(DEEMED TO BE UNIVERSITY)

# Digital Communication 23EC2208A

## Digital Carrier Modulation


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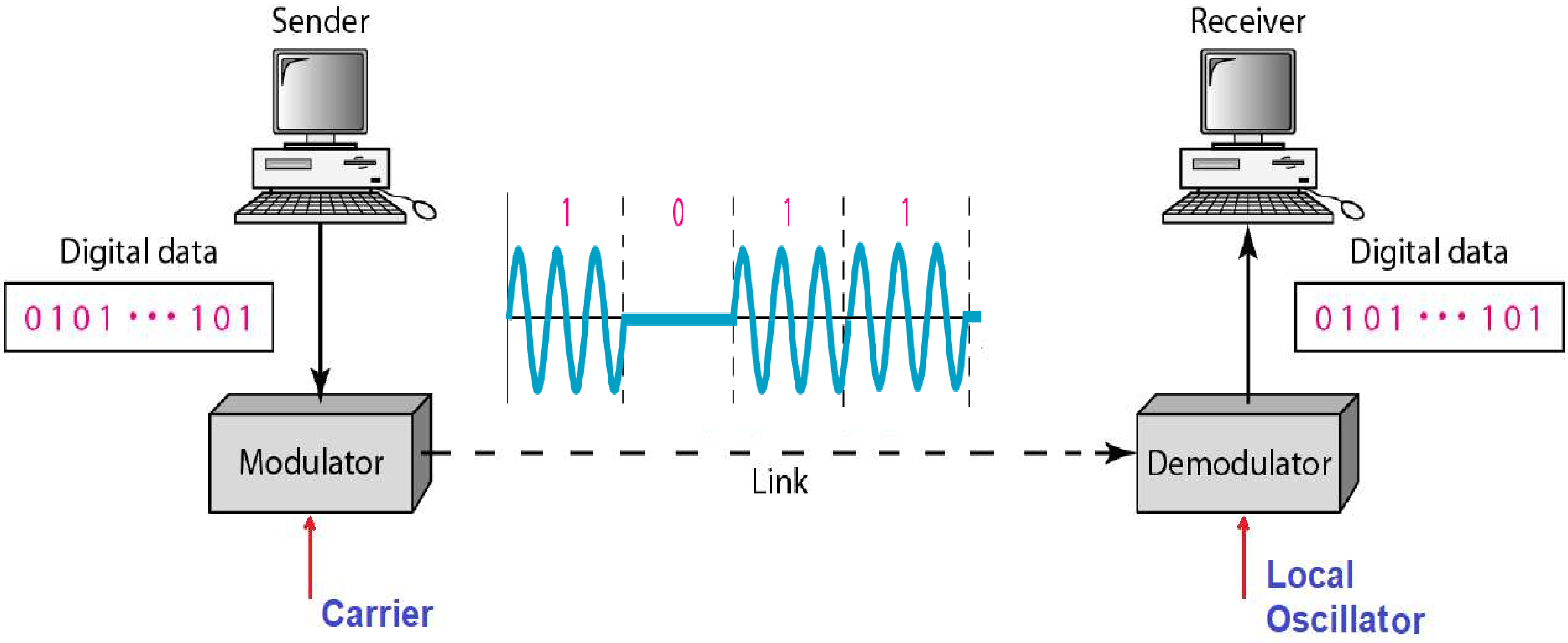
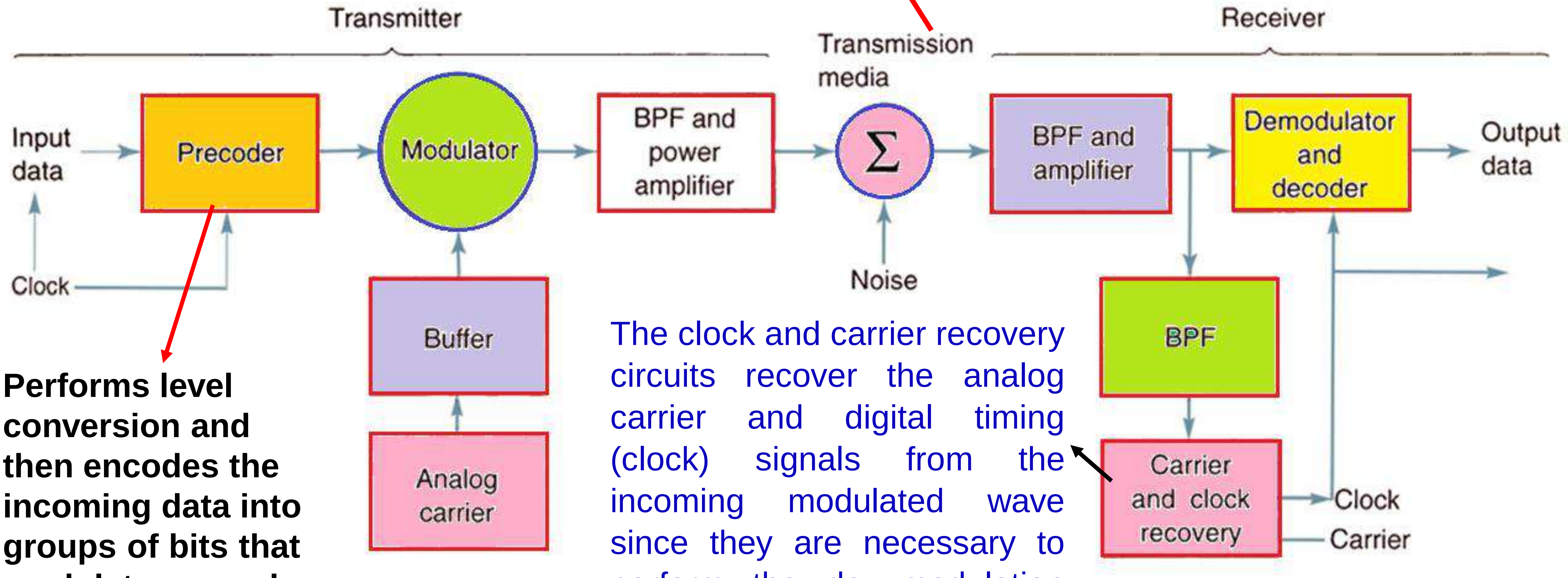
# Digital Carrier Modulation / Pass Band Modulation

# Pass-band Digital Transmitter



# Digital Communication / Digital Radio

The transmission medium can be a metallic cable, optical fiber cable, Earth's atmosphere, or a combination of two or more types of transmission systems.




**Performs level conversion and then encodes the incoming data into groups of bits that modulate an analog carrier**

The clock and carrier recovery circuits recover the analog carrier and digital timing (clock) signals from the incoming modulated wave since they are necessary to perform the de- modulation process.

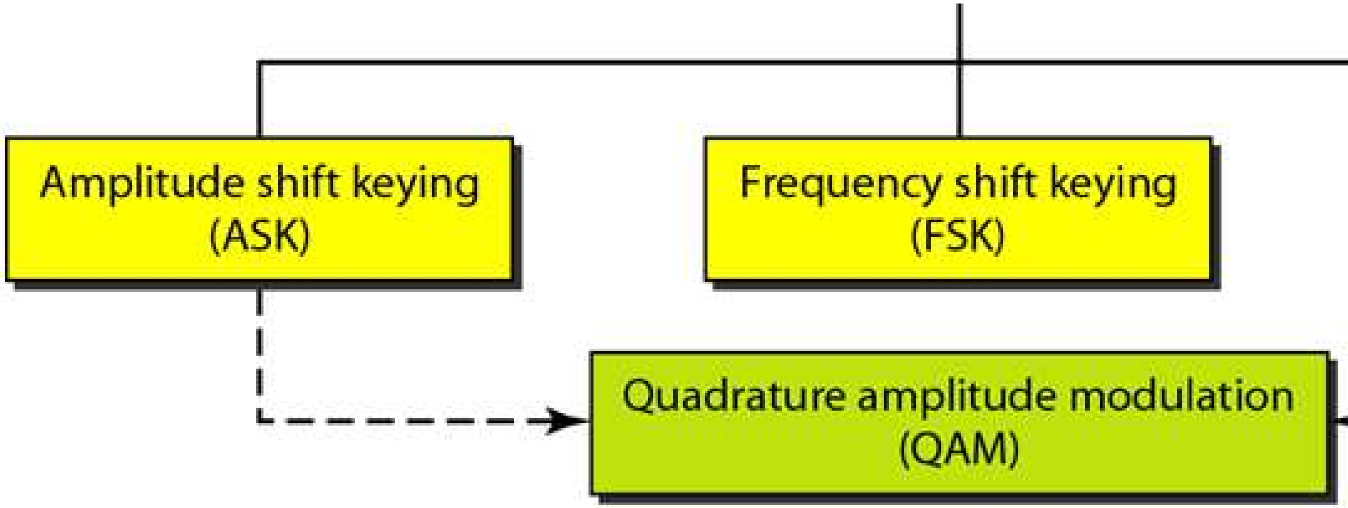
# Digital Modulation Techniques

$$S_i(t) = \sum_{n=-\infty}^{\infty} A_i(t)\cos(2\pi f_i t + \theta_i(t))$$

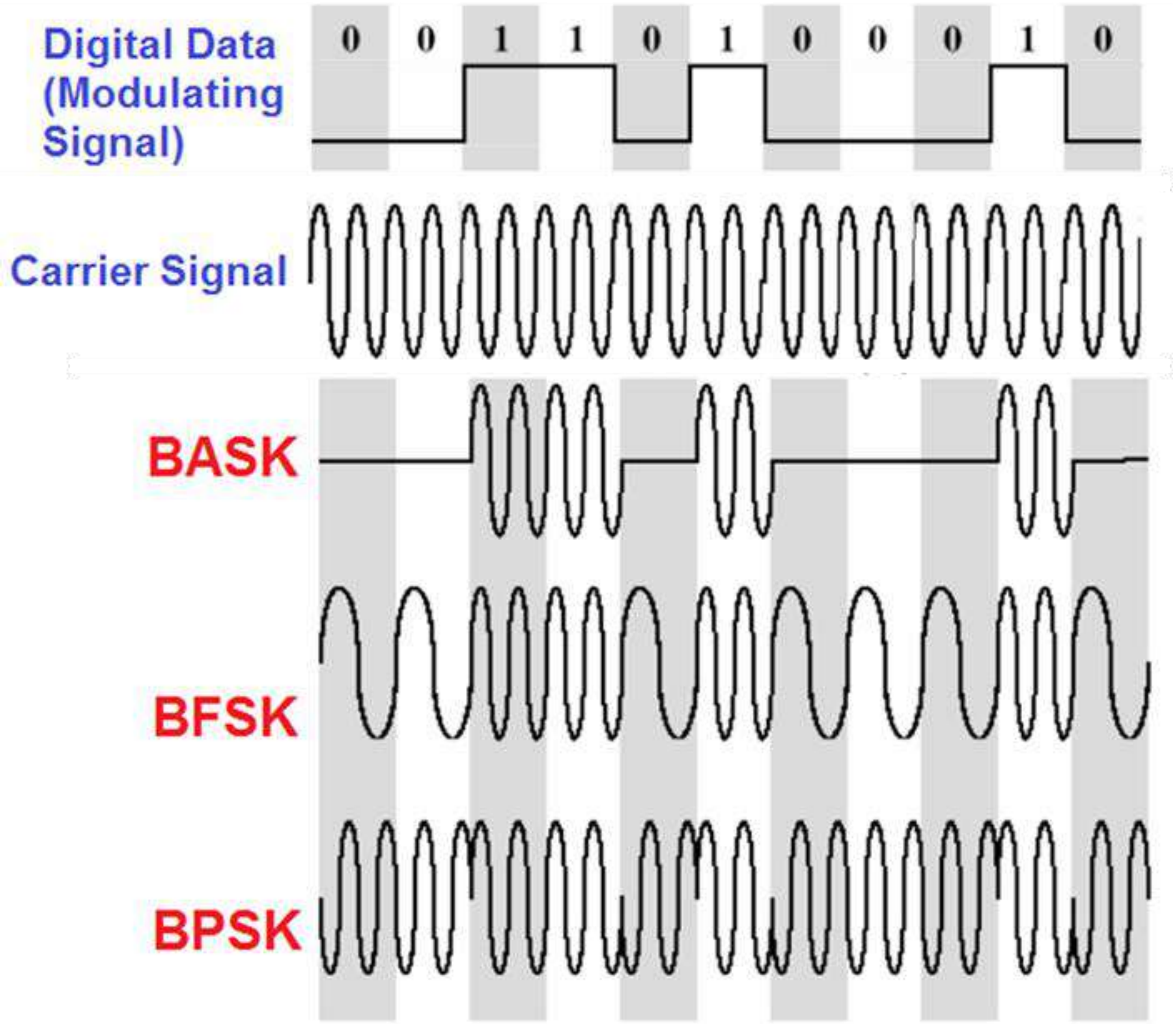
Time-varying Amplitude

Time-varying Frequency

Time-varying Phase




In the context of ASK, FSK, and PSK, "shift keying" refers to the process of changing a specific parameter of a carrier wave (amplitude, frequency, or phase respectively) to represent digital data, where different values of the parameter correspond to different binary digits (like 0 and 1).




Modulation of Analog Signals for Digital Data

# Fundamentals

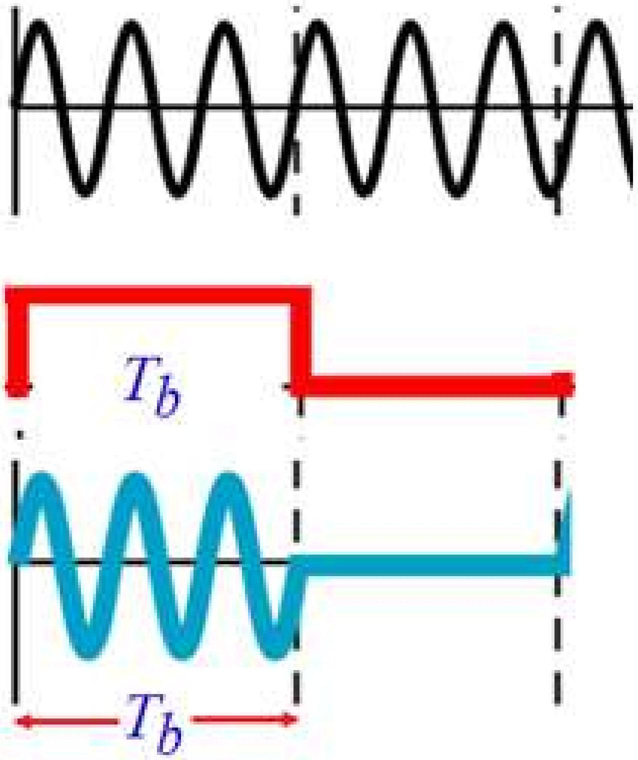
In digital communication literature, the usual practice is to assume that the carrier $c(t) = A_c \cos 2\pi f_c t$ has unit energy measured over one symbol (bit) duration.

The power of the carrier signal $P_c = \dfrac{A_c^2}{2}$ watts.

Energy for a duration $T_b$ pulse $E_b = T_b P_c = \dfrac{A_c^2}{2} T_b$

or $A_c = \sqrt{\dfrac{2E_b}{T_b}}$

$$c(t) = A_c \cos 2\pi f_c t = \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t$$




$\sqrt{\dfrac{2}{T_b}} \cos 2\pi f_c t$ referred to as basis function (Orthonormal)

# Quiz Test

Consider a sinusoidal carrier signal having unit amplitude

(a) Find the power of the signal

(b) Compute the energy of the signal for a pulse duration of 1 milli second.

Ans:

(a) 0.5 Watts

(b) 0.5 milli Jouls

# Binary Amplitude Shift Keying (BASK)

*Amplitude-shift keying* (ASK) was probably the first type of digital modulation to be practically applied. In its simplest form it has been used for radio telegraphy transmission in Morse code.

$$v_{(ask)}(t) = [1 + v_m(t)]\left[\frac{A_c}{2}\cos(\omega_c t)\right]$$

where $v_{ask}(t)$ = amplitude-shift keying wave

$v_m(t)$ = digital information (modulating) signal (volts)

$A_c/2$ = unmodulated carrier amplitude (volts)

$\omega_c$ = analog carrier radian frequency (radians per second, $2\pi f_c t$)

**Polar** Logic1 = +1V, $v_{(ask)}(t) = [1 + 1]\left[\frac{A_c}{2}\cos(\omega_c t)\right] = A_c\cos(\omega_c t)$

**Polar** Logic 0 = -1V, $v_{(ask)}(t) = [1 - 1]\left[\frac{A_c}{2}\cos(\omega_c t)\right] = 0$

# BASK In BASK a sinusoidal carrier is simply gated on and off by the bit sequence to be transmitted.

A *binary amplitude-shift keying* (BASK) signal can be defined as

$$s(t) = \begin{cases} A_c\, m(t) \cos 2\pi f_c t, & 0 \le t \le T_b \\ 0 & \text{elsewhere} \end{cases}$$

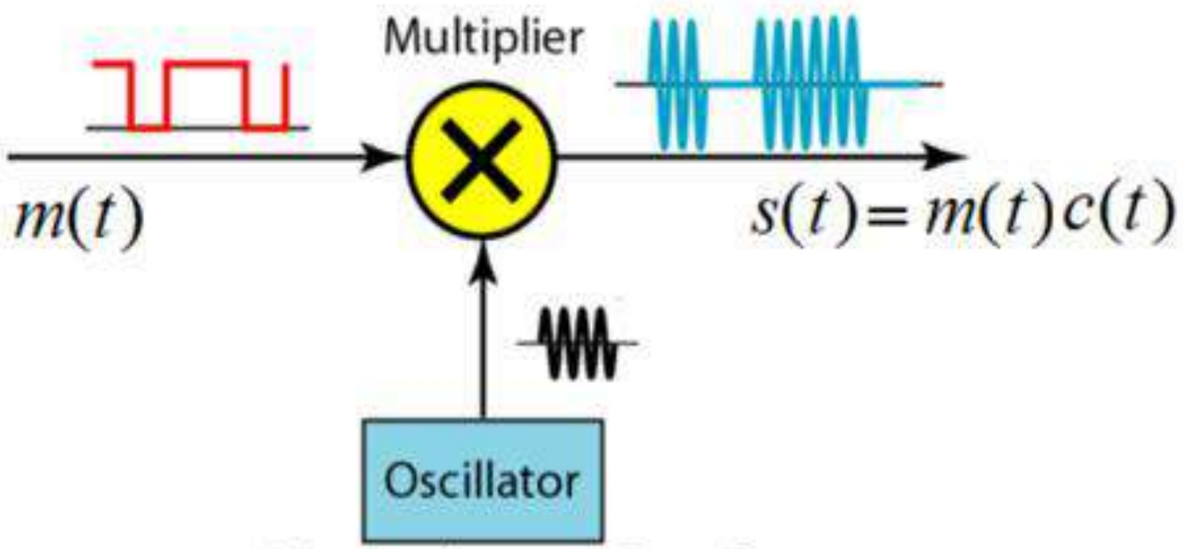
where $A_c$ is carrier signal amplitude

$m(t)$ is digital information signal

$m(t)$ = 1 or 0

$f_c$ is carrier signal frequency

$T_b$ is the bit duration



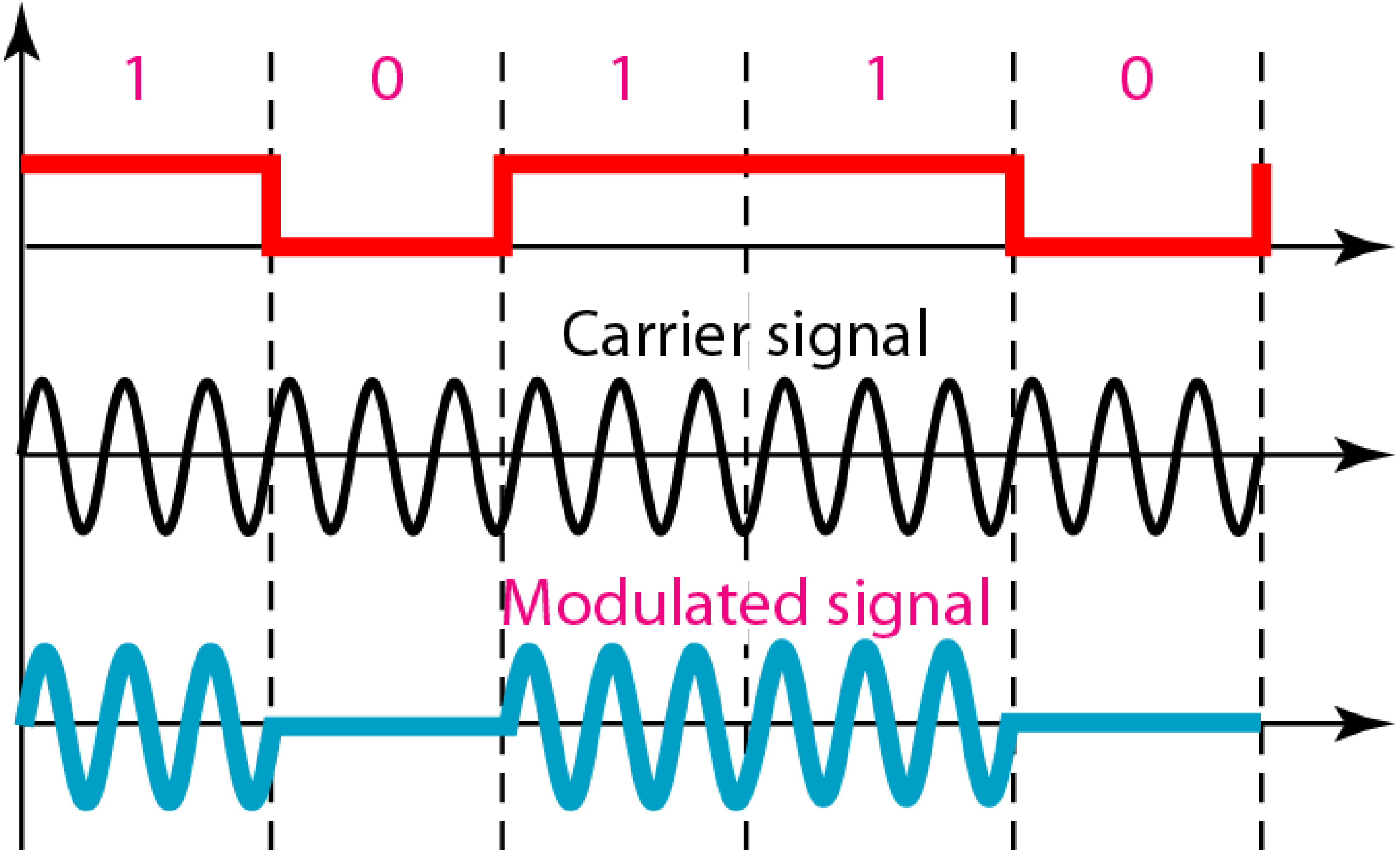

$$c(t) = A_c \cos 2\pi f_c t$$

$$s(t) = \begin{cases} s_1(t) = A_c \cos 2\pi f_c t \\ \quad = \sqrt{\dfrac{2E_b}{T_b}} \cos 2\pi f_c t, \quad 0 \le t \le T_b : \text{Logic 1} \\ s_2(t) = 0, \quad \text{Else : Logic 0} \end{cases}$$

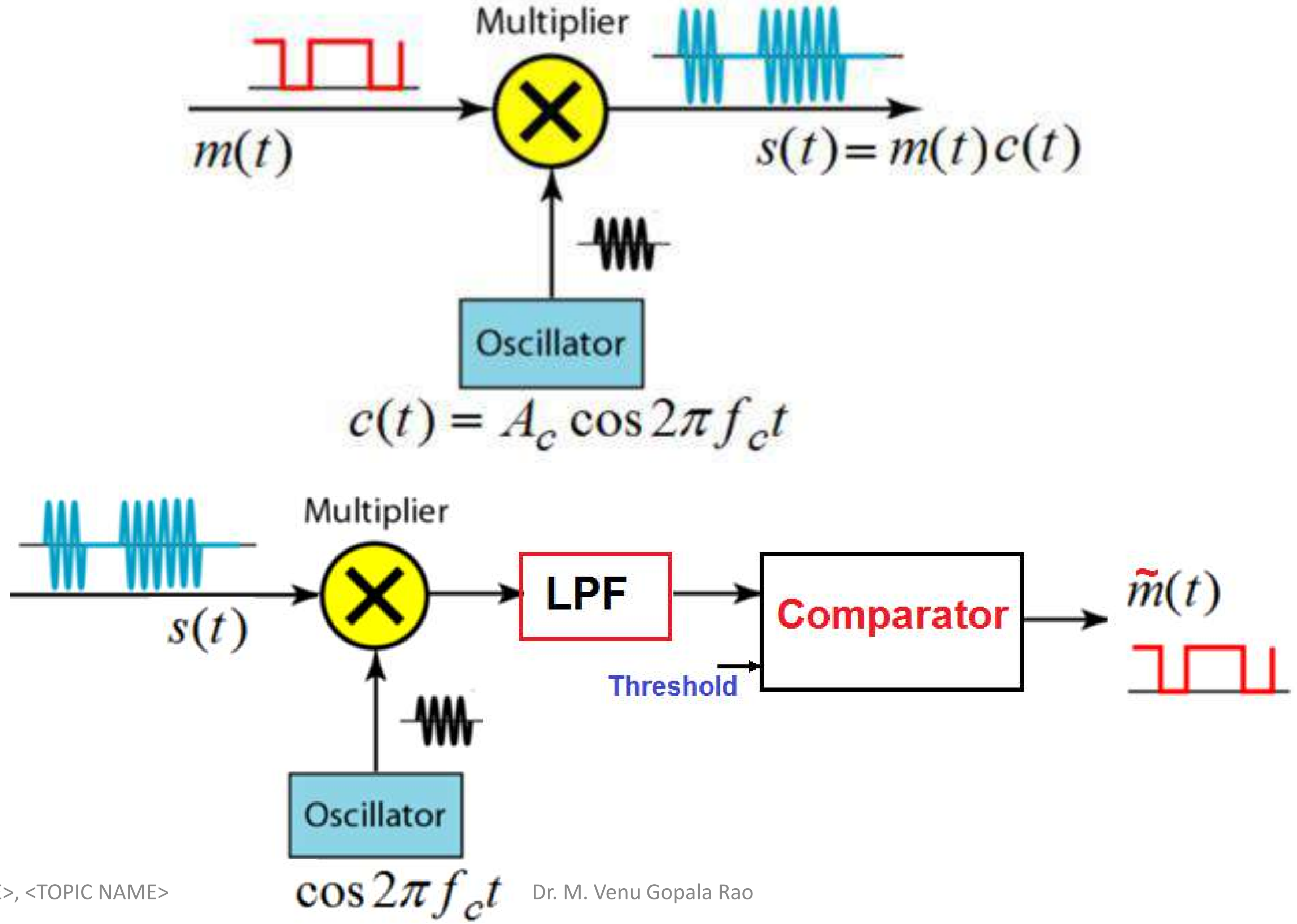
**Average Energy per bit**

$E_b$

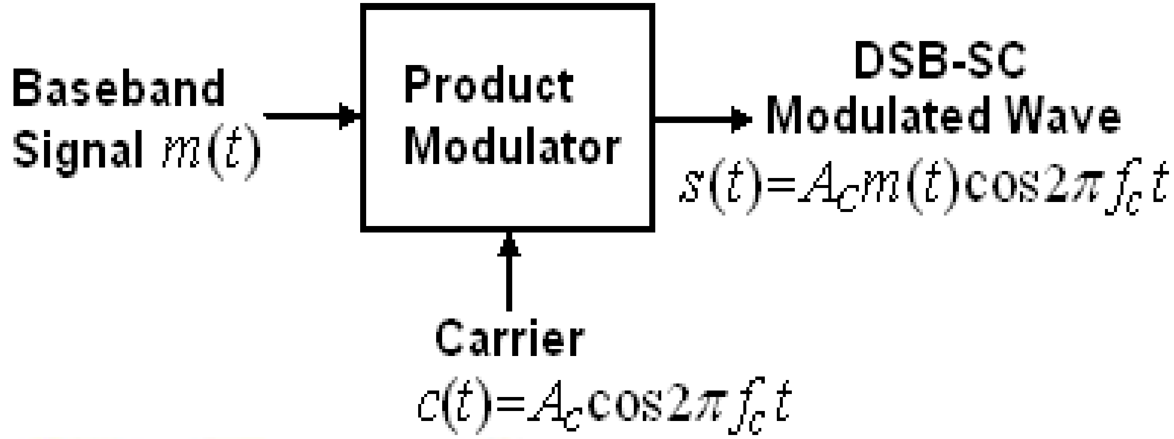
The amplitude of a carrier is switched or keyed by the binary signal $m(t)$.This is sometimes called on-off keying (OOK).



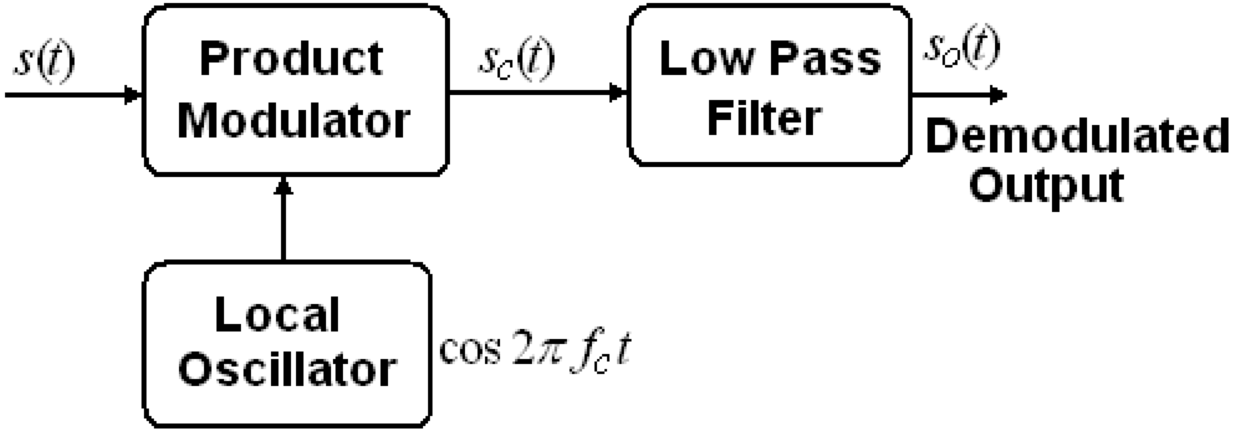
# ASK Transmitter and Receiver



# DSB-SC Modulation




# Demodulation




DSB-SC signal is $s(t) = A_c m(t) \cos 2\pi f_c t$

Then the product modulator output $s_c(t)$ is given by

$$s_c(t) = s(t) \cos 2\pi f_c t = [A_c m(t) \cos 2\pi f_c t] \cos 2\pi f_c t$$

$$= A_c m(t) \cos^2 2\pi f_c t = A_c m(t) \frac{1}{2}[1 + \cos 4\pi f_c t]$$

$$= \frac{1}{2} A_c m(t) + \frac{1}{2} A_c m(t) \cos 4\pi f_c t$$

$$s_o(t) = \frac{1}{2} A_c m(t)$$

# Advantages and Dis-advantages

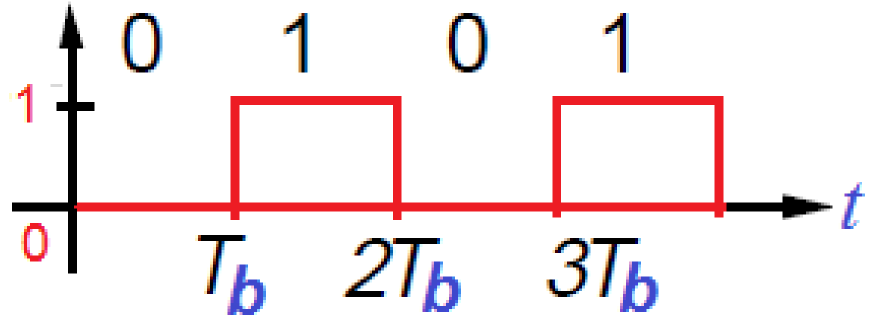
- Advantage:

  Simplicity

- Disadvantages:
  - ASK is very susceptible to noise interference usually (only) affects the amplitude, therefore ASK is the modulation technique most affected by noise
  - seldom used except for very low speed telemetry circuits.

Application: ASK is used to transmit digital data over optical fiber

# Spectrum of ASK

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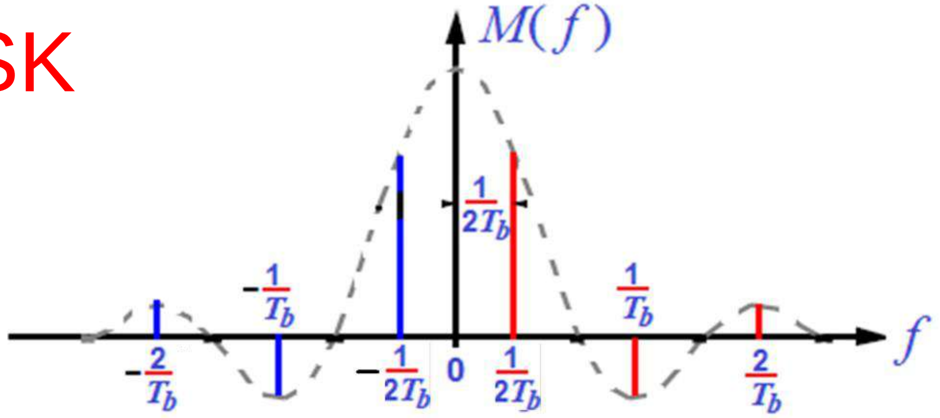


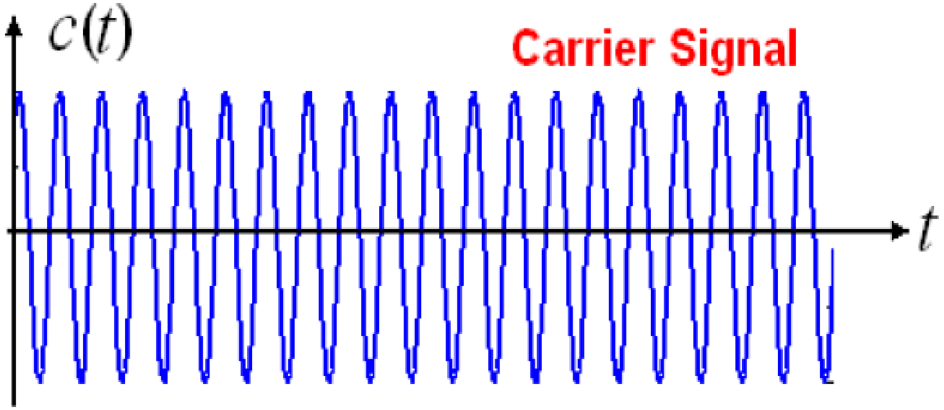


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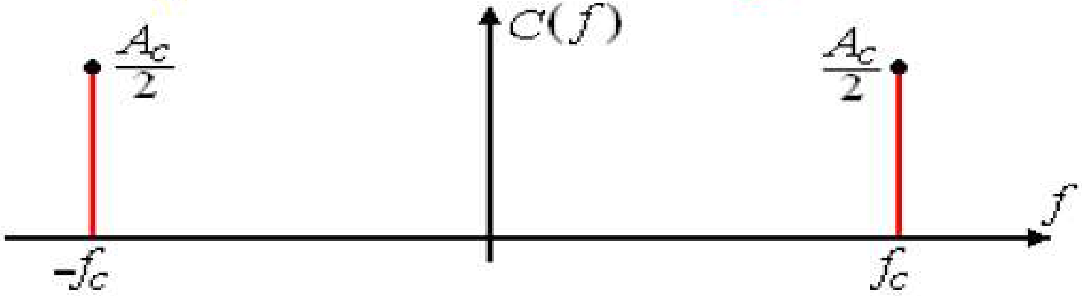
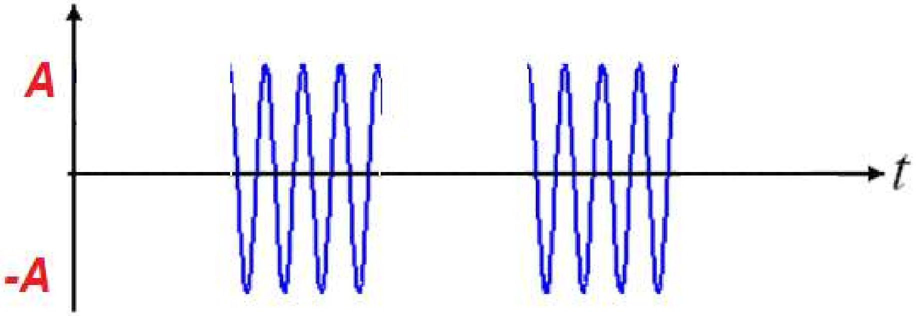
## Spectrum of Carrier Signal




$$S(f)=\frac{A_c}{2}M(f+f_c)+\frac{A_c}{2}M(f-f_c)$$

$$s(t)=A_c\,m(t)\cos 2\pi f_c t,\qquad 0\le t\le T_b$$

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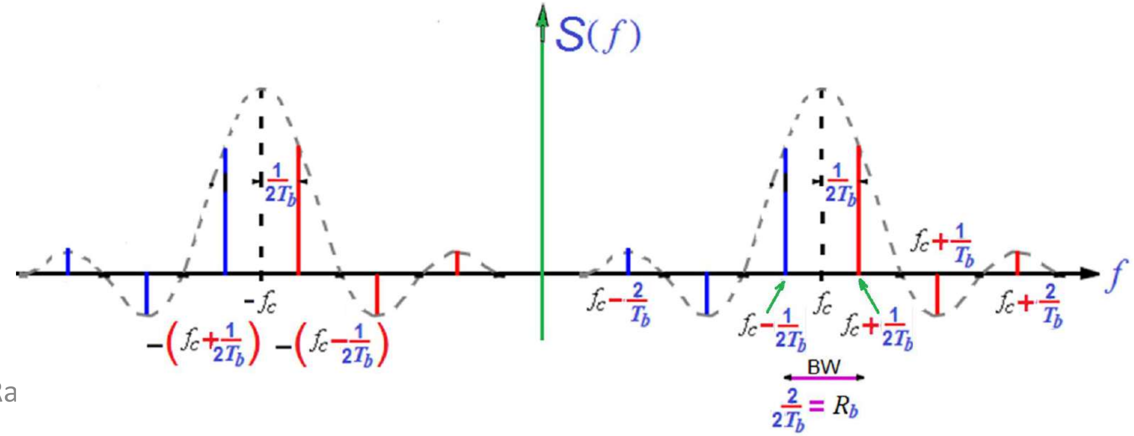
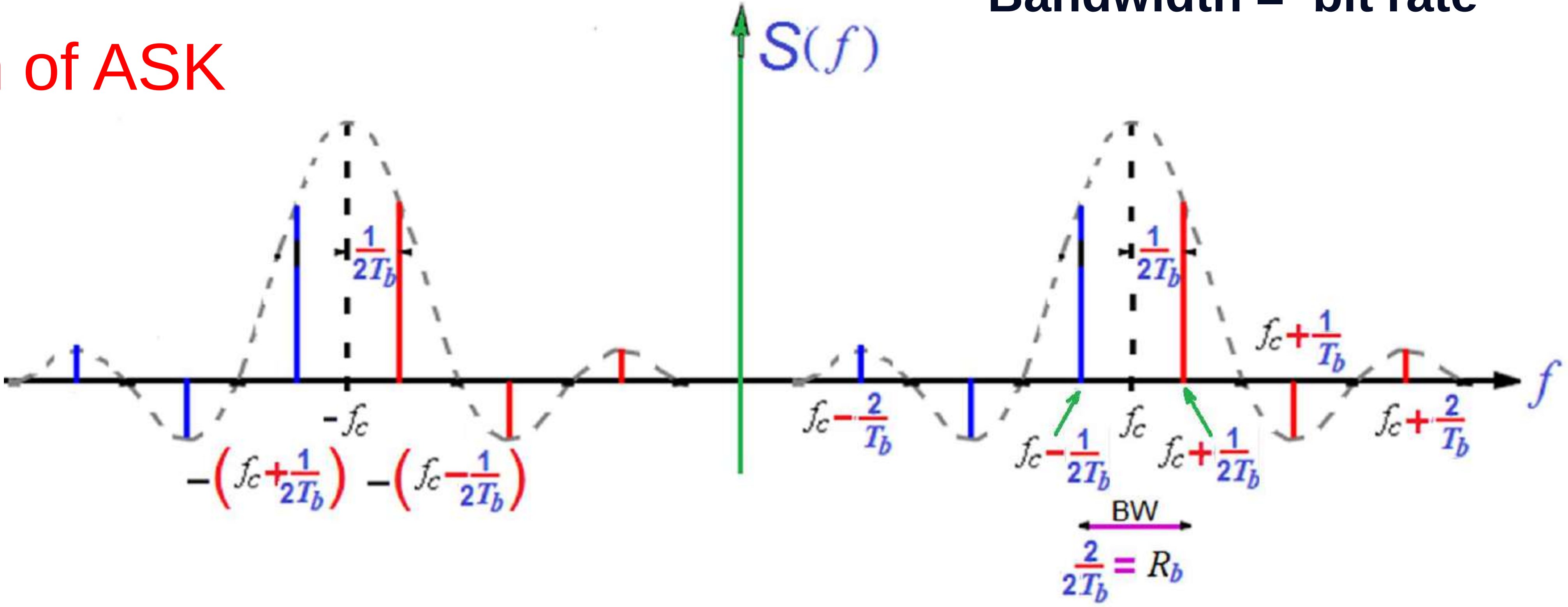


# Bandwidth of ASK

**Bandwidth = bit rate**




BW can be defined in two ways:

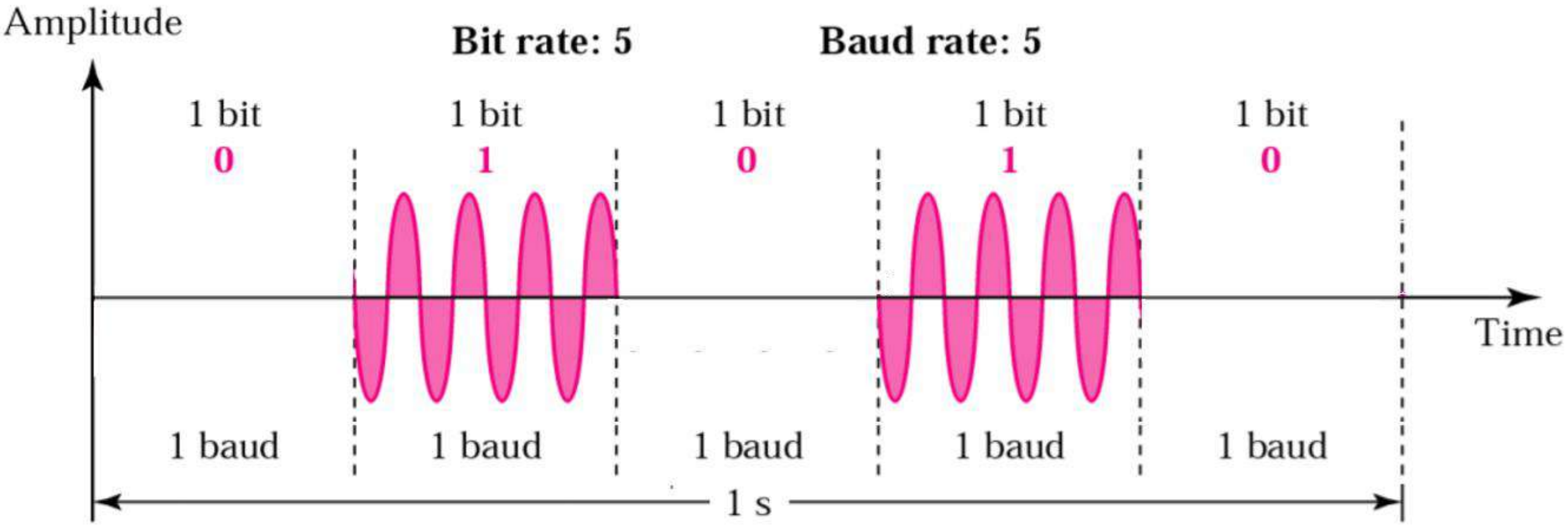
(a) bandwidth in hertz, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.

(b) bandwidth in bits per second, refers to the speed of bit transmission in a channel or link. Often referred to as Capacity

# Bit rate, Baud rate and Bandwidth for ASK

- Bit rate is the number of bits transmitted per second.
- Baud rate is the number of signal units transmitted per second. Baud rate is less than or equal to the bit rate.
- In ASK, the bit rate is equal to the minimum Nyquist bandwidth

$$BW = \frac{f_b}{1} = f_b; \quad Baud = \frac{f_b}{1} = f_b$$



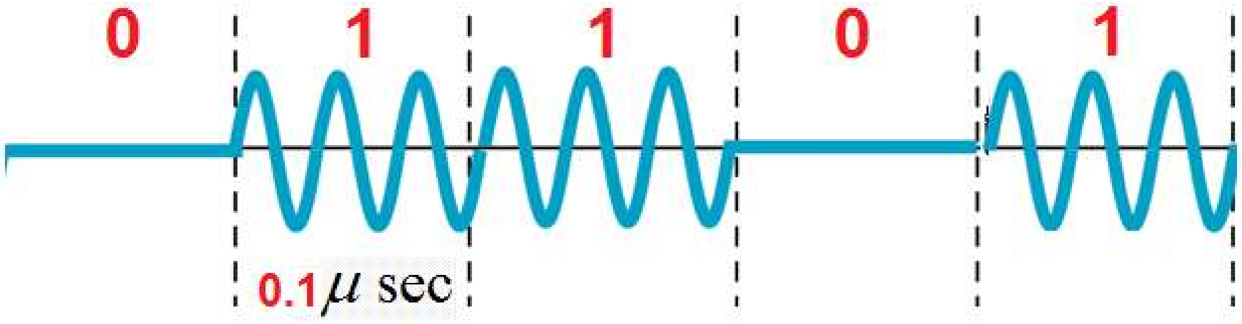
# Quiz Test

**Ex1:** Determine the baud and minimum bandwidth necessary to pass a 10 kbps binary signal using amplitude shift keying.

Bandwidth: 10 kHz

Baud: 10 Kbps

**Ex2:** Consider an ASK modulated signal shown below. Find the bit rate, baud rate and bandwidth.




Bit rate: 10 Mbps

Baud rate: 10 Mbps

Bandwidth: 10 MHz

Ex1: Find the minimum bandwidth required for an ASK signal transmitting at 2000 bps.

Ans: In ASK the baud rate and bit rate are the same.

The baud rate is therefore 2000.

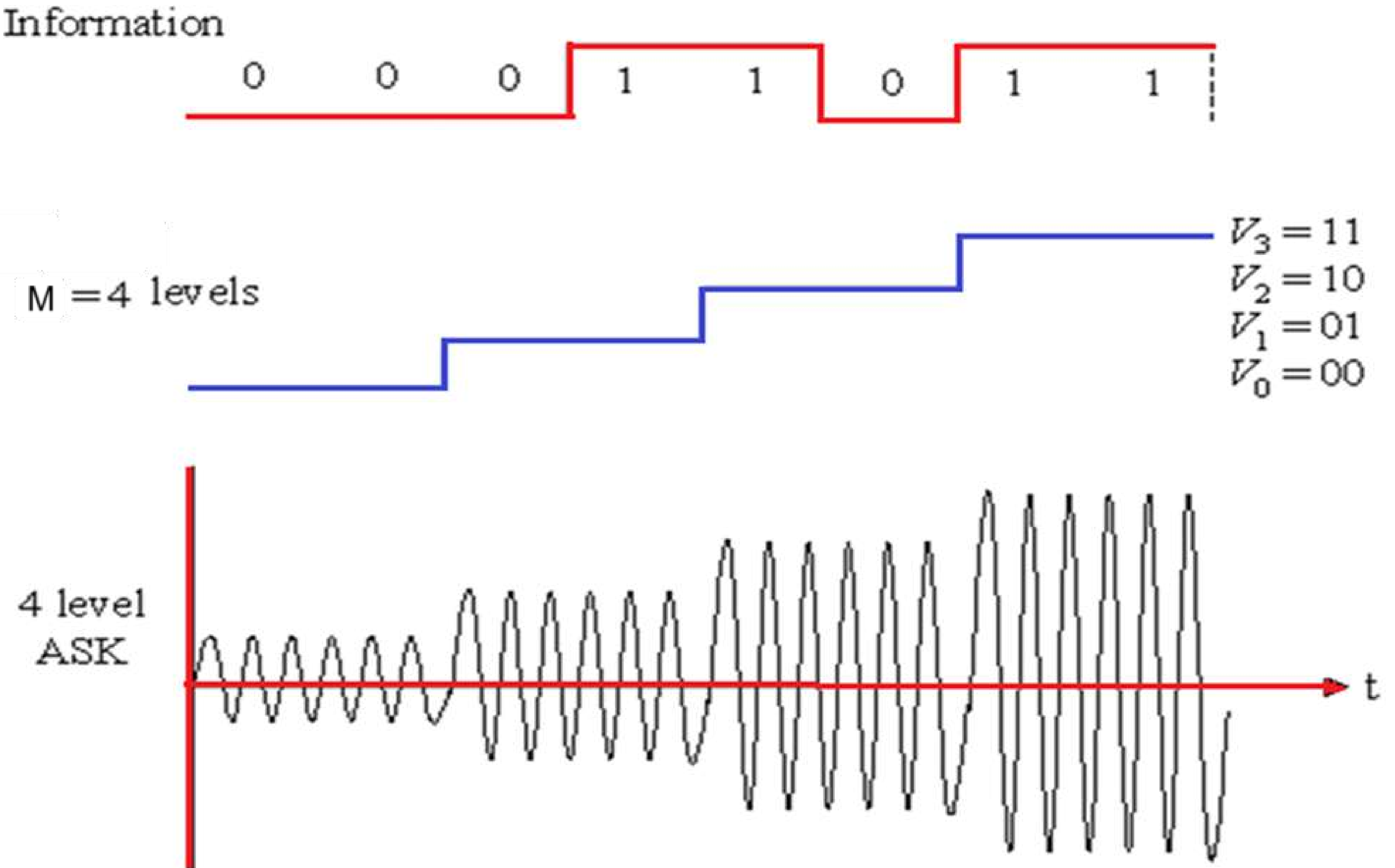
An ASK signal requires a minimum bandwidth equal to its baud rate.

Therefore, the minimum bandwidth is 2000 Hz.

Ex2: Given a bandwidth of 5000 Hz for an ASK signal, what are the baud rate and bit rate?

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

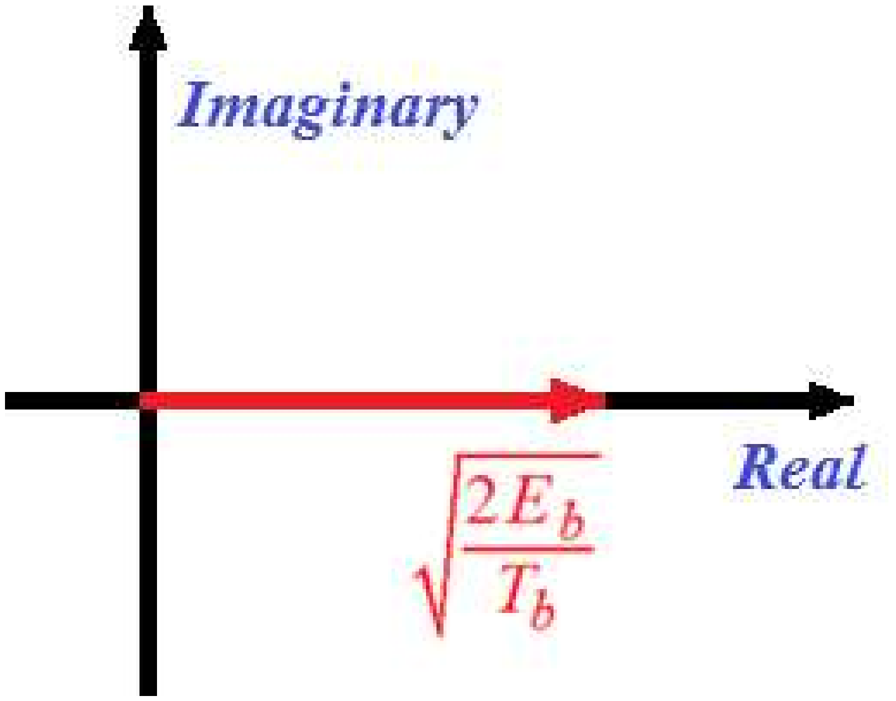
But because the baud rate and the bit rate are also the same for ASK, the bit rate is 5000 bps.


Information
0 0 0 1 1 0 1 1
M =4 levels
$V_3 = 11$
$V_2 = 10$
$V_1 = 01$
$V_0 = 00$
4 level ASK
t

# Signal Space: ASK

A "signal space" is a theoretical concept in digital communications that represents the possible states of a modulated signal as points in a multi-dimensional space

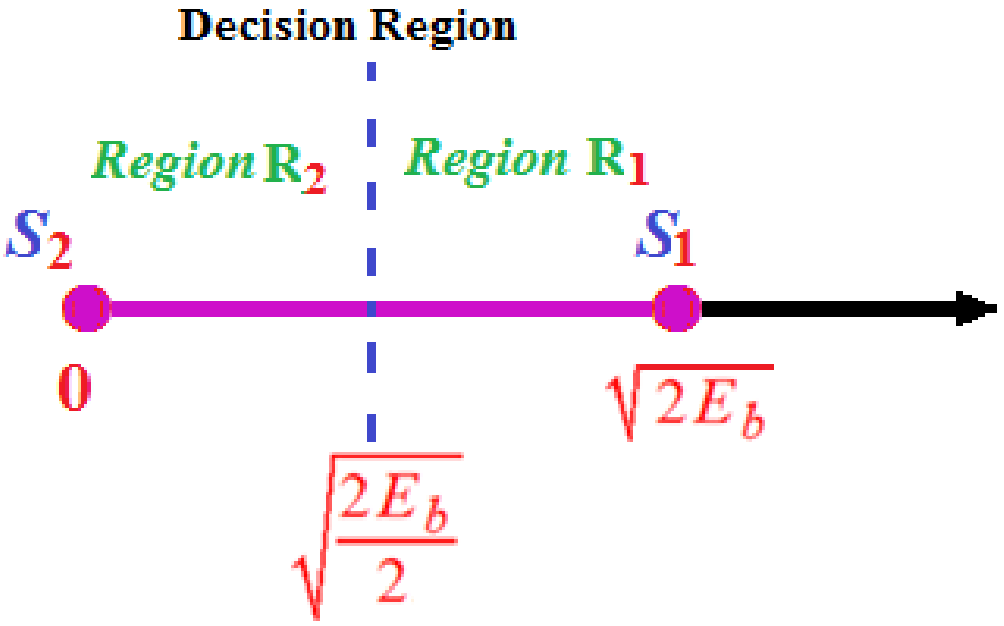
$$s(t)=\sqrt{\frac{2E_b}{T_b}}\cos 2\pi f_c t + j\,0 \qquad 0 \le t \le T_b$$

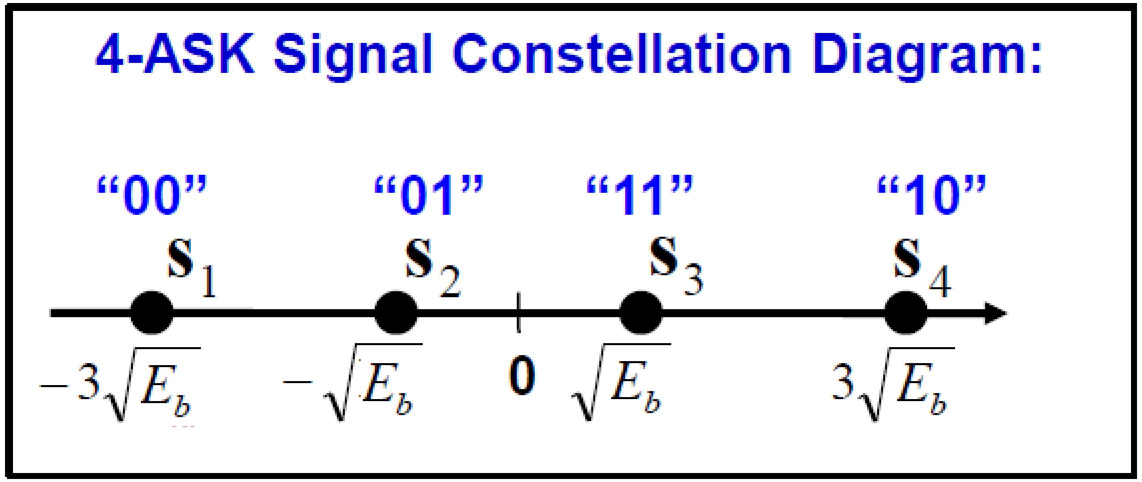


# ASK Constellation Diagram

"Constellation diagram" is a graphical representation of those signal points plotted on a 2D plane, typically showing the in-phase (*I*) and quadrature (*Q*) components of a signal, allowing for visual analysis of a modulation scheme and its performance under noise or interference conditions.

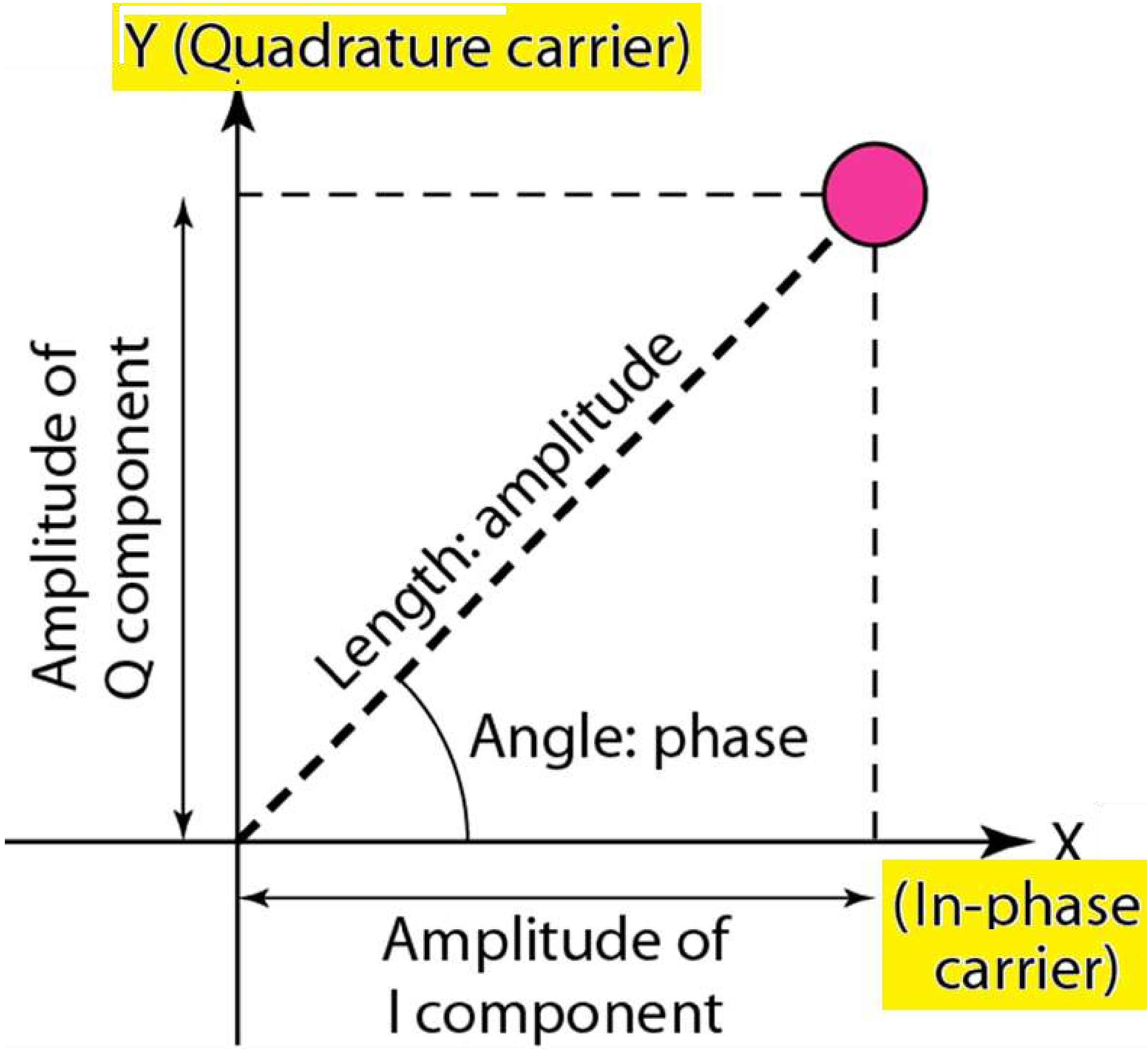
$$s(t) = \begin{cases} s_1(t) = A_c \cos 2\pi f_c t \\ \quad = \sqrt{\dfrac{2E_b}{T_b}} \cos 2\pi f_c t, \quad 0 \le t \le T_b : \text{Logic } 1 \\ s_2(t) = 0, \quad\quad Else : \text{Logic } 0 \end{cases}$$



# Constellation Diagram

- A graphical representation of the complex envelope of each possible signal.
- The distance between signals on a constellation diagram relates to *how different the modulation waveforms are* and *how well a receiver can differentiate between them* when random noise is present.



# Error Performance of ASK

# Error Performance: Bit Error Rate (BER)

The BASK signal at the receiver in the presence of noise is given by

$$r(t) = \alpha s(t) + n(t)$$

where $\alpha$ is attenuation introduced by Txion channel. Assume $\alpha$ =1.

$n(t)$ is AWGN with power spectral density $\frac{N_0}{2}$ W/Hz.

Then the Bit Error Rate for ASK is given by $\text{BER}_{\text{ASK}} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$

where $E_b = \frac{A_c^2 T_b}{4}$ is the average energy bit.

Ex: Binary data is transmitted using ASK through a channel that adds white Gaussuan noise with power spectral density $N_0 = 10^{-11}$ W / Hz. Determine the amplitude of a received carrier burst to provide a $BER = 10^{-5}$ for the following data rates

(a) 300 bps; (b) 3kbps; (c) 9.6 kbps

Use $Q(x) = 10^{-5} \Rightarrow x = 4.27$

Ans: The Bit Error Rate for ASK is given by $\mathrm{BER}_{\mathrm{ASK}} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$

To achieve a $BER = 10^{-5}$ $\sqrt{\frac{E_b}{N_0}} = 4.27 \Rightarrow \frac{E_b}{N_0} = 4.27^2 = 18.233$

$N_0 = 10^{-11}$ ; $E_b = 18.233\text{x}10^{-11}$

# Ex…

$$E_b = \frac{A_c^2 T_b}{4} = \frac{A_c^2}{4R_b} \Rightarrow Ac = 2\sqrt{E_b R_b}$$

$(a)$ For $R_b = 300\ bps;$

$$A_c = 2\sqrt{E_b R_b} = 2\sqrt{18.233\text{x}10^{-11}\text{x}300} = 466.7\,\mu V$$

$(b)$ For $R_b = 3\ kbps;$

$$A_c = 2\sqrt{E_b R_b} = 2\sqrt{18.233\text{x}10^{-11}\text{x}3000} = 1.479\ mV$$

$(c)$ For $R_b = 9.6\ kbps;$

$$A_c = 2\sqrt{E_b R_b} = 2\sqrt{18.233\text{x}10^{-11}\text{x}9600} = 2.646\ mV$$

# End