Desirable Properties for Line Codes

1. **Transmission Bandwidth: as small as possible**
2. **Power Efficiency: As small as possible for given BW and probability of error**
3. **Detection and Correction capability: Ex: Bipolar**
4. **Favourable power spectral density: dc=0**
5. **Adequate timing content: Extract timing from pulses**
6. **Transparency: Prevent long strings of 0s or 1s**

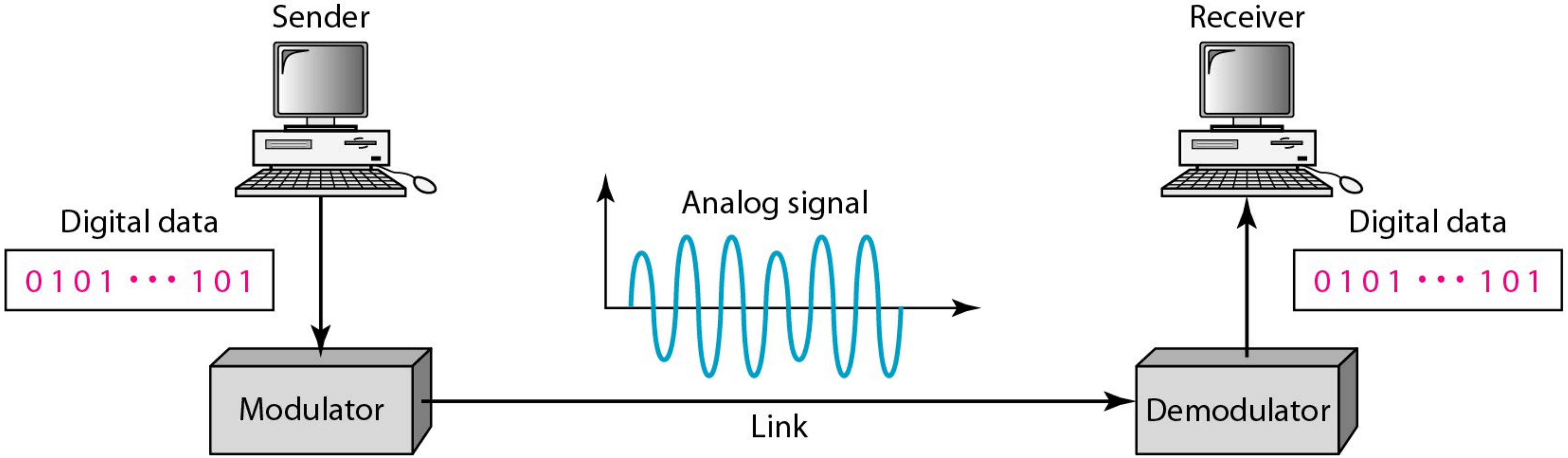
Digital Modulation is the process of changing one of the characteristics of an analog signal (carrier) based on the information message digital signals (0's and 1's).

- In digital modulation , an analog carrier signal is modulated by a digital signal

$$c(t) = A_c \cos(2\pi f_c t + \theta)$$

- In digital communications, the modulating wave consists of binary data and the carrier is sinusoidal wave

- Digital modulation can be considered as digital-to-analog and the corresponding demodulation as analog-to-digital conversion.



Digital Modulation Techniques

Modulation involved switching (known as keying) between short bursts of different signals to transmit the encoded message. The modulating signal ***m(t)*** is a **digital signal .** A general carrier signal has three parameters which can be used for impressing:

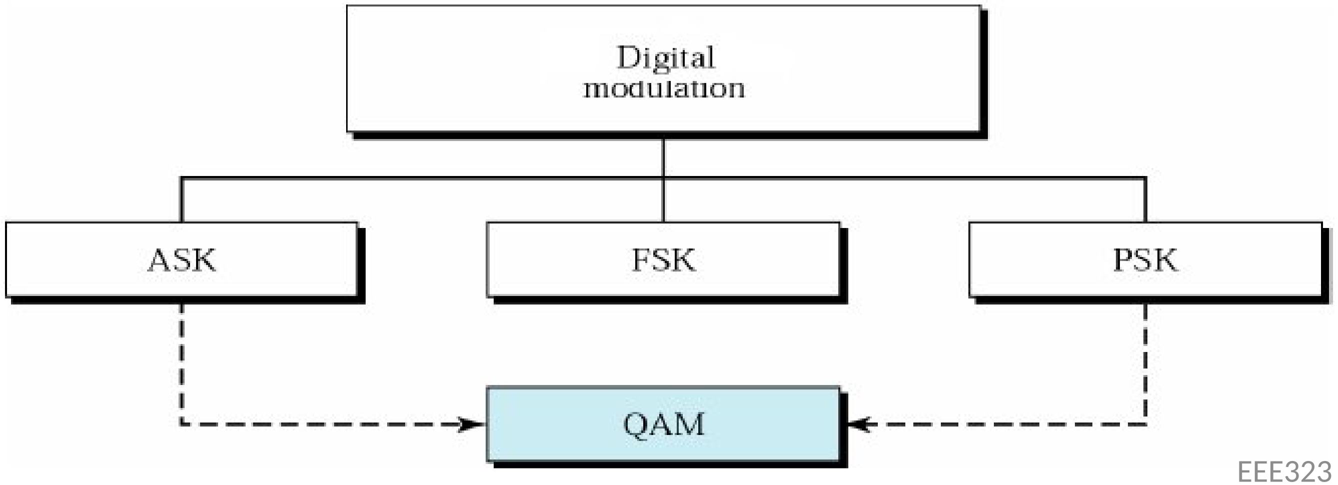
$$c(t) = A(t)\cos\theta(t)$$

$$\theta(t) = \omega_0 t + \phi(t)$$

$$\therefore\ c(t) = A(t)\cos[\omega_0 t + \phi(t)]$$

Amplitude Frequency Phase

If the Amplitude of the carrier is varied proportional to the information signal, a digital modulated signal is called Amplitude Shift Keying (ASK). If the frequency of the carrier is varied proportional to the information signal, a digital modulated signal is called Frequency Shift Keying (FSK). If the phase of the carrier is varied proportional to the information signal, a digital modulated signal is called Phase Shift Keying (PSK). If both the amplitude and the phase of the carrier are varied proportional to the information signal, a digital modulated signal is called Quadrature Amplitude Modulation (QAM).



Baseband digital message signal: ***m(t)***

Analog sinusoidal carrier signal:

A. Carrier signal: $A_c \cos(2\pi f_c t + \phi_c)$

ASK: Amplitude Shift Keying.

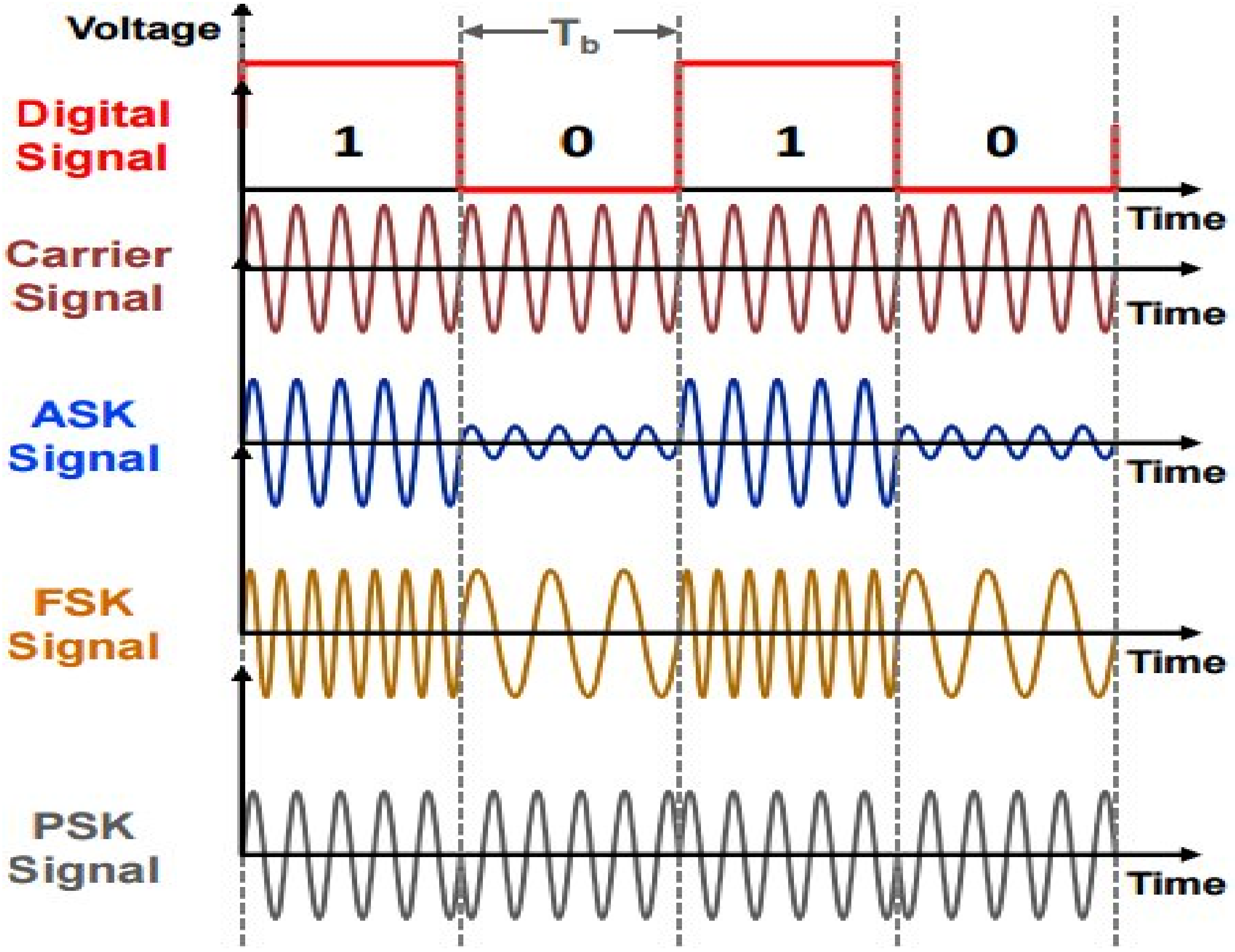
A. Message signal changes the carrier's **amplitude** : $A_i(t)$.

FSK: Frequency Shift Keying.

A. Message signal changes the carrier's **frequency** : $f_i(t)$.

PSK: Phase Shift Keying.

A. Message signal changes the carrier's **phase** : $\phi_i(t)$.



- Two basic aspects of digital-to-analog modulation; **bit rate** and **baud rate**.
- **Bit rate** - number of bits per second (rate at which bit changes, bps). Computer Efficiency – how long it takes to process each piece of information (time to send)
- **Baud rate** – number of signal units per second (rate at which signal element changes). Also called modulation rate or symbol rate. Data Transmission Efficiency – how efficient we can move those data from place to place.
- Binary digital signals can be propagated through an ideal noiseless transmission medium at a rate equal to two times the bandwidth of the medium.
- The minimum theoretical bandwidth necessary to propagate a signal is called the minimum Nyquist bandwidth or the minimum Nyquist frequency.
- Thus,

$$R_b = 2\,B$$

Where R_b = bit rate (bps)

B = ideal Nyquist bandwidth (hertz)

- Mathematically,

$$Baud = \frac{1}{T} = \frac{R_b}{N} \quad \text{(baud per second)}$$

where

T = time of one signalling element (second)

N = number of bits per signal element

Example

An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate.

Solution

In this case, N= 4, Baud = 1000, and R_b is unknown. We can find the value of R_b from

$$Baud = \frac{R_b}{N} \quad \textbf{or } \mathbf{R_b = Baud \times N = 1000 \times 4 = 4000\ bps}$$

Example

An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?

Solution

In this example, Baud=1000, $\boldsymbol{R_b}$ = 8000, and rand L are unknown. We first find the value of N and then the value of L.

$$Baud = \frac{R_b}{N} \quad \textbf{or } \mathbf{N = R_b / Baud = 8000 / 1000 = 8\ bits/baud}$$

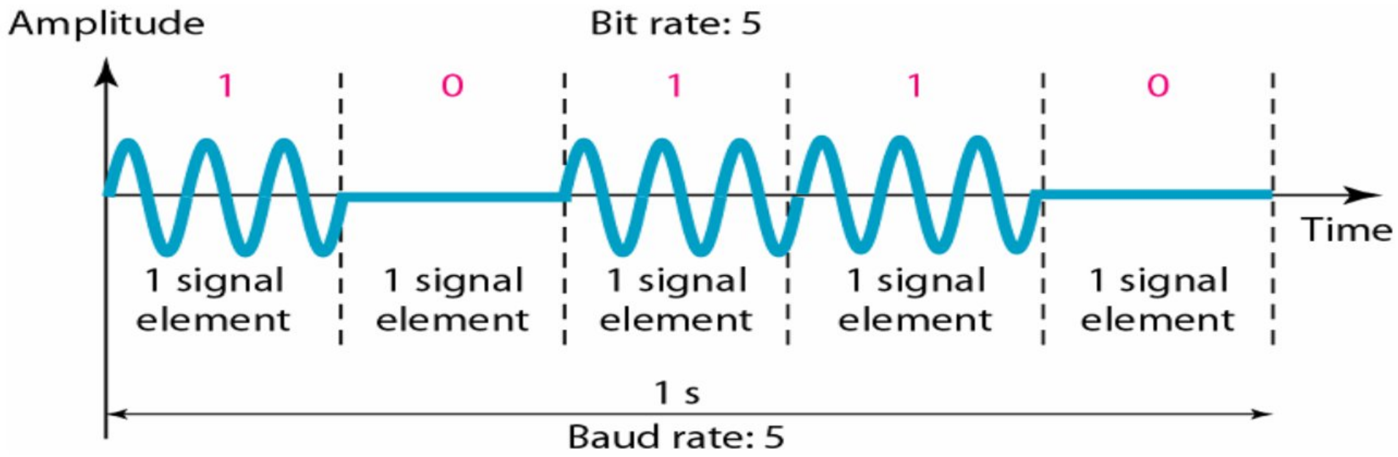
N= $\log_2$ L ------> L =2^N= 256 signal element

Amplitude Shift Keying (ASK) or On-Off Keying (OOK)

- **Amplitude Shift Keying** is a simple version of amplitude modulation used for digital modulation.
- Both frequency and phase remain constant while the amplitude changes.
- Uses logic levels in the data to control the amplitude of the carrier wave.
- ASK is similar to standard amplitude modulation except there are only two output amplitudes possible. ASK is sometimes called digital amplitude modulation (DAM).

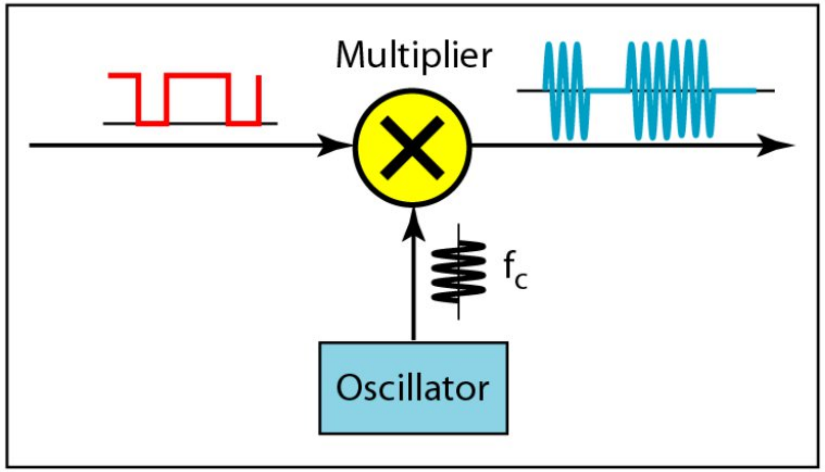
‘1’ for high amplitude (switch ON)
‘0’ for low amplitude (switch OFF).

$$s(t) = m(t)\, c(t) = \begin{cases} A_c \cos(2\pi f_c t) & m(nT_b) = 1 \\ 0 & m(nT_b) = 0 \end{cases}$$

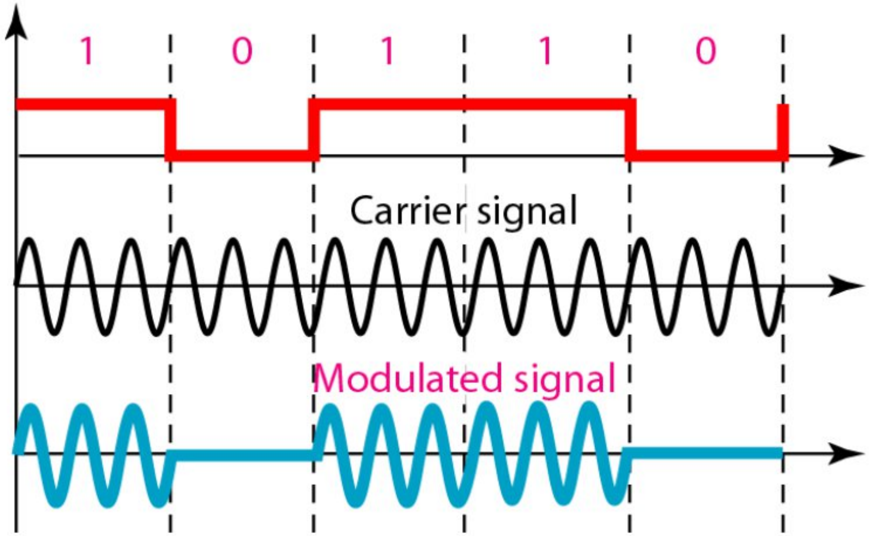


Basic implementation of Binary ASK

The modulator circuit has 2 inputs:
1. Data to be transmitted
2. High frequency carrier sinewave

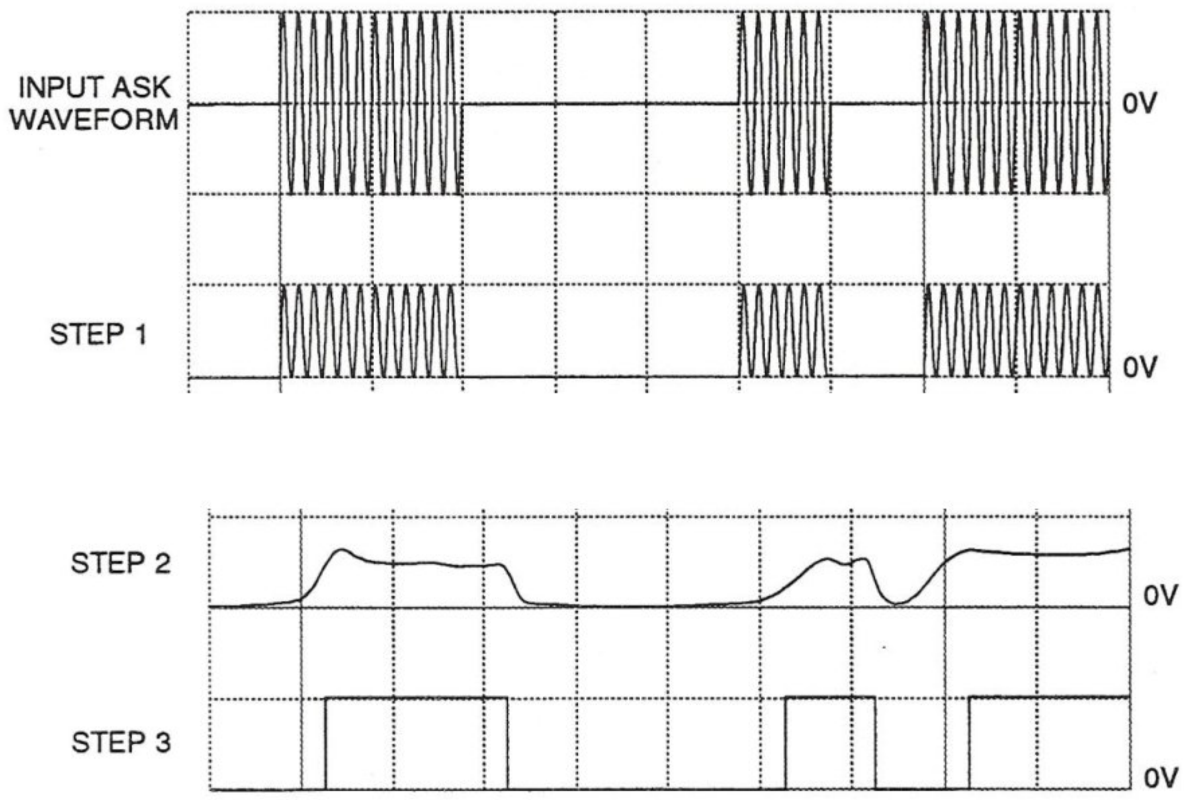


At the transmitter, let the input of a data stream is 10110… Then the modulated ASK modulated signal is shown below.

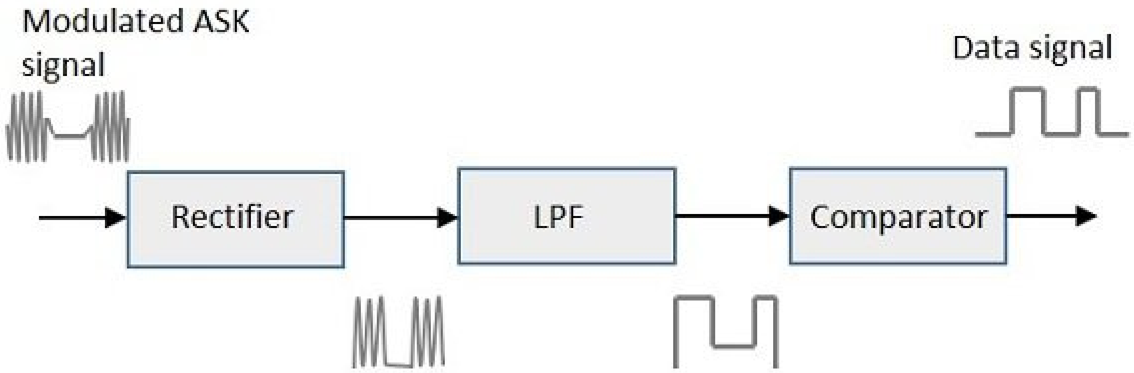


At the Rx, the data stream need to extracted:

1. Rectify the input ASK waveform to contain only +ve signal but it will still contain unwanted carrier wave component.
2. Pass through a LPF to remove the carrier component.
3. Pass through a voltage comparator to get a true copy of the original data stream



ASK Demodulator



Bandwidth: Bandwidth of ASK is proportional to baud rate of message signal **BW α *Baud***

$$\mathbf{BW} = \ (1+d)\ \mathit{Baud}\ = (1+d)\frac{R_b}{N}$$

d is Factor of modulating and filtering process **0≤ d ≤1,**

For ideal modulation ***d***=0, BW= Baud and for worst case modulation ***d***=1, BW=2Baud

Example – Given a bandwidth of 5000 Hz for an ASK signal, what are the baud rate and bit rate?

Solution

In ASK the baud rate is the same as the bandwidth, which means the baud rate is 5000.

The baud rate and the bit rate are also the same for ASK, the bit rate is 5000bps.

Example: Determine the baud and minimum bandwidth necessary to pass a 10 kbps binary signal using amplitude shift keying (ASK).

Solution

For ASK, N=1

$$B_{min} = R_b/N$$

$$B_{min} = 10k/1 = 10kHz$$

$$Baud = R_b/N = 10kbaud/sec$$