence of bits being transmitted.

Biphase codes are popular for LAN but not been widely used in long-distance application. The principle reason is that they require high signaling rate relative to the data rate. This sort of inefficiency is more costly in long-distance application.

usually one symbol represents multiple bit
In manchester, multiple symbol (2) represents one bit.

Scrambling schemes — Sequence that would create a constant voltage level on the line are replaced by filling sequences that will provide sufficient transition for the receiver's clock to maintain synchronization. The filling sequence must be recognized by the receiver and replaced with the original data sequence. The filling sequence is the same length as the original sequence, so there is no data rate penalty. The design goals are —

* No dc component
* No long sequence of zero-level signals
* No reduction in data rate.
* Error-detection capability.

Two techniques are commonly used in long-distance transmission.

Bipolar with 8-zeros substitution (B8ZS) [used in North America]

Based on bipolar AMI. This is used to overcome the problem of long string of 0s that may results in loss of synchronization

* If an octet of all zeros occur and the last voltage pulse preceding this octet was positive, the eight zeros of the octet are encoded as 0 0 0 + - 0 - +.
* If an octet of all zeros occur and the last voltage pulse preceding this octet was negative, the eight zeros of the octet are encoded as 0 0 0 - + 0 + - .

This technique forces two code violation (pattern not allowed in AMI) of the AMI code, an event unlikely to be caused by noise. The receiver recognizes the pattern and interprets the octet as consisting of all zeros.