CS311: DATA COMMUNICATION

Transmission of Analog Signal - II

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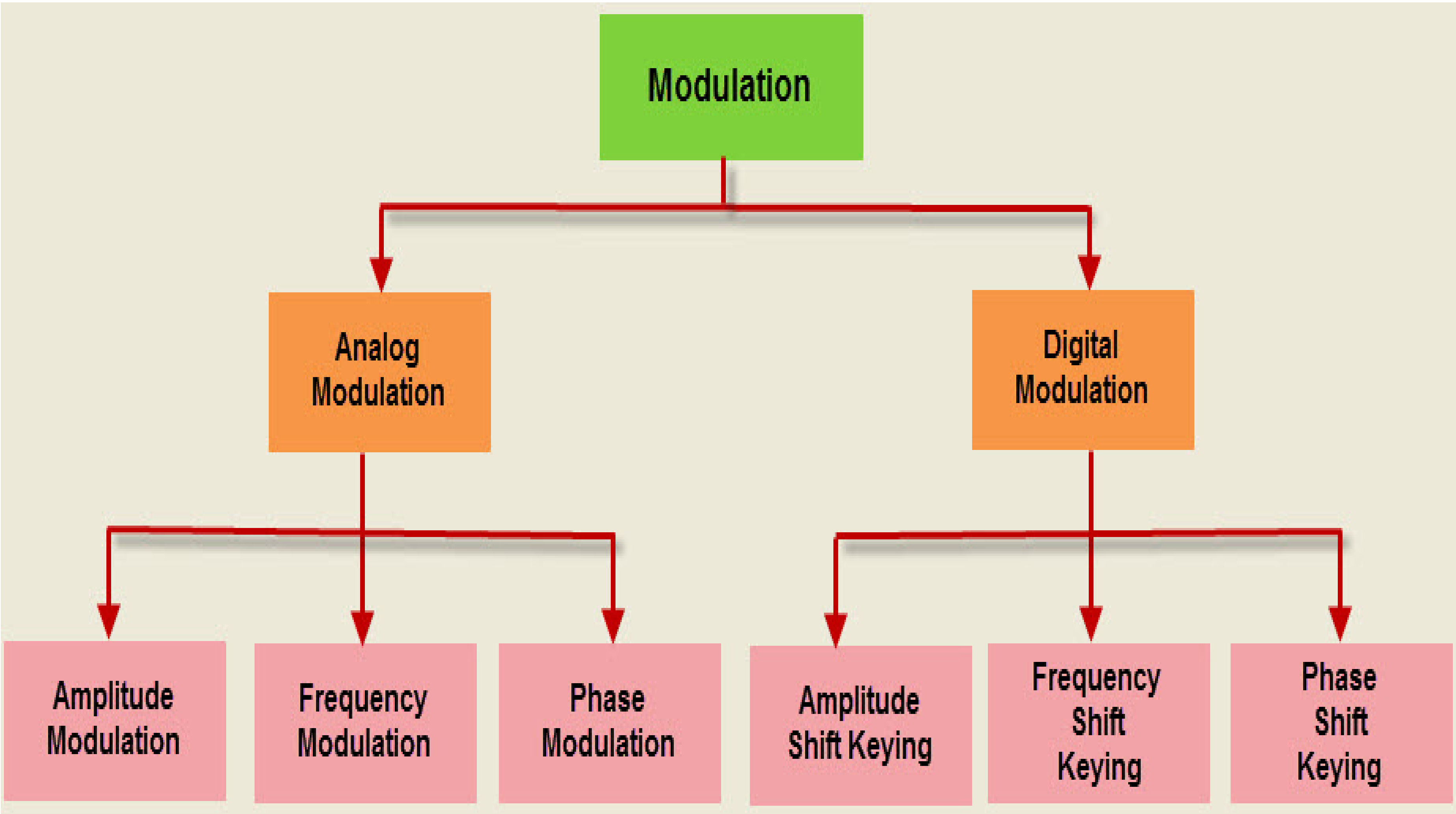
Transmission of Analog Signal-II

On completion, the student will able to:

- Explain the basic concept of analog modulation.
- Distinguish between FM and PM.
- Explain the basic concepts of digital data to digital signal conversion
- Explain different aspects of ASK, FSK, PSK and QAM conversion techniques.
- Explain bandwidth and power requirement.

Modulation Technique



Frequency Modulation

- The modulating signal $e_m(t)$ is used to vary the carrier frequency.
- The change in frequency is proportional to the modulating voltage $ke_m(t)$, K is the constant known as frequency deviation constant, expressed in Hz/V.
- The instantaneous frequency of the modulated signal is $f_i(t) = f_c + ke_m(t)$, where f_c is the carrier frequency.

Sinusoidal FM

For sinusoidal modulation

$e_m(t)= E_m\cos 2\prod f_m t$ and $f_i(t)= f_c + ke_m(t)$

$= f_c + kE_m\cos 2\prod f_m t= f_c + \Delta f\cos 2\prod f_m t$

Therefore

$s(t)=E_c\cos\theta(t)$

$= E_c\cos(2\prod f_c t + 2\prod\Delta f\int_0^t\cos 2\prod f_m t dt)$

$= E_c\cos(2\prod f_c t + (\Delta f/f_m)\sin 2\prod f_m t)$

The modulation index, denoted by β, is given by

$\beta=(\Delta f/f_m)$

Or $s(t)= E_c\cos(2\prod f_c t + \beta\sin 2\prod f_m t)$

Bandwidth

- The modulated signal will contain frequency components $f_c + f_{m,}$ $f_c + 2f_m$, and so on
- Carson's Rule

  $B_T = 2(\beta+1)B_m$

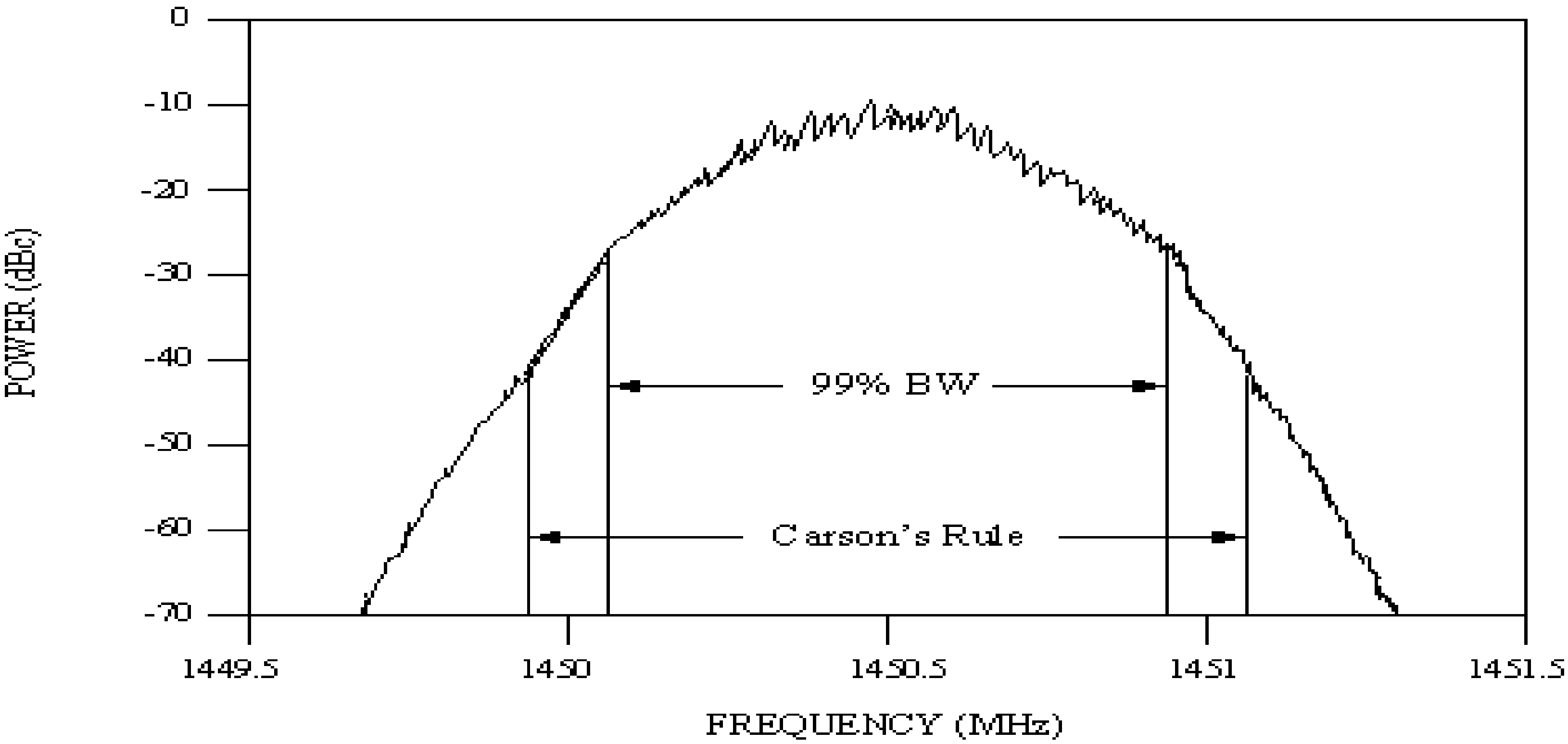
  Where $\beta = \Delta f/B = n_f A_m / 2\prod B$

  $B_T = 2\Delta f + 2B$
- FM requires greater bandwidth than AM

Bandwidth

Peak Deviation=$\Delta f=(1/ 2\prod)n_f A_m$ Hz

Where A_m is the maximum value of m(t)



Power

- As the amplitude remains constant, total average power is equal to the unmodulated carrier power.
- Power $=A_c^2/2$
- Although A_m increases the bandwidth, it does not affect power.
- Transmission power for FM is less at the expense of high bandwidth.

Phase Modulation

- Representation of modulated signal

  $s(t)=A_c\cos[w_c t+\phi(t)]$
- The angle $w_c t+\phi(t)$ goes under modulation around the angle $\theta= w_c t$
- The signal is therefore an angular-velocity modulated signal.
- When the phase is directly proportional to the modulating signal, i.e, $\phi(t)= n_p m(t)$, we call it phase modulation, where n_p is phase modulation index.

Relation Between FM and PM

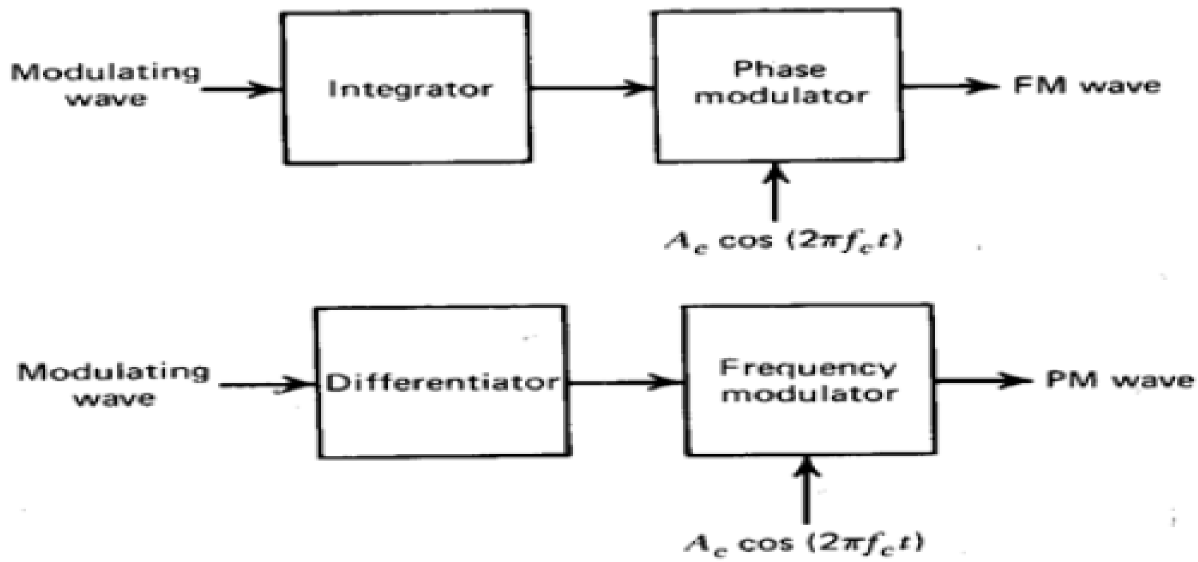


Fig: 5.2 – Scheme for generation of FM and PM Waveforms

The instantaneous frequency of the phase modulated signal

$s(t)=E_c\cos[w_c t+k'm(t)]$, Where k' is constant.

Relation Between FM and PM

- Let m(t) be derived as an integral of the modulated signal $e_m(t)$, so that
- $m(t)=k''\int e(t)$, then with $k=k'k''$, we get
- $s(t)=E_c\cos(w_c t+k\int e(t))$,
- The instantaneous angular frequency of s(t) is

  $2\prod f_i(t)=d/dt(2\prod f_c t+k\int e(t))$

  or $f_i(t)=f_c+(1/2\prod)ke(t)$
- The waveform is therefore modulated in frequency
- In summary, these two together are referred to as **angle modulation** and modulated signals have similar characteristics.

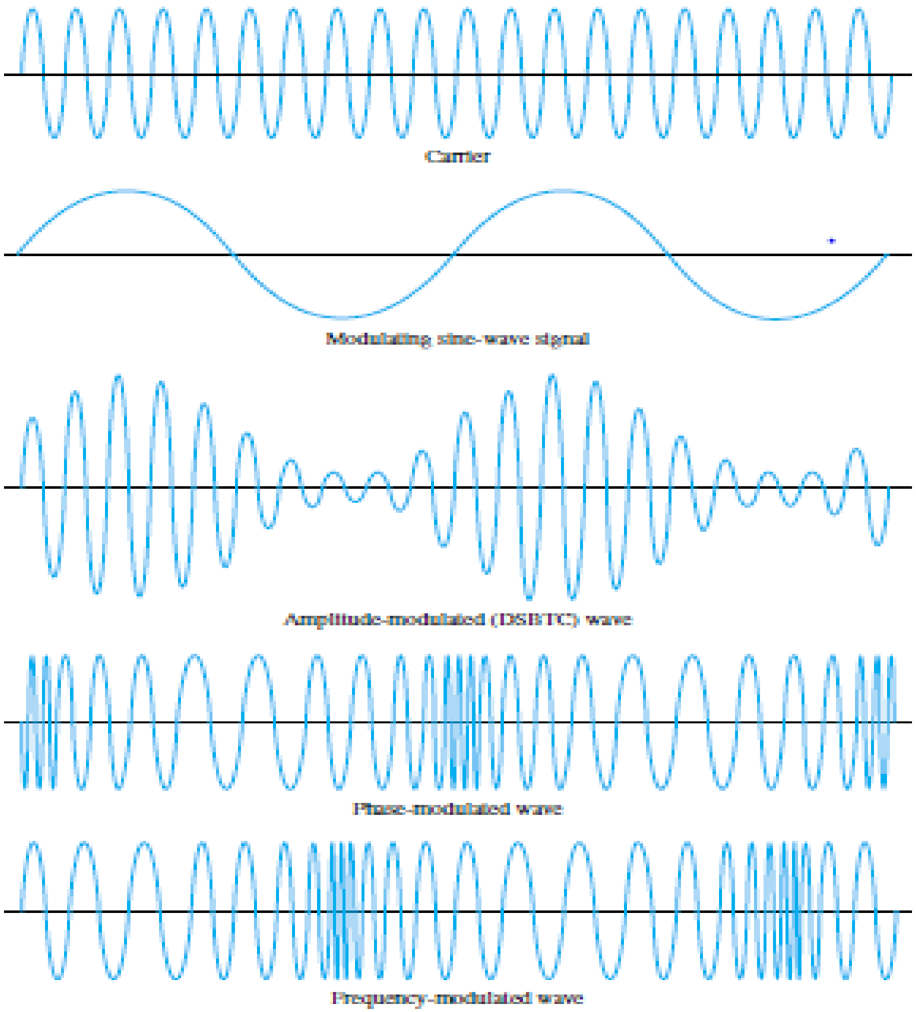


Figure 5.24 Amplitude, Phase, and Frequency Modulation of a Sine-Wave Carrier by a Sine-Wave Signal

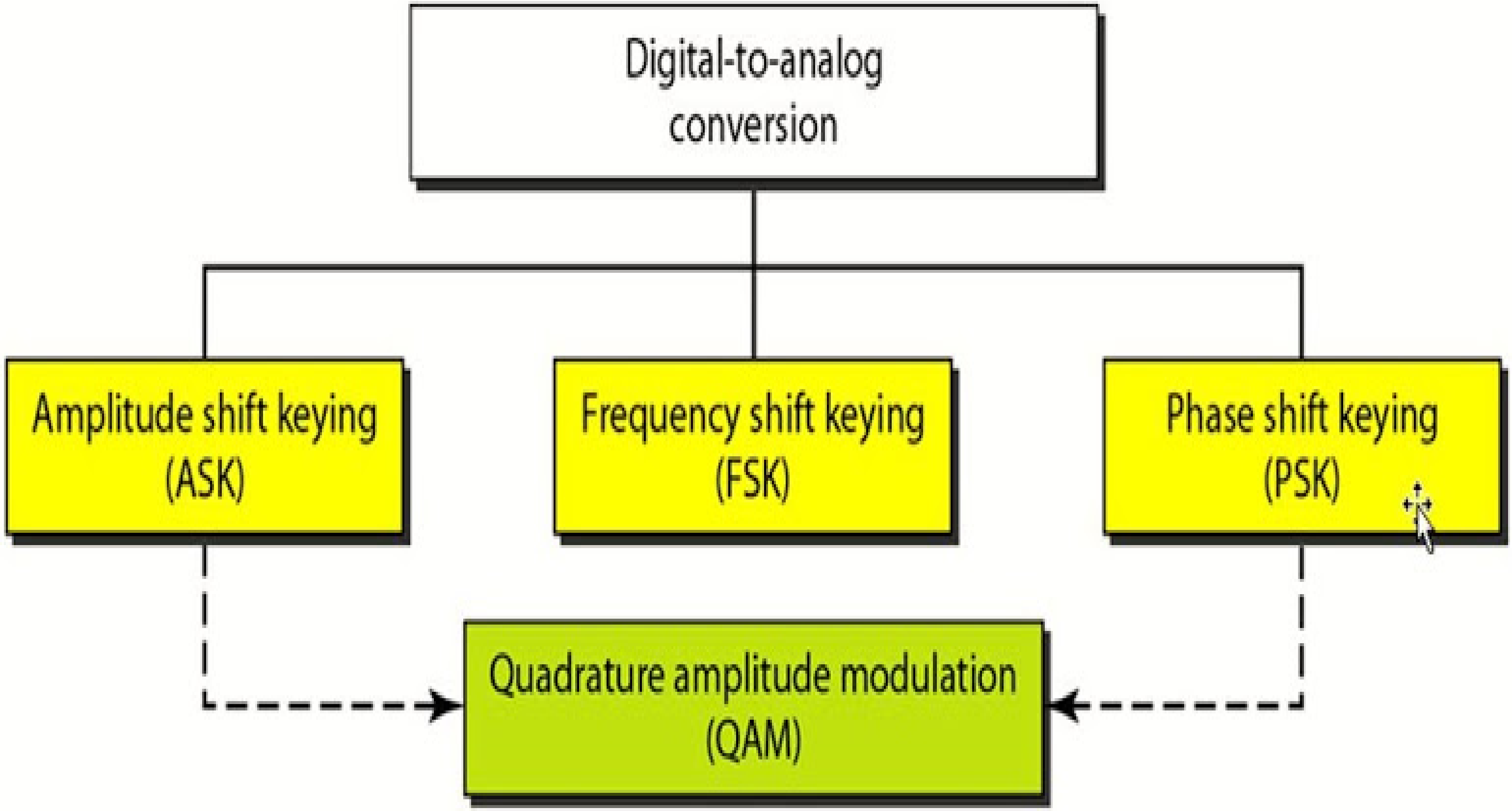
Analog Data to analog signal modulation technique at a glance.

Why digital data to analog signal conversion

- Quite often we have to send digital data through analog transmission media.

Digital Data-Analog Signal

- Types of digital-to-analog modulation



Amplitude Shift keying(ASK)

- The unmodulated signal can be represented by $e_c(t)=E_c\cos 2\prod f_c t$
- The modulated signal can be written as

$$s(t)=ke_m\cos 2\prod f_c t$$

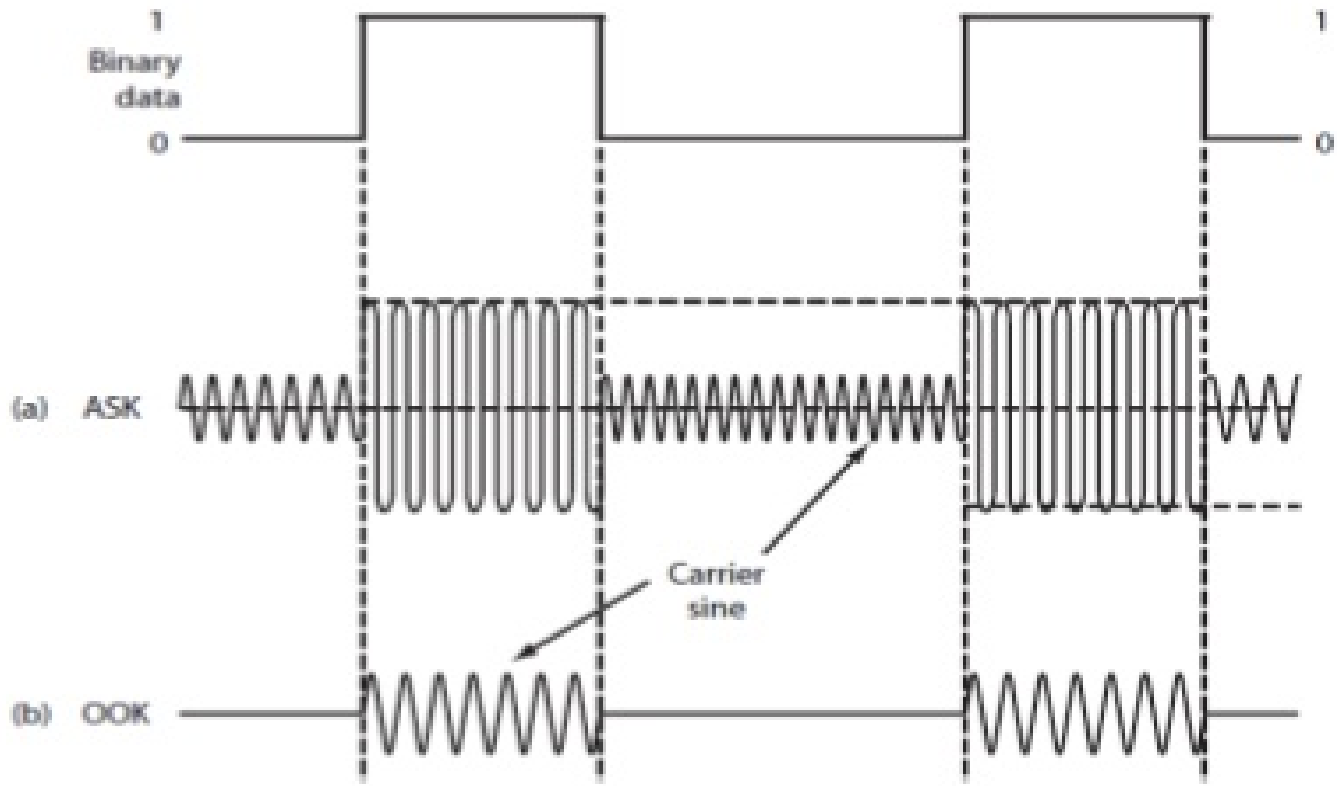
$s(t)=A_1\cos 2\prod f_c t$ for 1

$s(t)=A_2\cos 2\prod f_c t$ for 0

Special case: on off keying(OOK), A_2 is 0

- **ASK** is susceptible to sudden gain change.
- **OOK is used to transmit digital data over optical fibers.**

OOK



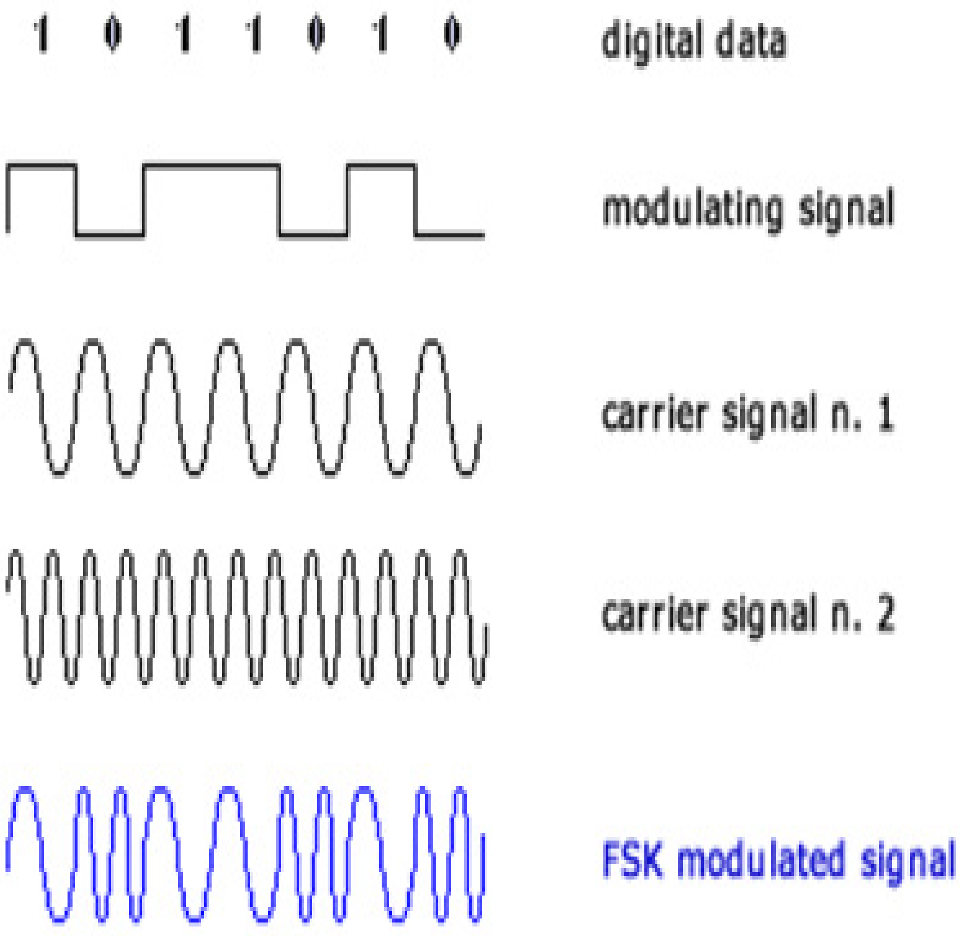
Frequency Spectrum of ASK Signal

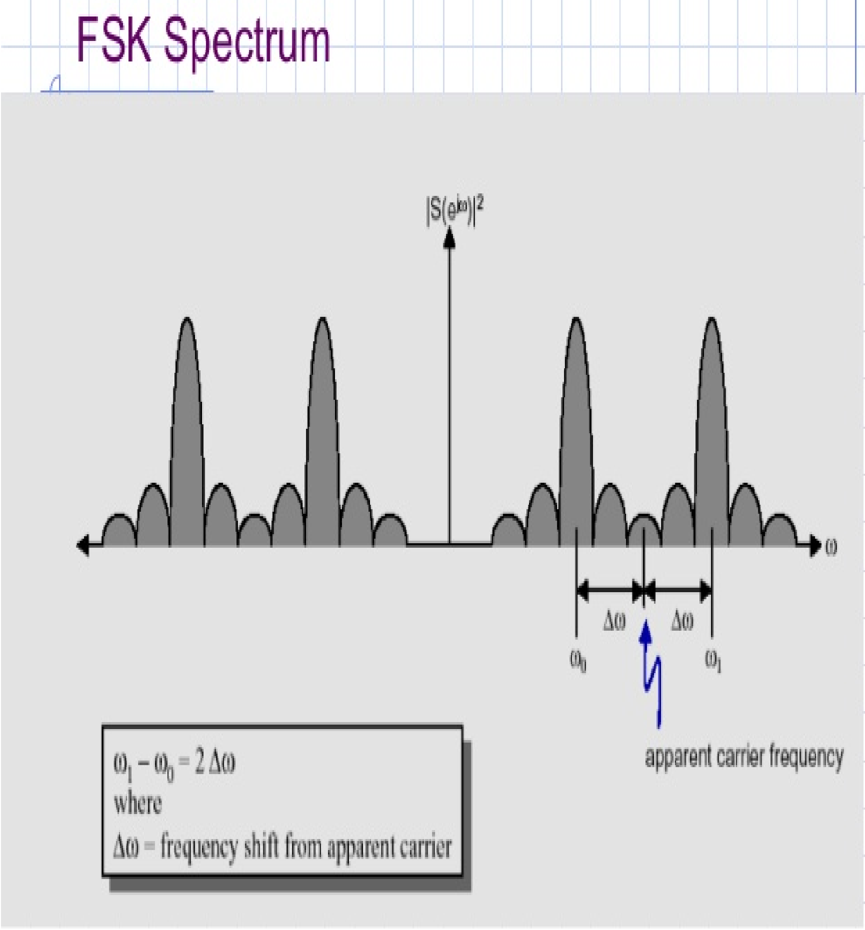
- If B_m is the overall bandwidth of the binary signal, the bandwidth of the modulated signal is $B_T = N_b$, Where N_b is the baud rate.

Frequency Shifting Keying

- Frequency of the carrier is used to represent 0 or 1.
- $s(t)=A\cos 2\prod f_{c1}t$ for binary 1
- $s(t)=A\cos 2\prod f_{c2}t$ for binary 0
- It is much less susceptible to noise and gain change.

FSK


1 0 1 1 0 1 0
digital data
modulating signal
carrier signal n. 1
carrier signal n. 2
FSK modulated signal

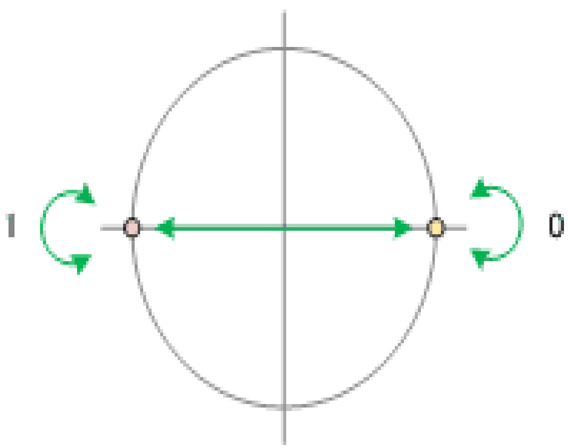

FSK Spectrum
$|S(e^{j\omega})|^2$
ω
$\Delta\omega$
$\Delta\omega$
ω_0
ω_1
apparent carrier frequency
$\omega_1 - \omega_0 = 2\,\Delta\omega$
where
$\Delta\omega$ = frequency shift from apparent carrier

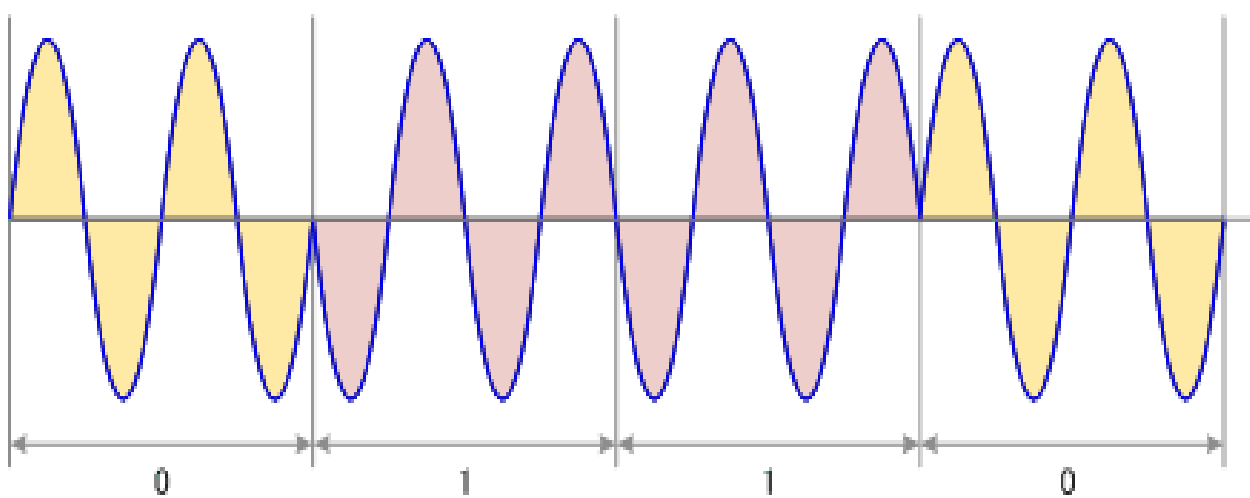
Frequency Sprectrum of The FSK Signal

- FSK may be consider as combination of two ASK spectra centered around f_{c1} and $f_{c2.}$
- Bandwidth= f_{c2} - f_{c1} + N_b

Phase Shifting Keying(PSK)

- The phase of carrier is used to represent 0 or 1
- $s(t)=A\cos(2\pi f_c t + \pi)$ for binary 1
- $s(t)=A\cos 2\pi f_c t$ for binary 0
- 2-PSK





- For more efficient use of bandwidth Quadrature Phase – Shifting keying

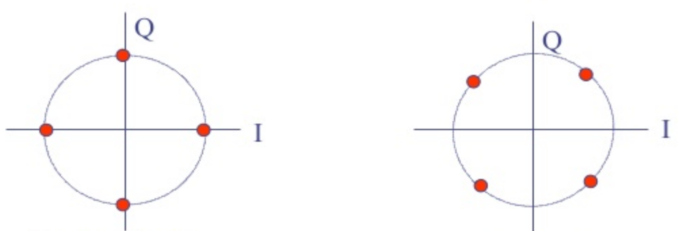
QPSK $s(t) = A\cos(2\prod f_c t)$ for 00

$= A\cos(2\prod f_c t + 90)$ for 01

$= A\cos(2\prod f_c t + 180)$ for 10

$= A\cos(2\prod f_c t + 270)$ for 11

QPSK Constellation Diagram



Carrier phases $\{0, \pi/2, \pi, 3\pi/2\}$

Carrier phases $\{\pi/4, 3\pi/4, 5\pi/4, 7\pi/4\}$

- Quadrature Phase Shift Keying has twice the bandwidth efficiency of BPSK since 2 bits are transmitted in a single modulation symbol

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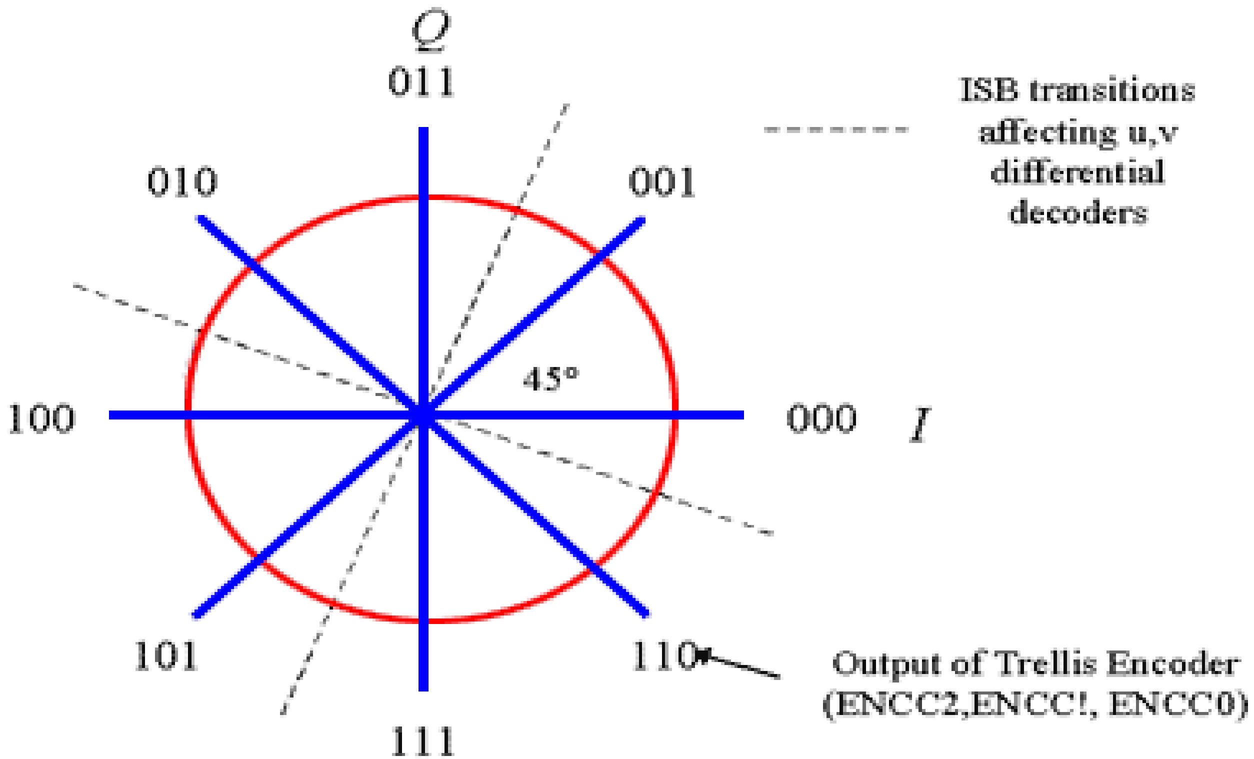
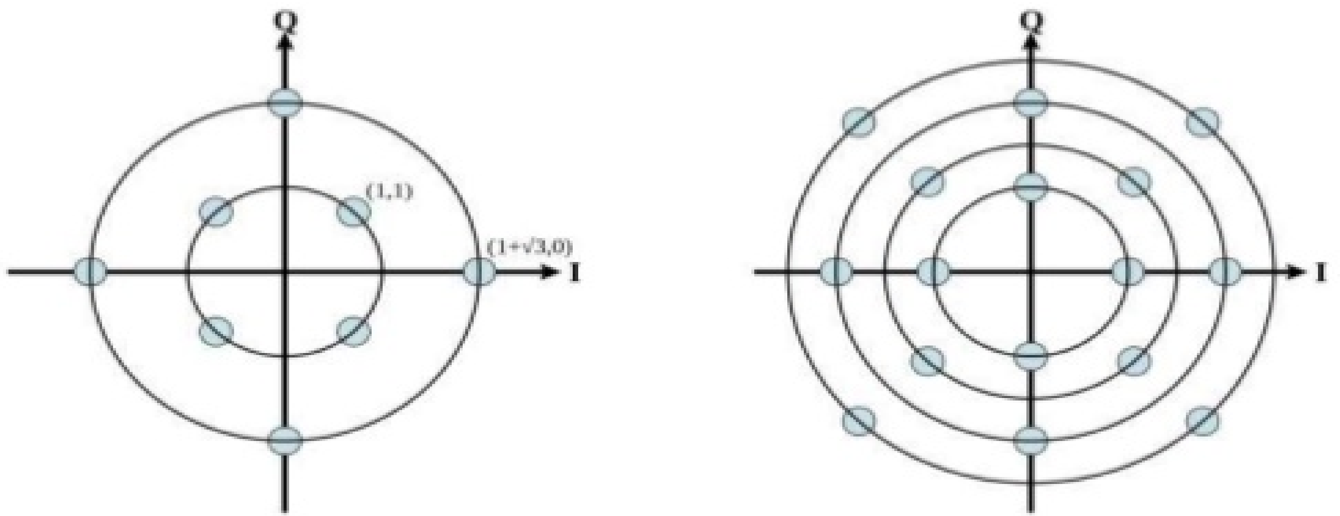
8-PSK

- The idea can be extended to have 8-PSK.
- The phase is shift by 45^0.



QAM Modulation



- Peek some fixed set of complex amplitude points and encode your information by switching carrier between these points.
- Such set is called QAM constellation.
- Each point encodes several bits and called QAM symbol.
- The more points are packed in QAM symbol the faster the information will be transferred, but symbols with many points are sensible to noise. So, balance is needed.

Bit Rate and Baud Rate

Table 5.1 Bit and baud rate comparison

Modulation	Units	Bits/Baud	Baud rate	Bit Rate
ASK, FSK, 2-PSK $\log_2 2 = \log_2 2^1 = 1$	Bit	1	N	N
4-PSK, 4-QAM $\log_2 4 = \log_2 2^2 = 2$	Dibit	2	N	2N
8-PSK, 8-QAM $\log_2 8 = \log_2 2^3 = 3$	Tribit	3	N	3N
16-QAM $\log_2 16 = \log_2 2^4 = 4$	Quadbit	4	N	4N
32-QAM $\log_2 32 = \log_2 2^5 = 5$	Pentabit	5	N	5N
64-QAM $\log_2 64 = \log_2 2^6 = 6$	Hexabit	6	N	6N
128-QAM $\log_2 128 = \log_2 2^7 = 7$	Septabit	7	N	7N
256-QAM $\log_2 256 = \log_2 2^8 = 8$	Octabit	8	N	8N

Dial-up modem

- Traditional, telephone lines can carry frequencies between 300 and 3300Hz, giving them a bandwidth of 3000 Hz.
- The effective bandwidth of a telephone line being used for data communication is 2400 Hz, covering the range from 600 and 3000 Hz.

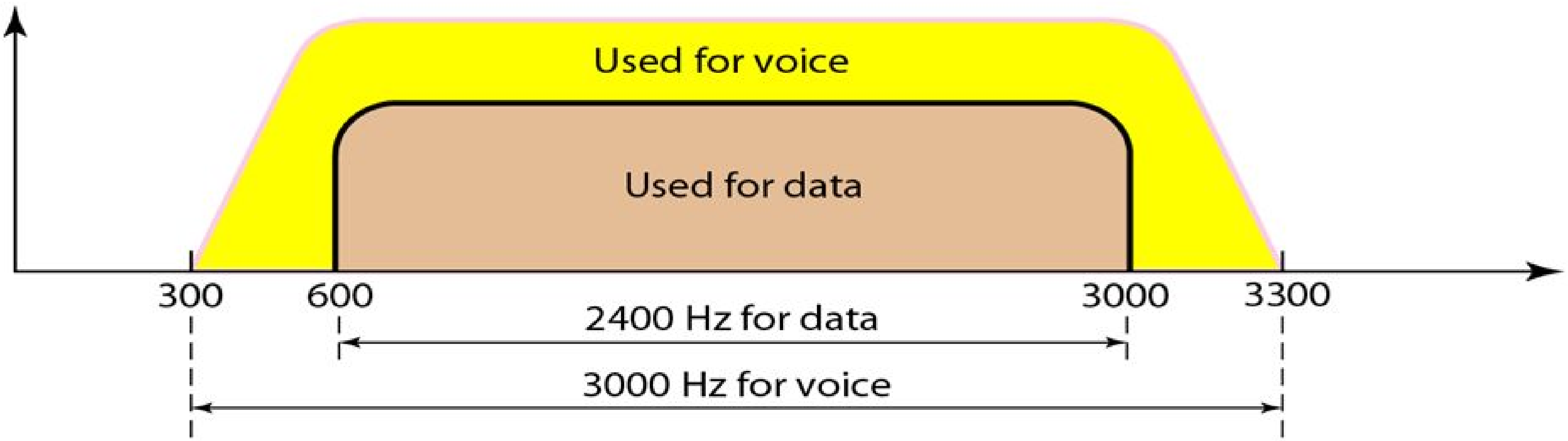


Figure 9.6 *Telephone line bandwidth*

Thanks!