Electrical Engineering Department
3 rd Class: digital Communications
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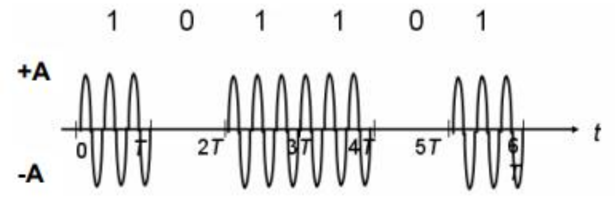
2024-2025

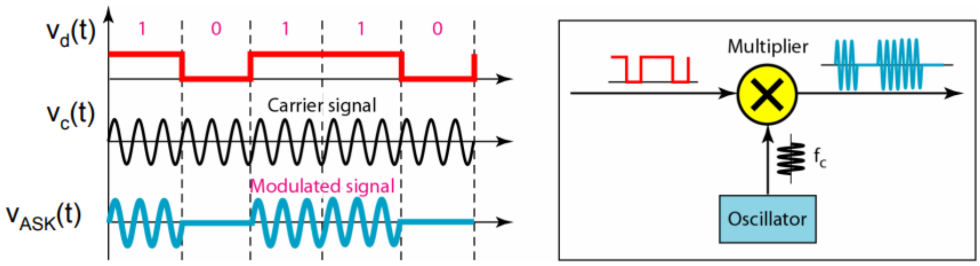
ASK – strength of carrier signal is varied to represent binary 1 or 0

- both frequency & phase remain constant while amplitude changes
- commonly, one of the amplitudes is zero

$$s(t) = \begin{cases} A_0 \cos(2\pi f_c t), & binary\ 0 \\ A_1 \cos(2\pi f_c t), & binary\ 1 \end{cases}$$



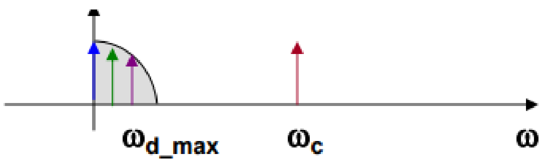
- demodulation: only the presence or absence of a sinusoid in a given time interval needs to be determined
- advantage: simplicity
- disadvantage: ASK is very susceptible to noise interference – noise usually (only) affects the amplitude, therefore ASK is the modulation technique most affected by noise
- application: ASK is used to transmit digital data over optical fiber

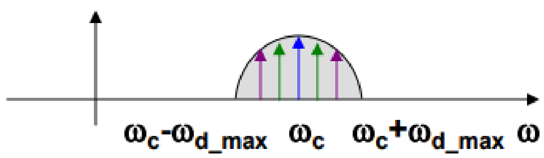


Carrier signal: $v_c(t) = \cos(2\pi f_c t) = \cos(w_c t)$

Digital signal: $v_d(t) = A\left[\frac{1}{2} + \frac{2}{\pi}\cos(w_0 t) - \frac{2}{3\pi}\cos(3w_0 t) + \frac{2}{5\pi}\cos(5w_0 t) - \cdots\right]$

Modulated signal $v_{ASK}(t) = v_c(t).v_d(t) = \frac{1}{2}\cos(w_0 t) + \frac{1}{\pi}[\cos(w_c - w_0)t + \cos(w_c + w_0)t] - \frac{1}{3\pi}[\cos(w_c - 3w_0)t + \cos(w_c + 3w_0)t]$





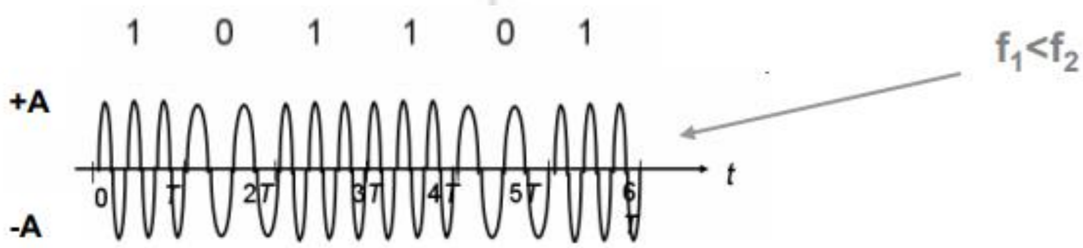
Example

Determine the minimum bandwidth necessary to pass a 10 kbps binary signal using amplitude shift keying.

FSK – frequency of carrier signal is varied to represent binary 1 or 0

• peak amplitude & phase remain constant during each bit interval

$$s(t) = \begin{cases} A\cos(2\pi f_1 t), & binary\ 0 \\ A\cos(2\pi f_2 t), & binary\ 1 \end{cases}$$

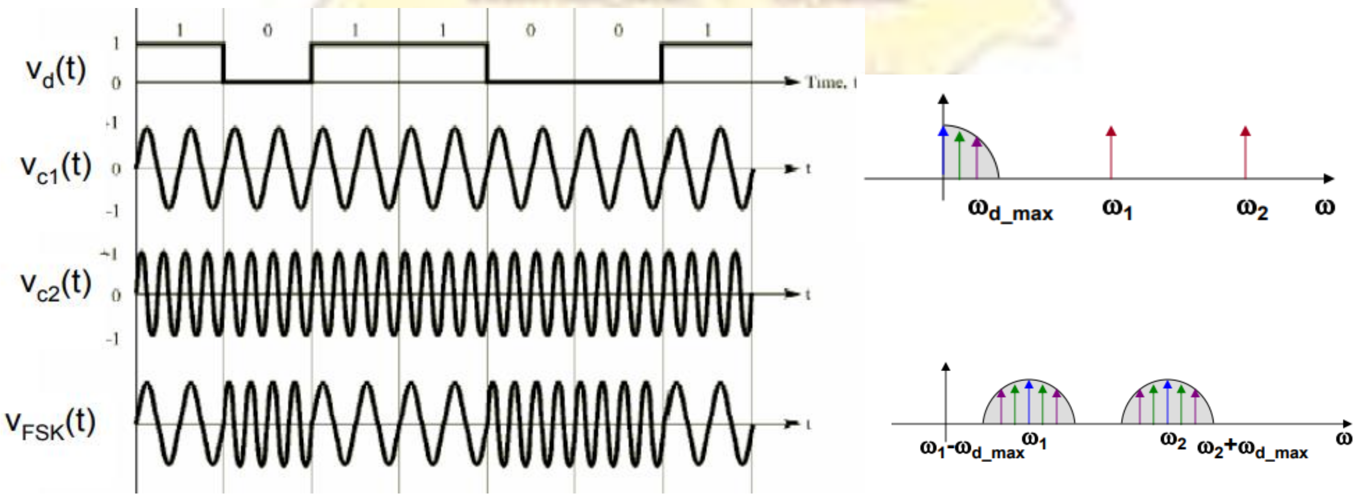


• demodulation: demodulator must be able to determine which of two possible frequencies is present at a given time

• advantage: FSK is less susceptible to errors than ASK – receiver looks for specific frequency changes over a number of intervals, so voltage (noise) spikes can be ignored

• disadvantage: FSK spectrum is 2 x ASK spectrum

• application: over voice lines, in high-freq. radio transmission, etc.



Digital signal: $v_d(t)\ modulated\ with\ w_1$

$v_d{}^{/}(t)\ modulated\ with\ w_2$

Modulated signal: $v_{FSK}(t) = \cos w_1 t . v_d(t) + \cos w_2 t . \left(1 - v_d(t)\right) = \frac{1}{2}\cos w_1 t . + \frac{1}{\pi}[\cos(w_1 - w_0)t + \cos(w_1 + w_0)t] - \frac{1}{3\pi}[\cos(w_1 - 3w_0)t + \cos(w_1 + 3w_0)t] + \cdots + \frac{1}{2}\cos w_2 t . - \frac{1}{\pi}[\cos(w_2 - w_0)t + \cos(w_2 + w_0)t] + \frac{1}{3\pi}[\cos(w_2 - 3w_0)t + \cos(w_2 + 3w_0)t] + \cdots +$

Example

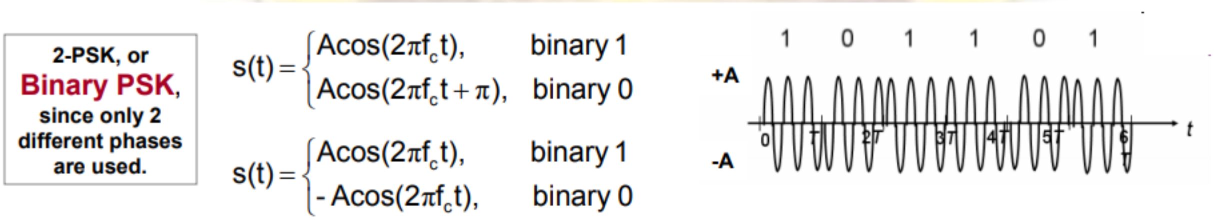
Determine (a) the peak frequency deviation, (b) minimum bandwidth, and (c) baud for a binary FSK signal with a mark frequency of 49 kHz, a space frequency of 51 kHz, and an input bit rate of 2 kbps.

PSK – phase of carrier signal is varied to represent binary 1 or 0

• peak amplitude & freq. remain constant during each bit interval

• example: binary 1 = 0º phase, binary 0 = 180º (πrad) phase

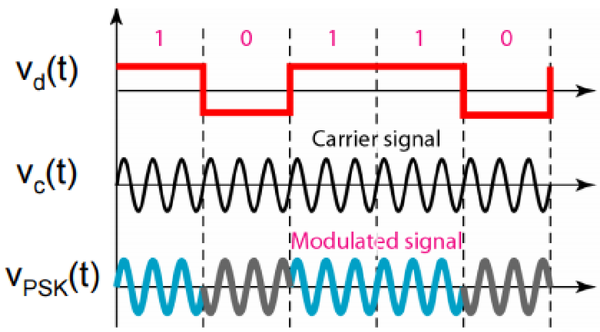
⇒ PSK is equivalent to multiplying carrier signal by +1 when the information is 1, and by -1 when the information is 0

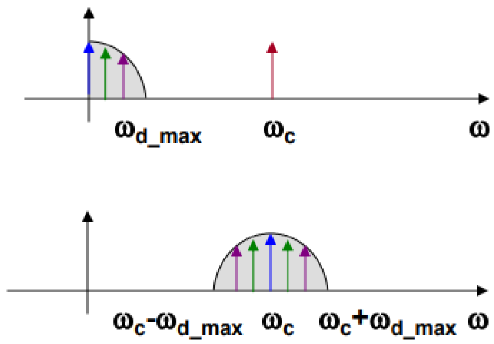


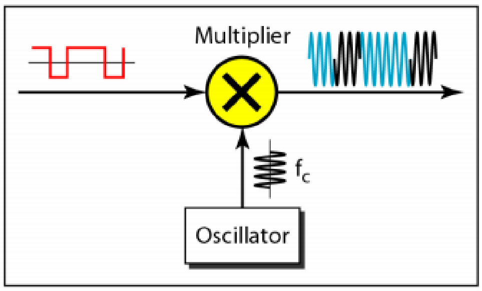
• demodulation: demodulator must determine the phase of received sinusoid with respect to some reference phase

• advantage: ƒ PSK is less susceptible to errors than ASK, while it requires/occupies the same bandwidth as ASK ƒ more efficient use of bandwidth (higher data-rate) are possible, compared to FSK !!!

• disadvantage: more complex signal detection / recovery process, than in ASK and FSK







PSK Detection

$\cos^2 A = \frac{1}{2}(1+\cos 2A)$

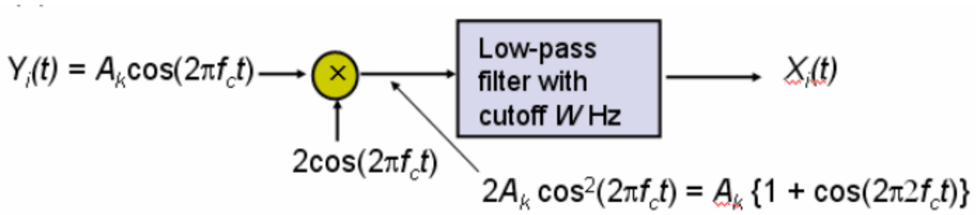
– **multiply the received / modulated signal** $\pm A\cos(2\pi f_c t)$ **by** **2*cos(2πf_ct)**

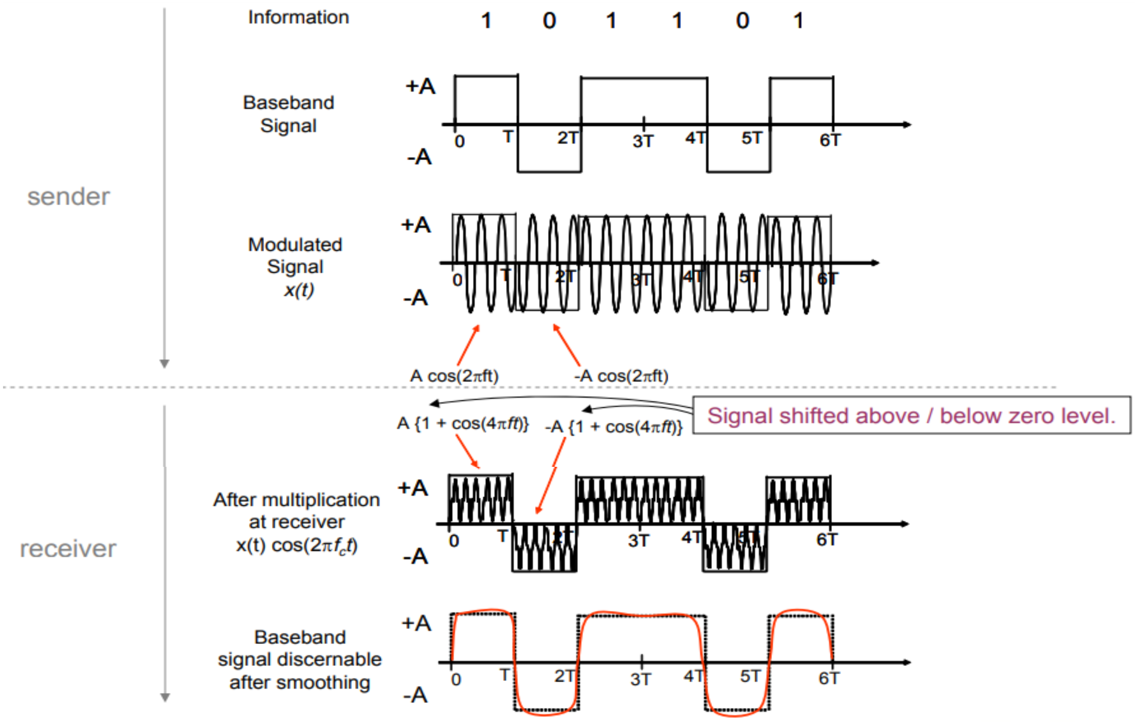
- **resulting signal**

$$2A\cos^2(2\pi f_c t) = A[1+\cos(4\pi f_c t)], \quad \text{binary 1}$$

$$-2A\cos^2(2\pi f_c t) = -A[1+\cos(4\pi f_c t)], \quad \text{binary 0}$$

• by removing the oscillatory part with a low-pass filter, the original baseband signal (i.e. the original binary sequence) can be easily determined



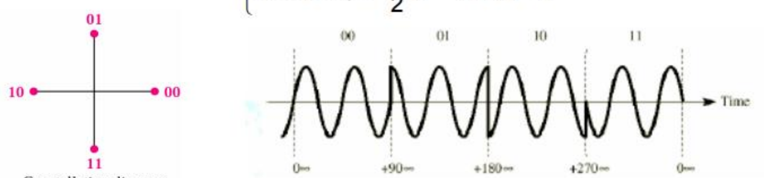


QPSK = 4 QPSK = 4-PSK – PSK that uses phase shifts of 90º= π/2 rad ⇒ 4 different signals generated, each representing 2 bits

$$s(t)=\begin{cases} A\cos(2\pi f_c t), & \text{binary } 00 \\ A\cos(2\pi f_c t+\frac{\pi}{2}), & \text{binary } 01 \\ A\cos(2\pi f_c t+\pi), & \text{binary } 10 \\ A\cos(2\pi f_c t+\frac{3\pi}{2}), & \text{binary } 11 \end{cases}$$

Dibit	Phase
00	0
01	90
10	180
11	270

Dibit (2 bits)



Constellation diagram

• advantage: higher data rate than in PSK (2 bits per bit interval), while bandwidth occupancy remains the same

• 4-PSK can easily be extended to 8-PSK, i.e. n-PSK

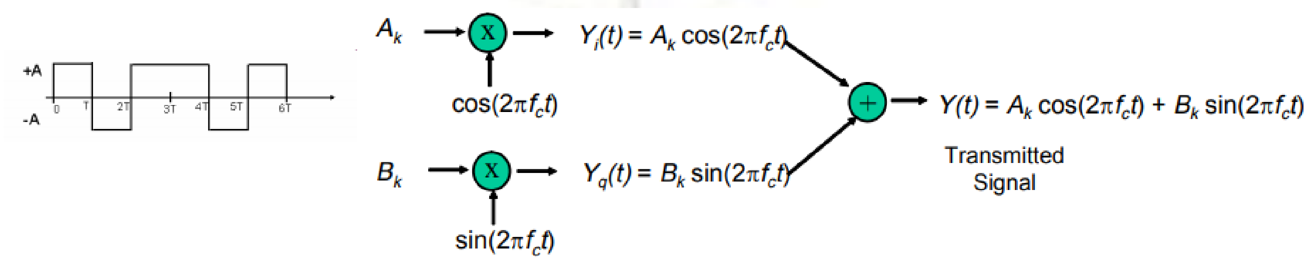
• however, higher rate PSK schemes are limited by the ability of equipment to distinguish small differences in phase

Quadrature Amlitude Modulation – uses two dimentional signalling

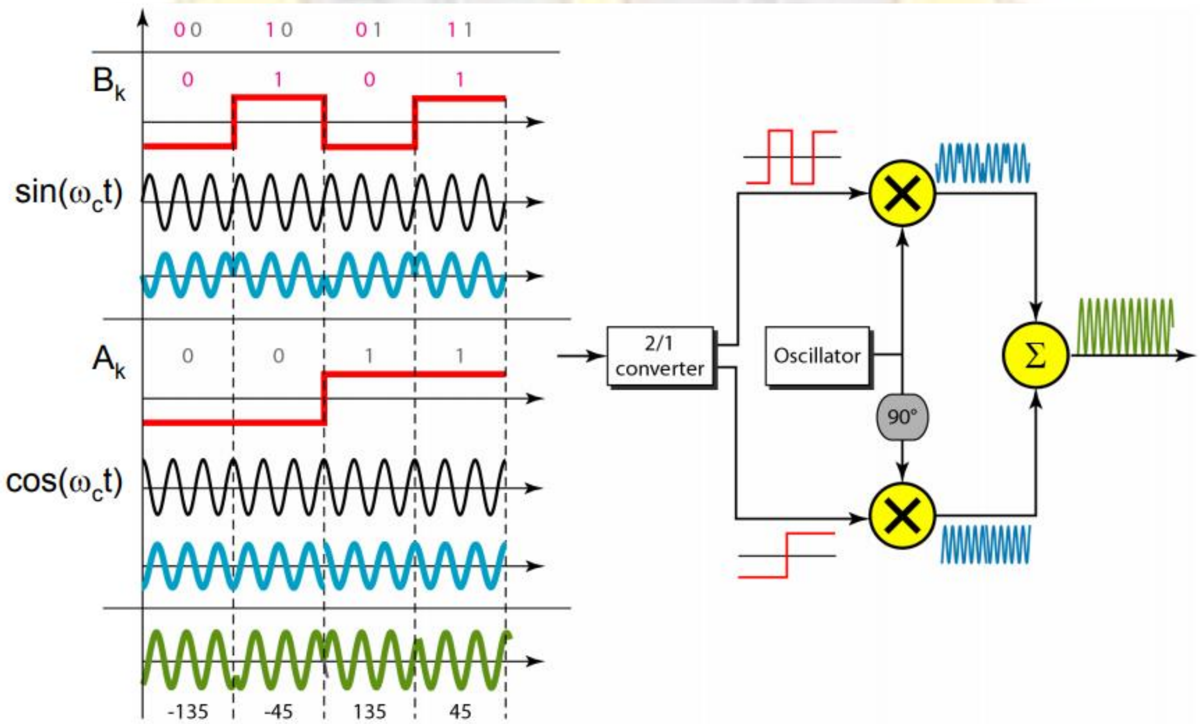
- Orignal information stream is split into two sequences that consists of odd and even symbols, e.g B_k and A_k

1 -1 2 -2 3 -3

A_k sequence (in-phase comp.) is modulated by $\cos(2\pi f_c t)$
B_k sequence (quadrature-phase comp.) is modulated by $\sin(2\pi f_c t)$
Composite signal $A_k \cos(2\pi f_c t) + B_k \sin(2\pi f_c t)$ is sent through the channel

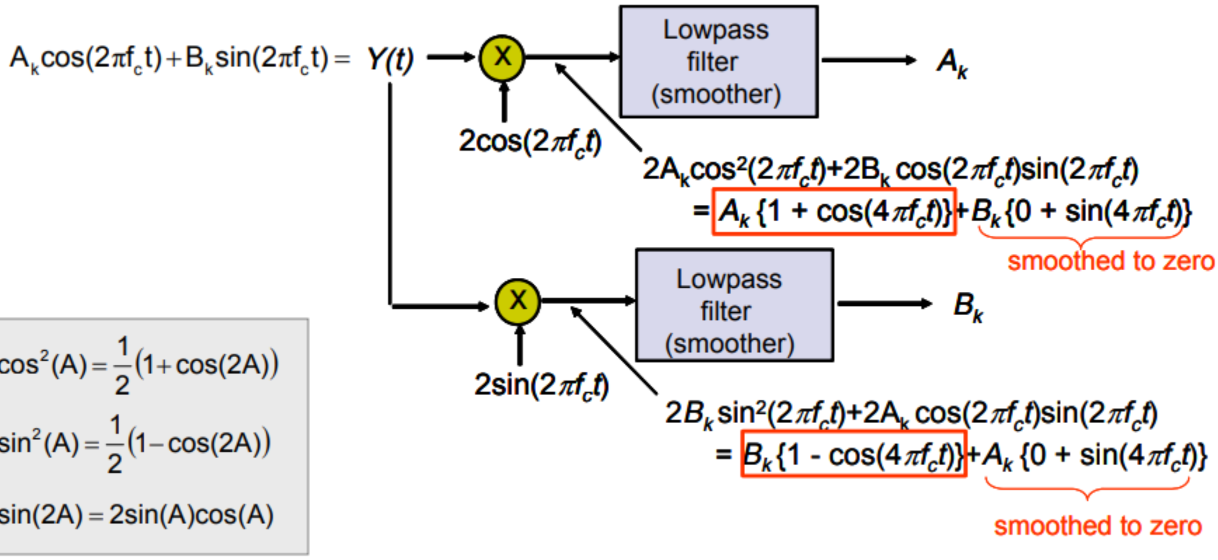


• advantage: data rate = 2 bits per bit-interval!



QAM Demodulation

- **by multiplying Y(t) by $2 \cdot \cos(2\pi f_c t)$ and then low-pass filtering the resultant signal, sequence A_k is obtained**
- **by multiplying Y(t) by $2 \cdot \sin(2\pi f_c t)$ and then low-pass filtering the resultant signal, sequence B_k is obtained**



$$\cos^2(A) = \frac{1}{2}(1+\cos(2A))$$

$$\sin^2(A) = \frac{1}{2}(1-\cos(2A))$$

$$\sin(2A) = 2\sin(A)\cos(A)$$