Digital Modulation Techniques

In baseband data transmission (PCM, DPCM, DM, and ADM) an incoming serial data stream is represented in the form of a discrete pulse-amplitude modulated wave that can be transmitted over a low-pass channel (e.g. a coxial cable).

Baseband digital signals however can not be transmitted over a radio link (wireless and satellite) because this would require impractically large antennas to efficiently radiate the low frequency sprectrum of the signal.

Note:. Radio link is example of band-pass channel.

In applications of this kind, digital modulation techniques dealing with band-pass data transmission is utilized.

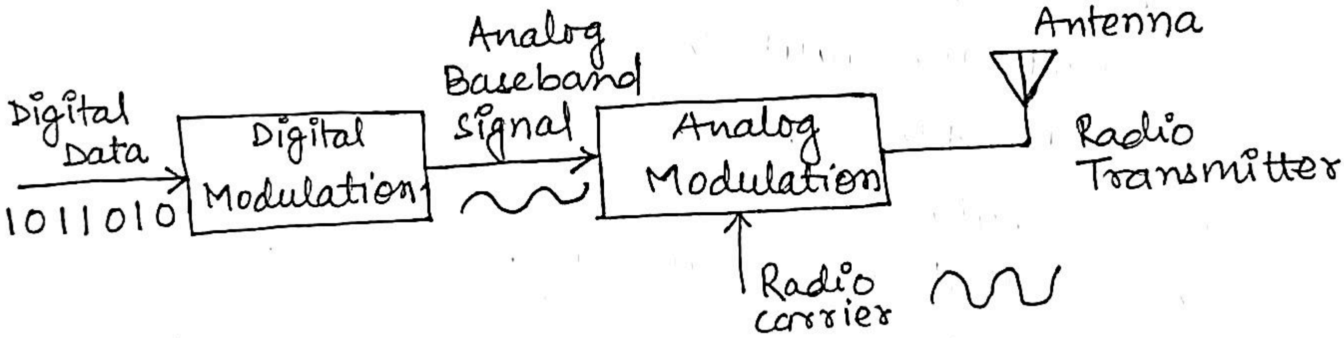


Figure:- Block Diagram of digital and Analog modulation system.

Digital communication

- Baseband data Tranemission
  - Pulse Analog
    - PAM
    - PWM
    - PPM
  - Pulse Digital
    - PCM
    - DPCM
    - DM
    - ADM
- Band-pass data Transmission
  - Binary Transmission
    - BASK
    - BPSK
    - BFSK
  - QAM
    - [BASK + BPSK]
  - M-ary Transmission

If baseband digital signals are to be transmitted over a wireless communication link, they should first modulate a continuous wave high-frequency carrier.

Digital modulation provides more information capacity, high data security. Hence, digital modulation techniques have a greater demand for their capacity to convey large amount of data than analog ones.

- We know that there are many modulation/demodulation schemes available to the designer of a digital communication system required for data transmission over band-pass channel.
- Each scheme offers system trade off of its own. The final choice made by designer is determined by the way in which the available primary communication resources are best exploited.
- In particular, the choice is made in favour of the scheme that attains as many of the following design goals as possible.
  (1) Maximum data rate
  (2) Minimum probability of error (BER or SER)
  BER → Bit error rate; SER → symbol error rate
  (3) Minimum transmitted power
  (4) Minimum channel bandwidth
  (5) Minimum circuit complexity.

In analog communication → AM/FM/PM

$m(t)$ = Analog signal → low freq. signal

$c(t) = A_c \cos \omega_c t$ → high freq. signal

In digital communication → BASK/BFSK/BPSK

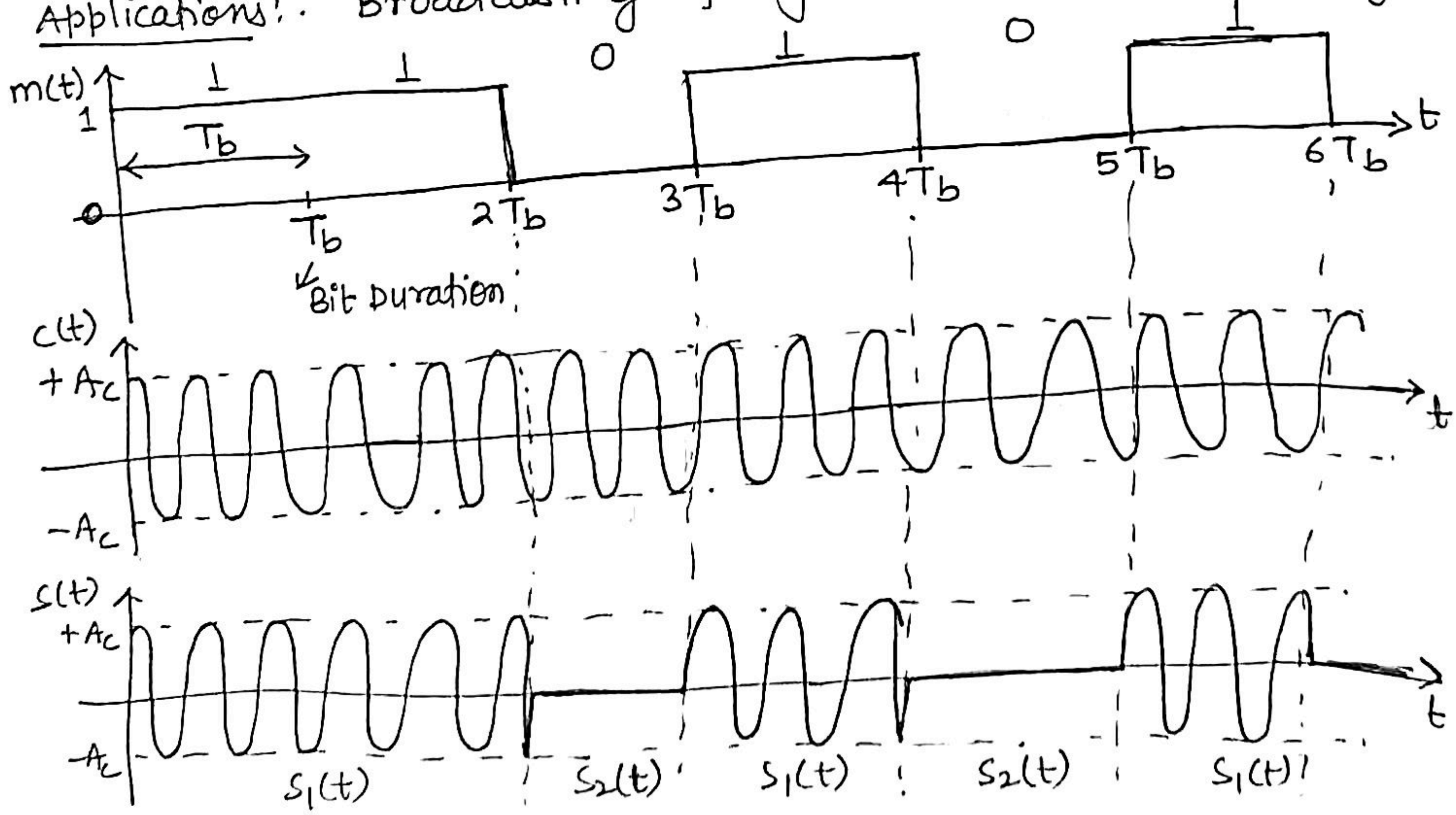
$m(t)$ = Digital/binary signal (0's or 1's)

$c(t) = A_c \cos \omega_c t$

Binary Amplitude shift Keying (BASK)

- ASK converts digital signal into Analog signal
- The amplitude of carrier signal (analog carrier) is varied in accordance with the instantaneous values of modulating signal (Binary data).
- In the simplest form of ASK, the carrier signal is switched ON and OFF depending upon whether a '1' or '0' is to be transmitted. ASK is also known as ON-OFF keying (OOK).

Applications:. Broadcasting of signals and radio telegraphy.



$$f_c = \frac{n}{T_b}$$ → Integer

$$s(t) = \begin{cases} A_c \cos \omega_c t, & \text{for symbol 1} \\ 0, & \text{for symbol 0} \end{cases}$$

The power the symbol $P_s = \frac{A_c^2}{2} \Rightarrow A_c = \sqrt{2P_s}$

$$s(t) = \begin{cases} \sqrt{2P_s} \cos \omega_c t, & \text{for symbol 1} \\ 0, & \text{for symbol 0} \end{cases}$$

Bit Energy, $E_b = P_s \times T_b$

$$= \frac{A_c^2}{2} \cdot T_b \Rightarrow E_b = \frac{A_c^2 T_b}{2}$$

$$A_c = \sqrt{\frac{2E_b}{T_b}}$$ $\Rightarrow E_b =$ Transmitted signal energy per bit

$$s(t) = \begin{cases} \sqrt{\frac{2E_b}{T_b}} \cos \omega_c t, & \text{for symbol 1} \\ 0, & \text{for symbol 0} \end{cases}$$

An ASK waveform can be represented by a ~~sign~~ single orthonormal basis function using GSOP.

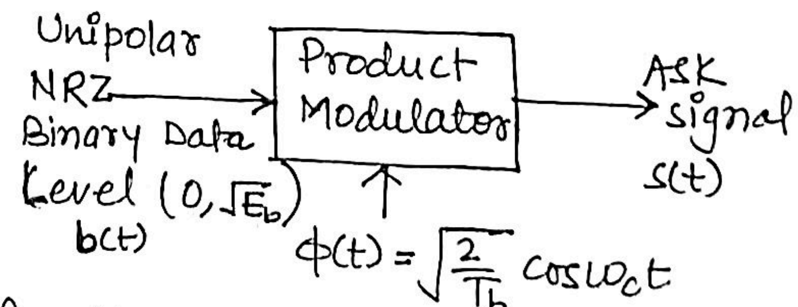
$$\phi(t) = \frac{s(t)}{\sqrt{E_b}}$$ → having unit energy $0 \leq t \leq T_b$

$$\phi(t) = \sqrt{\frac{2}{T_b}} \cos \omega_c t$$

$$s(t) = \sqrt{E_b}\, \phi(t)$$

~~Here~~,

Modulation of ASK



$$s(t) = \begin{cases} \sqrt{\frac{2E_b}{T_b}} \cos \omega_c t, & \text{for binary symbol 1} \\ 0, & \text{for binary symbol 0} \end{cases}$$

$$b(t) = \begin{cases} \sqrt{E_b} & , \text{ for bit } 1 \\ 0 & , \text{ for bit } 0 \end{cases}$$

$$\phi(t) = \begin{cases} \sqrt{\frac{2}{T_b}} \cos \omega_c t & , \text{ for bit } 1 \\ 0 & , \text{ for bit } 0 \end{cases}$$

$\Rightarrow$ Here, $\phi(t)$ acts as a carrier (Normalized carrier).

$$s(t) = \begin{cases} \sqrt{\frac{2E_b}{T_b}} \cos \omega_c t & , \text{ for bit } 1 \\ 0 & , \text{ for bit } 0 \end{cases}$$

$$s(t) = \sqrt{E_b}\, \phi(t)$$

$$\boxed{s(t) = b(t)\, \phi(t)}$$

Transmission Bandwidth of ASK Signal :-

Let PSD of $b(t)$ is $S_B(f)$ and PSD of $s(t)$ is $S_s(f)$.

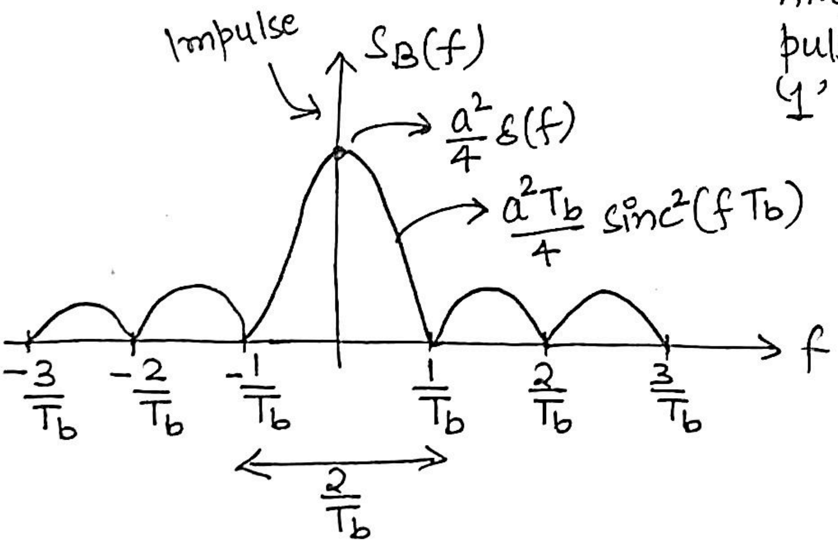
$S_B(f)$ = PSD of Unipolar NRZ binary data level $(0, \sqrt{E_b})$

$$S_B(f) = \frac{a^2}{4} \delta(f) + \frac{a^2 T_b}{4} \operatorname{sinc}^2(f T_b)$$

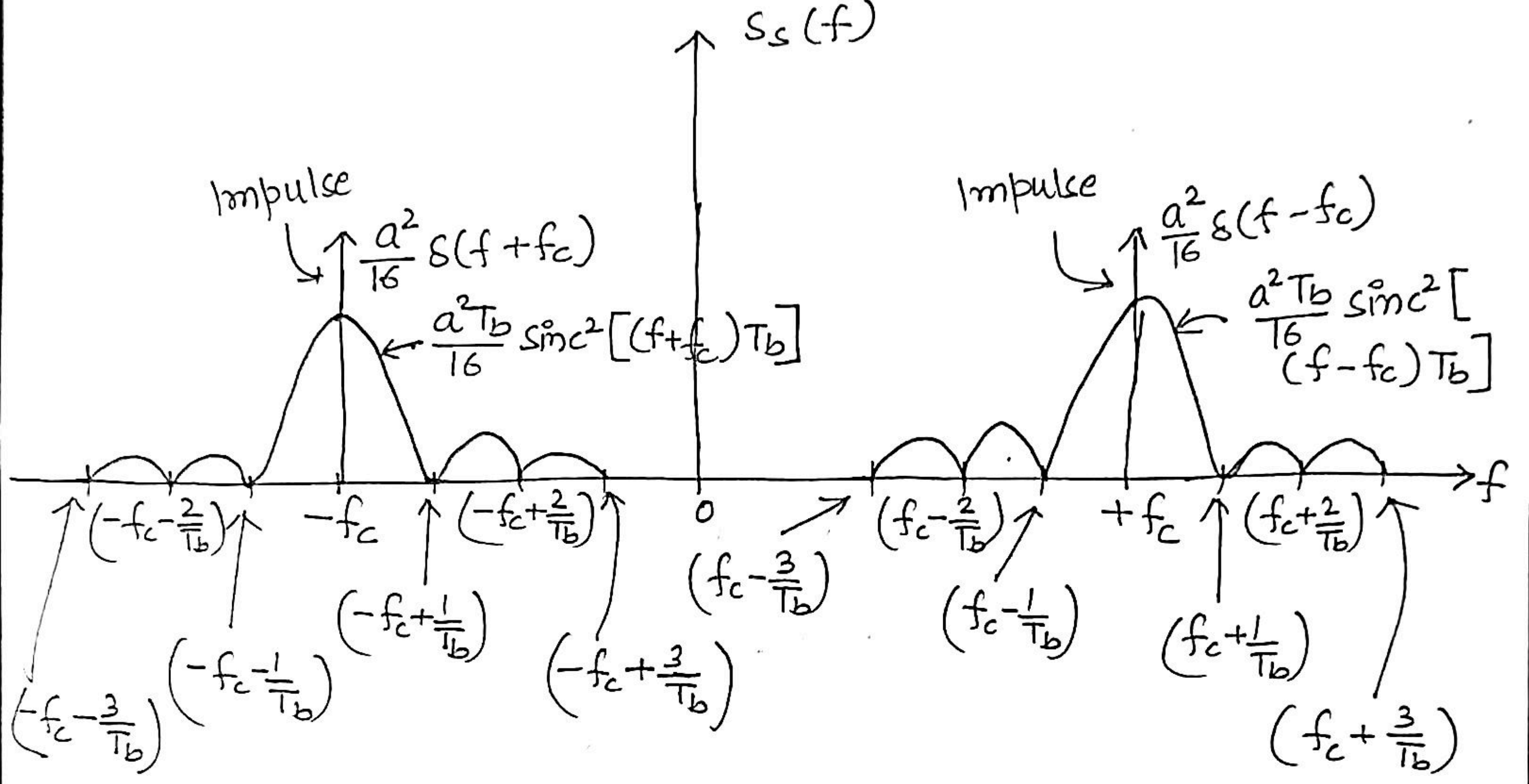
where, $a = \sqrt{\frac{2E_b}{T_b}} = \sqrt{E_b} \times \sqrt{\frac{2}{T_b}}$

$\sqrt{E_b}$ → Amplitude of rectangular pulse representing symbol '1'.

$\sqrt{\frac{2}{T_b}}$ → Carrier amplitude

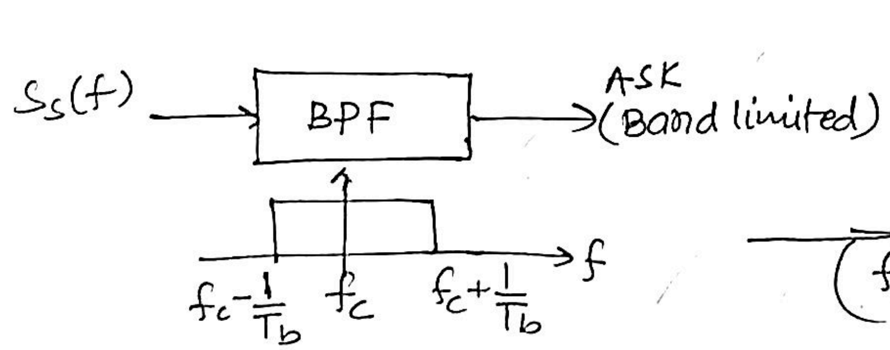


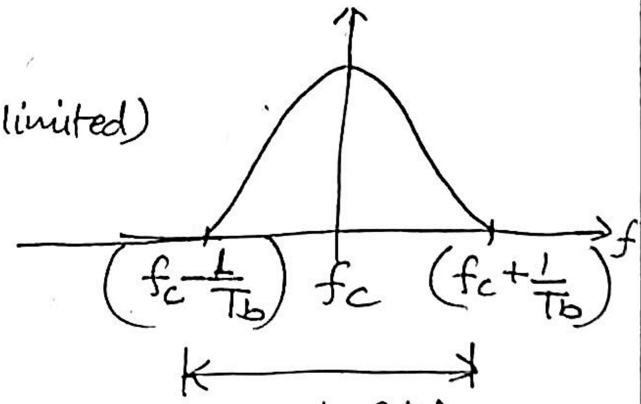
$$S_s(f) = \frac{1}{4}\left[S_B(f - f_c) + S_B(f + f_c) \right]$$



<u>Ideally</u>: $S_s(f)$ is an infinite bandwidth signal.

<u>Practically</u>:- Bandwidth of $S_s(f)$ is defined as the bandwidth of an ideal bandpass filter centred at f_c.





Bandwidth

$$BW_{max} = \frac{2}{T_b} = 2R_b$$

<u>Keeping ~~in~~ practical BPF in mind</u>

$$B_T = (1+\alpha)R_b$$

α = factor related to filter characteristics and modulator
$(0, 1)$

(min) $B_T = R_b$ at $\alpha = 0$ (ideal case)

(max) $B_T = 2R_b$ at $\alpha = 1$ (worst case)