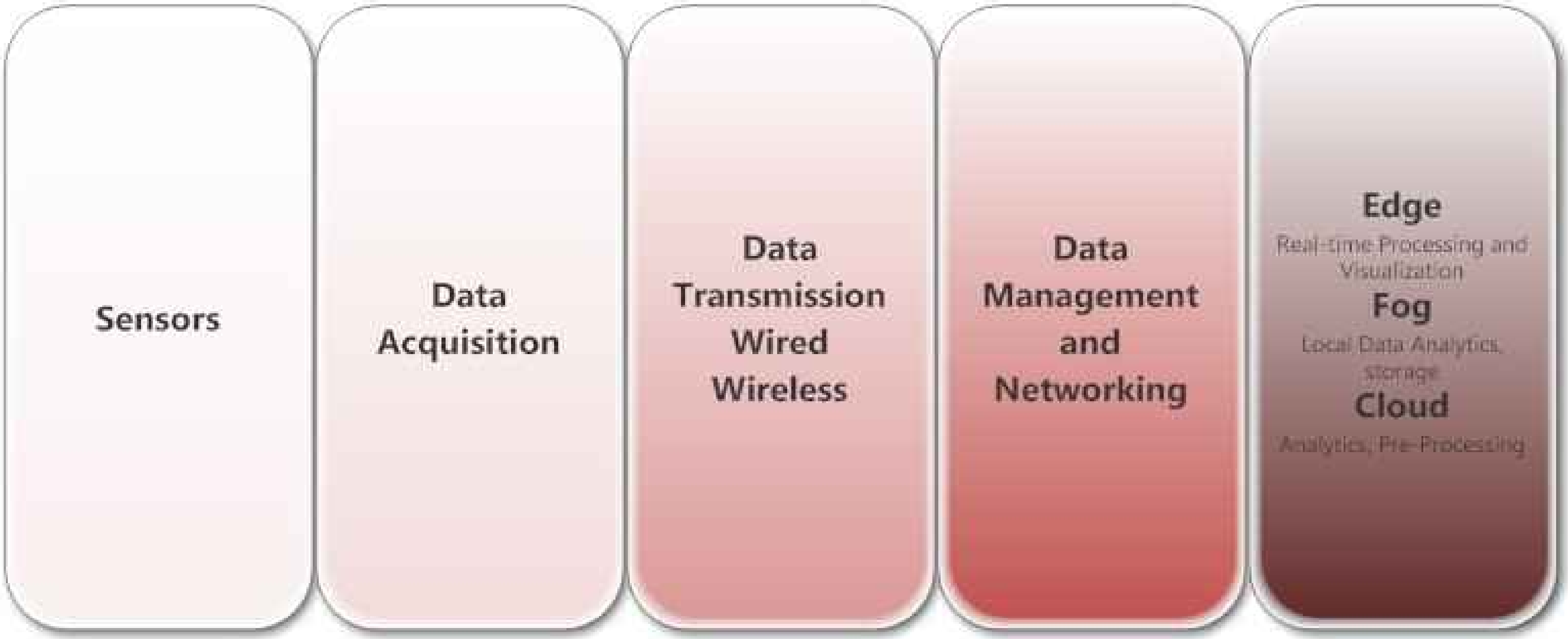
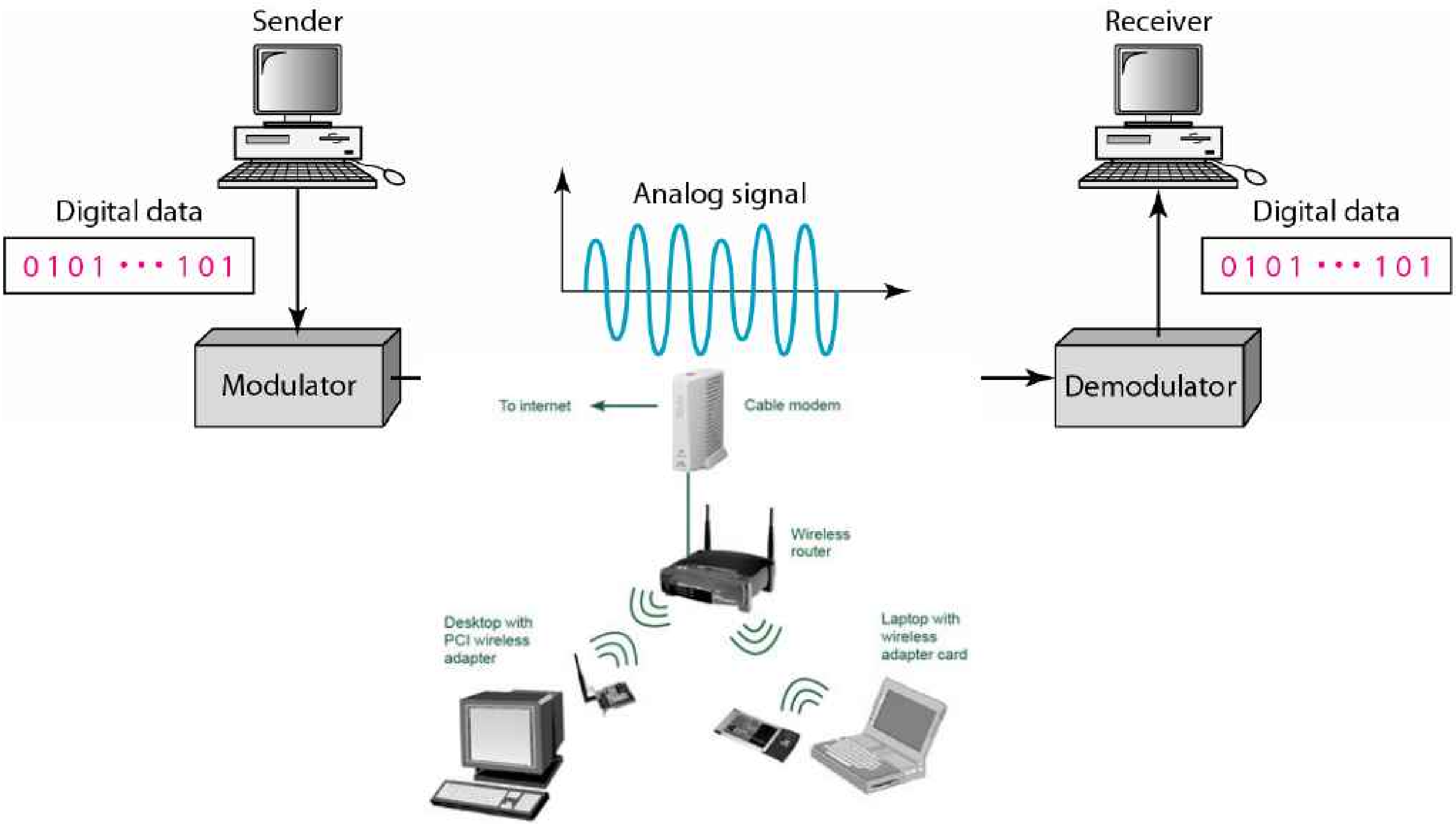
Wireless
Digital Data Communication

Dr Tassadaq Hussain Cheema
Professor NAMAL Univeristy
Pakistan Supercomputing Center, Islamabad
Barcelona Supercomputing Center, Spain
www.tassadaq.pakistansupercomputing.com

Course Overview



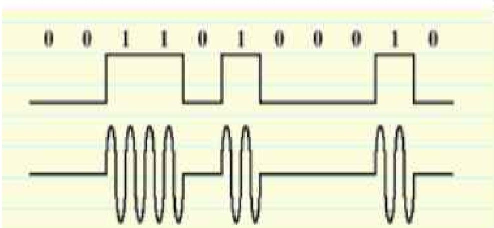
Analog Digital Transmission



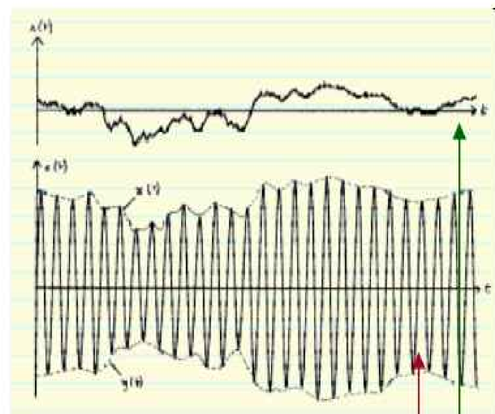
Analog Transmission of Digital Data

- Amplitude Shift Keying
- Frequency Shift Keying
- Phase Shift Keying
- Quadratic Amplitude Modulation

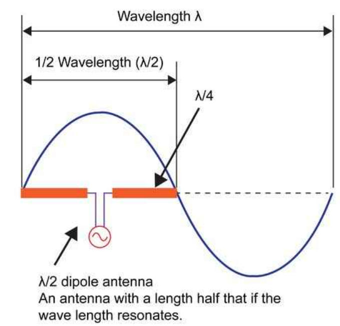
Modulation – process of converting digital data or a low-pass analog to band-pass (higher-frequency) analog signal.



Digital-to-analog modulation.

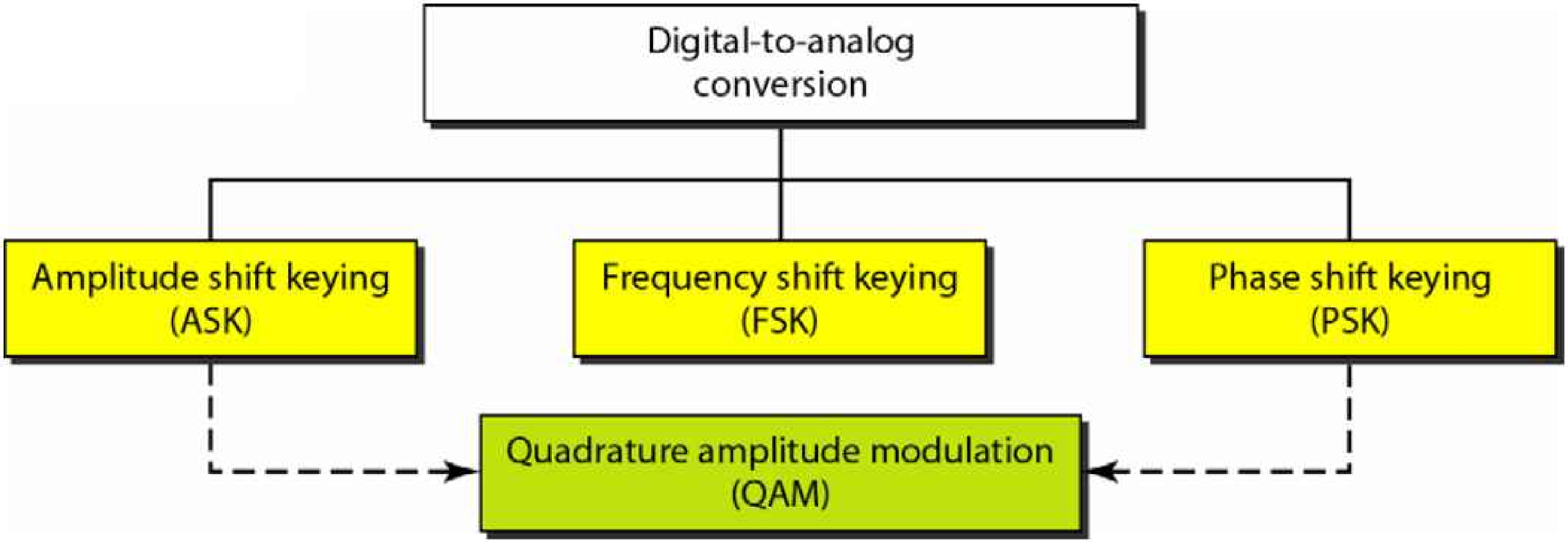


Analog-to-analog modulation.



Carrier Signal – aka carrier freq. or <u>modulated signal</u> - high freq. signal that acts as a basis for the information signal

- information signal is called <u>modulating signal</u>



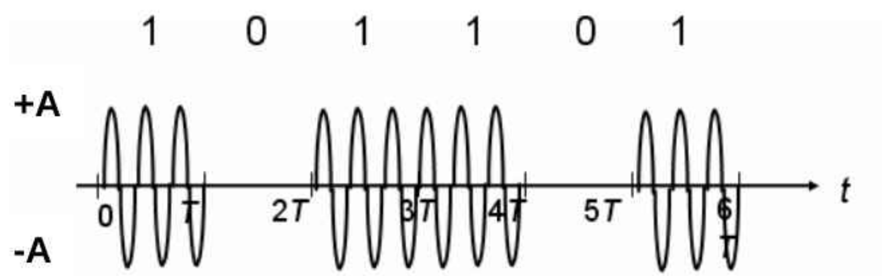
Digital-to-analog
conversion
Amplitude shift keying
(ASK)
Frequency shift keying
(FSK)
Phase shift keying
(PSK)
Quadrature amplitude modulation
(QAM)

Amplitude Shift Keying

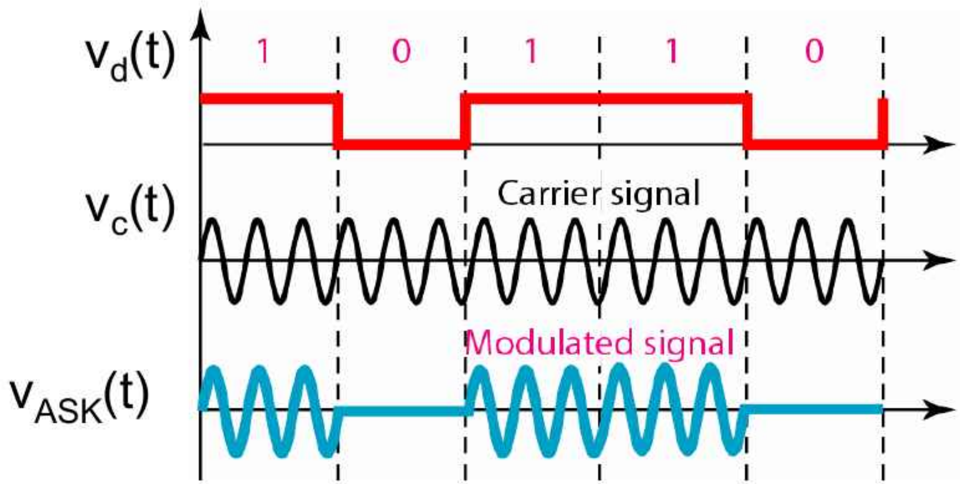
- Strength of carrier signal is varied to represent binary 1 or 0
- Both frequency & phase remain constant while amplitude changes
- Commonly, one of the amplitudes is zero

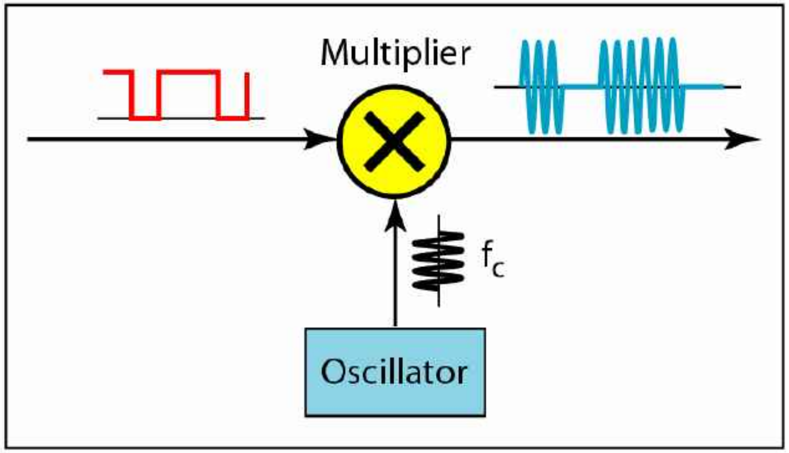
$$s(t) = \begin{cases} A_0 \cos(2\pi f_c t), & \text{binary } 0 \\ A_1 \cos(2\pi f_c t), & \text{binary } 1 \end{cases}$$

Is this picture, from the textbook, entirely correct?!



Working Example

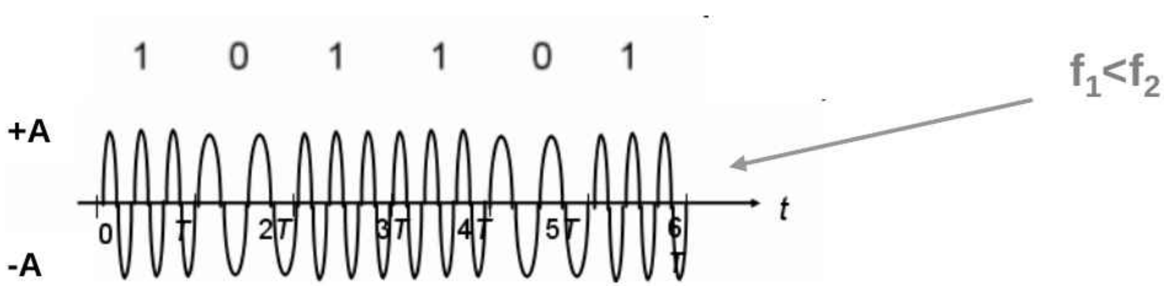




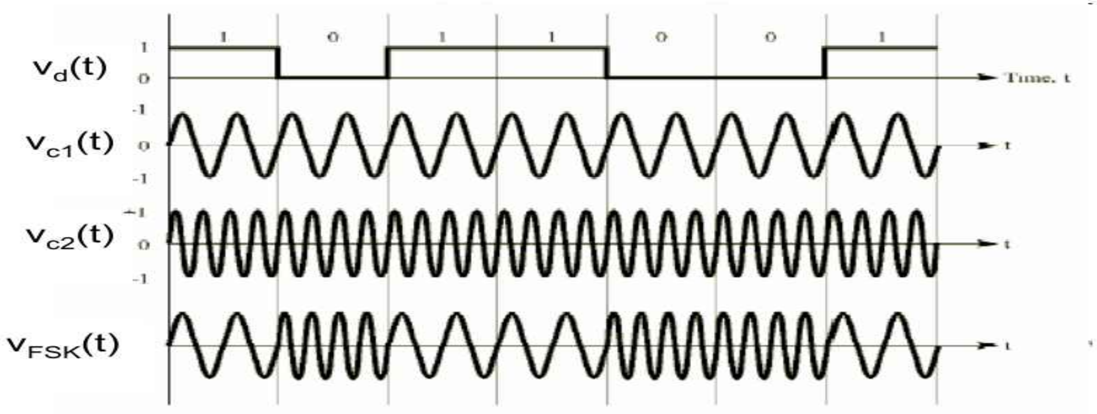
Frequency Shift Keying

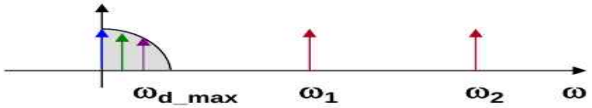
- Frequency of carrier signal is varied to represent binary 1 or 0
- Peak amplitude & phase remain constant during each bit interval

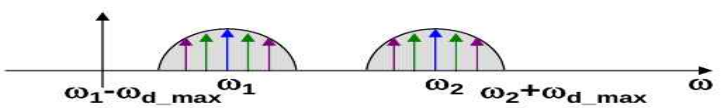
$$s(t) = \begin{cases} A\cos(2\pi f_1 t), & \text{binary } 0 \\ A\cos(2\pi f_2 t), & \text{binary } 1 \end{cases}$$



- 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.







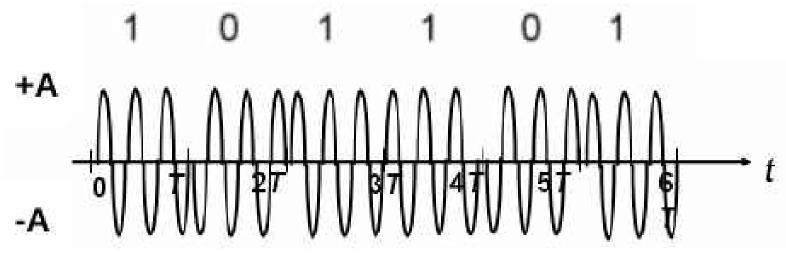
Phase Shift Keying

- 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

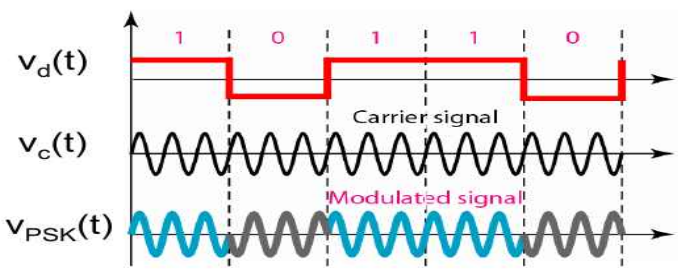
2-PSK, or Binary PSK, since only 2 different phases are used.

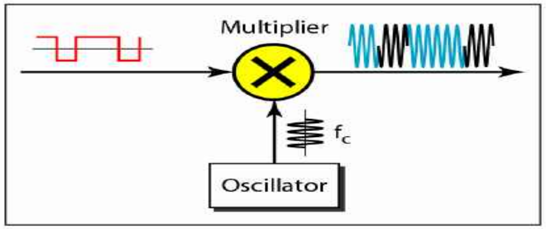
$$s(t) = \begin{cases} A\cos(2\pi f_c t), & \text{binary 1} \\ A\cos(2\pi f_c t + \pi), & \text{binary 0} \end{cases}$$

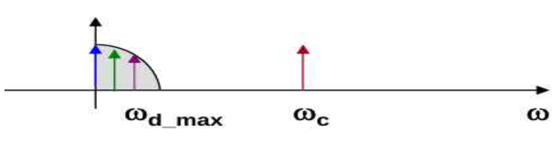
$$s(t) = \begin{cases} A\cos(2\pi f_c t), & \text{binary 1} \\ -A\cos(2\pi f_c t), & \text{binary 0} \end{cases}$$

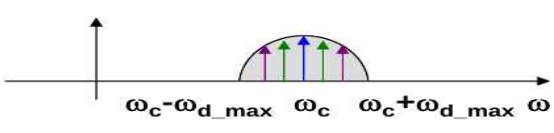


- Demodulation: demodulator must determine the phase of received sinusoid with respect to some reference phase
- Advantage: PSK is less susceptible to errors than ASK, while it
- requires/occupies the same bandwidth as ASK more efficient use of bandwidth (higher data-rate) are possible, compared to FSK !!!
- Disadvantage: more complex signal detection / recovery process, than in ASK and FSK









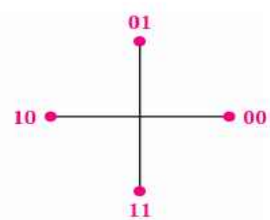
Quadratic Phase Shift Keying

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

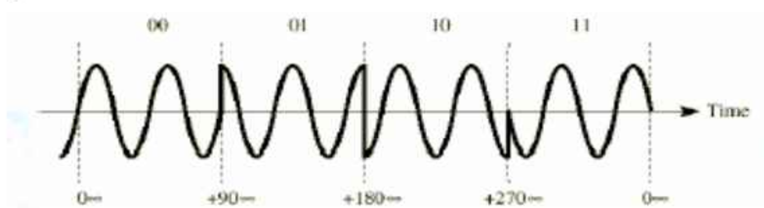
$$
s(t) = \begin{cases} A\cos(2\pi f_c t), & \text{binary } 00 \\ A\cos(2\pi f_c t + \frac{\pi}{2}), & \text{binary } 01 \\ A\cos(2\pi f_c t + \pi), & \text{binary } 10 \\ A\cos(2\pi f_c t + \frac{3\pi}{2}), & \text{binary } 11 \end{cases}
$$

Dibit	Phase
00	0
01	90
10	180
11	270

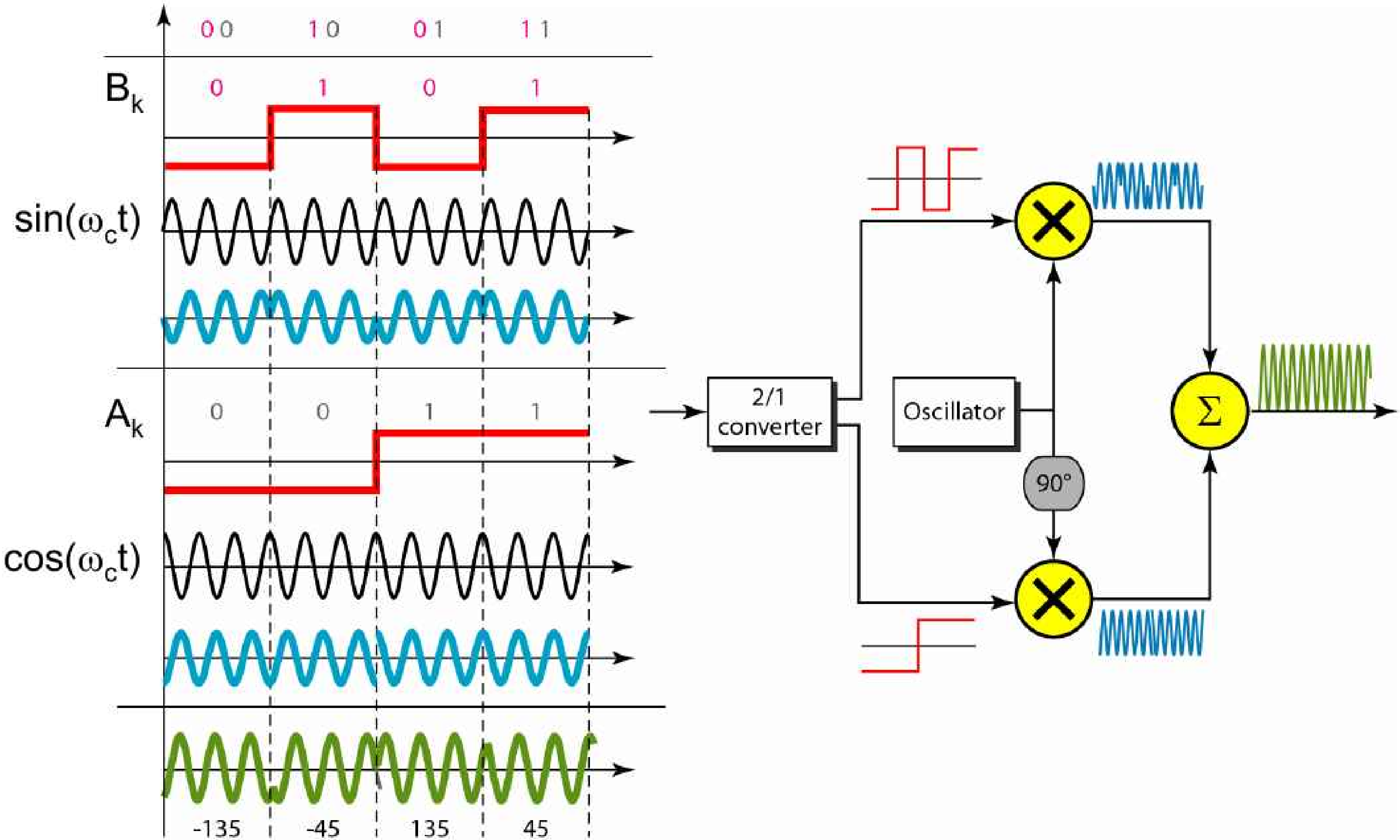
Dibit
(2 bits)



Constellation diagram

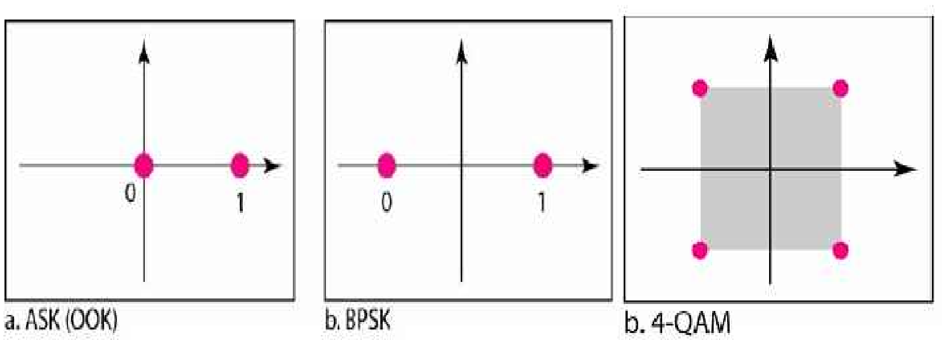


- Advantage: higher data rate than in PSK (2 bits per bit interval), while bandwidth occupancy remains the same
- 4-PSK can easily be extended to 8-PSK, i.e. n-PSK
- However, higher rate PSK schemes are limited by the ability of equipment to distinguish small differences in phase

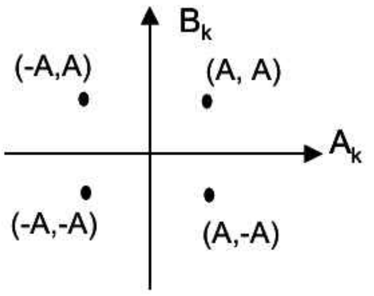


0 0
1 0
0 1
1 1
B k
0
1
0
1
sin(ωct)
A k
0
0
1
1
cos(ωct)
-135
-45
135
45
2/1 converter
Oscillator
90°
Σ

- Constellation Diagram – used to represents possible symbols that may be selected by a given modulation scheme as points in 2-D plane



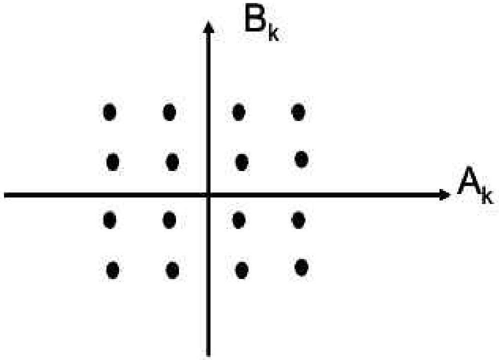
4-level QAM



16-level QAM – the number of bits transmitted per T [sec] interval can be further increased by increasing the number of levels used

- in case of 16-level QAM, A_k and B_k individually can assume 4 different levels: -1, -1/3, 1/3, 1
- data rate: **4 bits/pulse $\Rightarrow$ 4W bits/second**

$$Y(t) = A_k \cos(2\pi f_c t) + B_k \sin(2\pi f_c t) = \left(A_k^{\,2} + B_k^{\,2}\right)^{\frac{1}{2}} \cos(2\pi f_c t + \tan^{-1}\frac{B_k}{A_k})$$



A_k and B_k individually can take on 4 different values; the resultant signal can take on (only) 3 different values!!!

- Propose a sensor system architecture to detect air pollutants in a room.