

# Encoding Digital Data with Analog Signals

## Computer Networks(CS31204)

**Prof. Sudip Misra**

Department of Computer Science and Engineering

Indian Institute of Technology Kharagpur

Email: [smisra@sit.iitkgp.ernet.in](mailto:smisra@sit.iitkgp.ernet.in)

Website: <http://cse.iitkgp.ac.in/~smisra/>

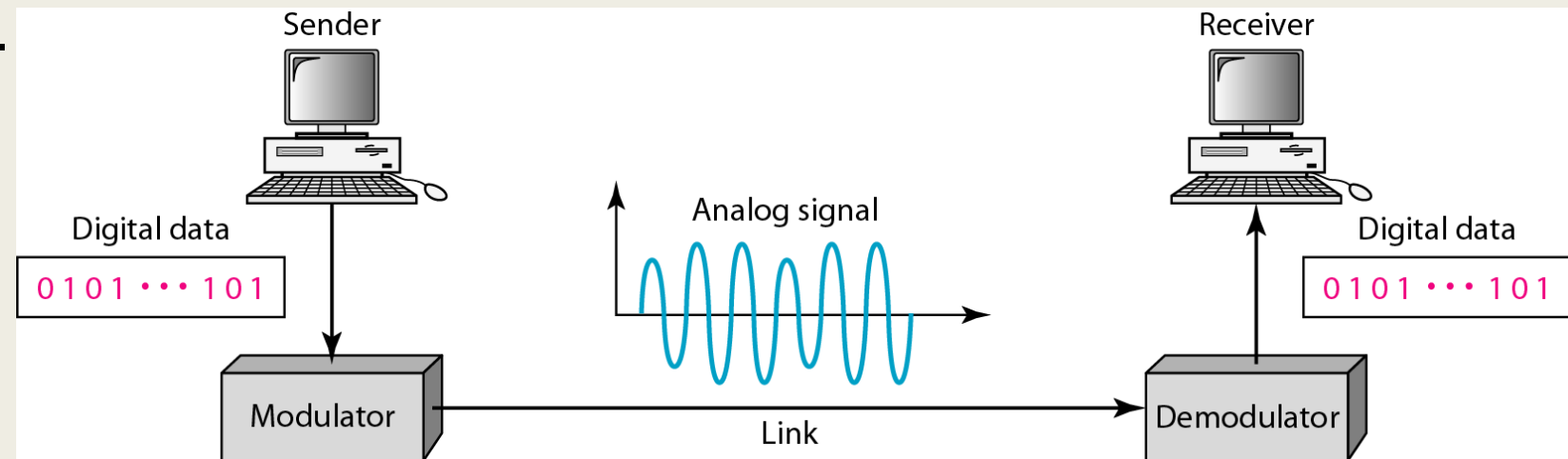
Research Lab: [cse.iitkgp.ac.in/~smisra/swan/](http://cse.iitkgp.ac.in/~smisra/swan/)





# Digital to Analog Conversion

- Digital-to-analog conversion is the process of changing one of the characteristics of an analog signal based on the information in digital data.
- Digital data needs to be carried on an analog signal.
- A carrier signal (frequency  $f_c$ ) performs the function of transporting the digital data in an analog waveform.
- The analog carrier signal is manipulated to uniquely identify the digital data being carried.



Source: B. A. Forouzan, "Data Communications and Networking," McGraw-Hill Forouzan Networking Series, 5E.

# Cont...

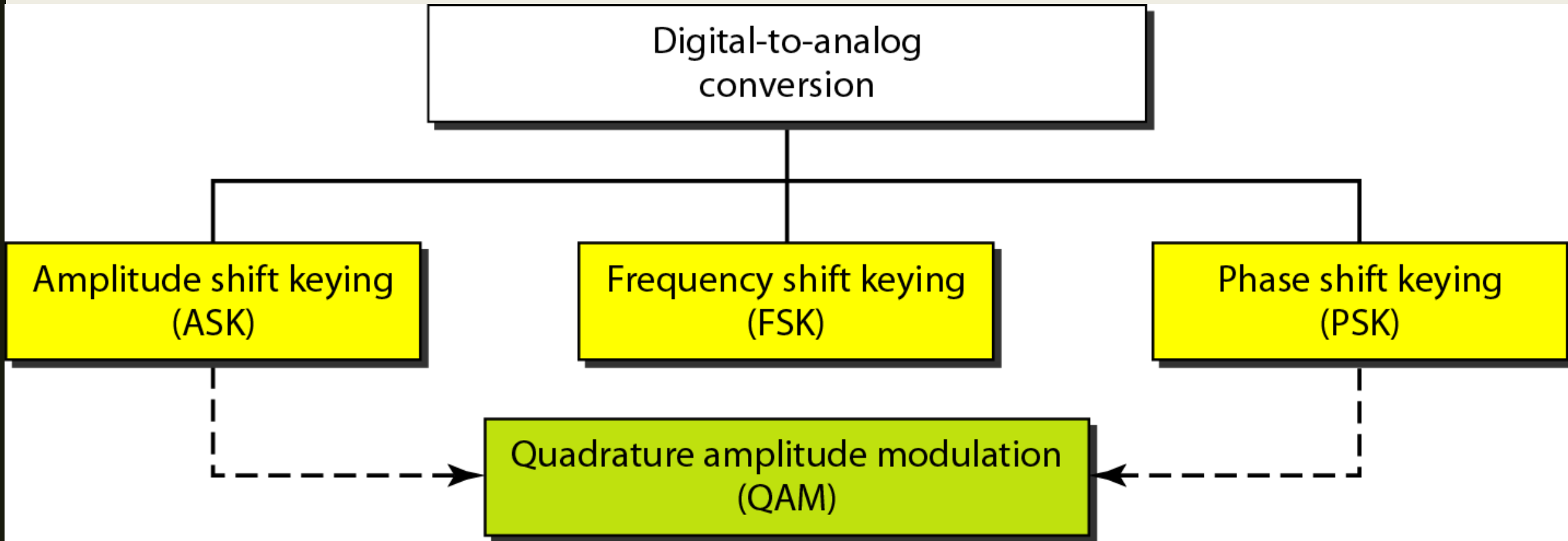


- Bit rate,  $N$ , is the number of bits per second (bps).
- Baud rate is the number of signal elements per second (bauds).
- In the analog transmission of digital data, the signal or baud rate is less than or equal to the bit rate.

$$S = N \times 1/r \text{ bauds}$$

Where  $r$  is the number of data bits per signal element.

# Types



Source: B. A. Forouzan, "Data Communications and Networking," McGraw-Hill Forouzan Networking Series, 5E.

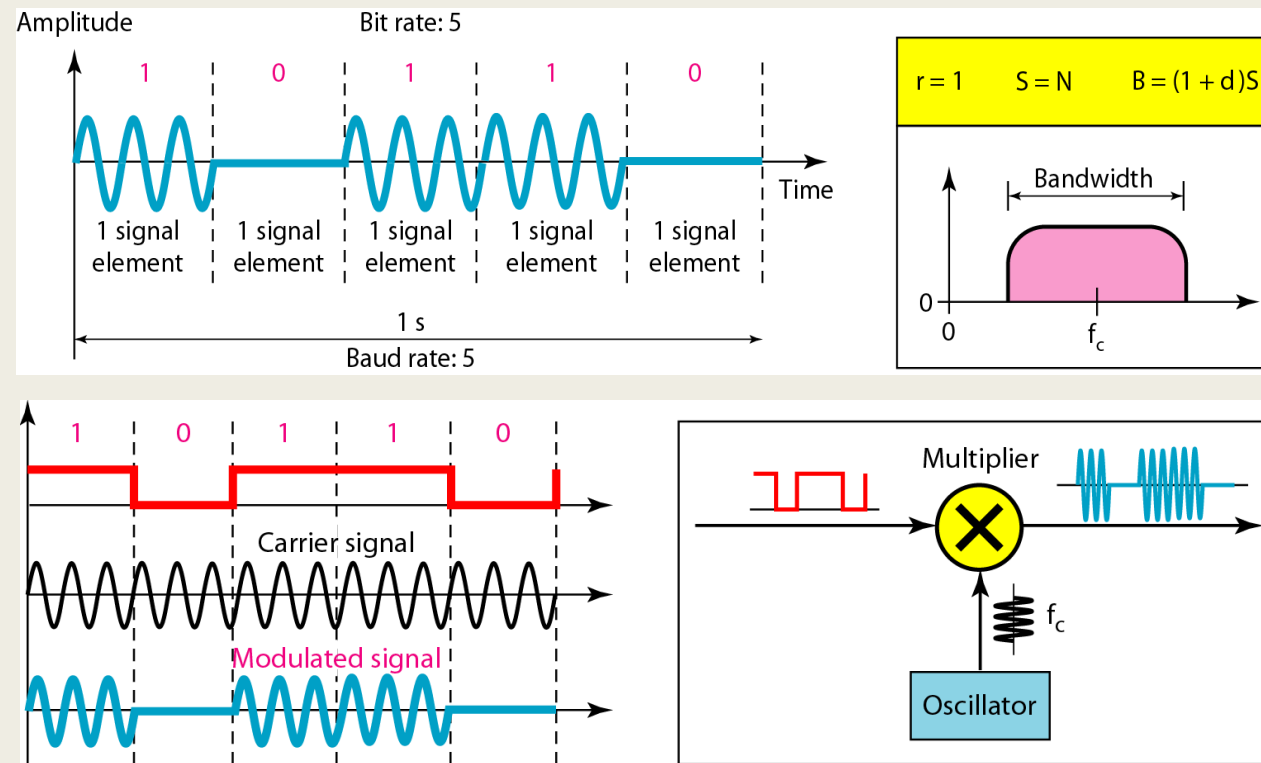


# Amplitude Shift Keying

- ASK is implemented by changing the amplitude of a carrier signal to reflect amplitude levels in the digital signal.
- For example: a digital “1” could not affect the signal, whereas a digital “0” would, by making it zero.
- The line encoding will determine the values of the analog waveform to reflect the digital data being carried.

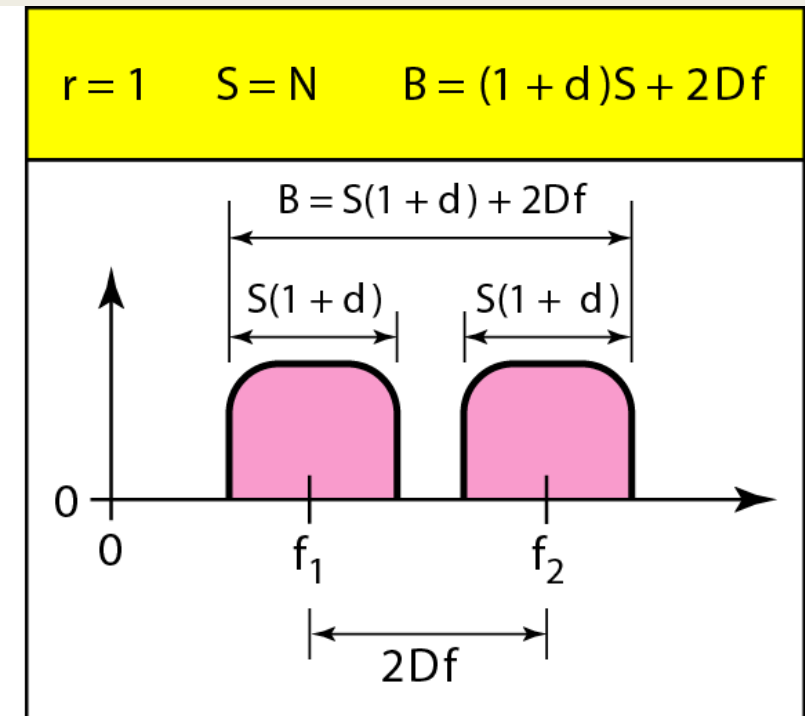
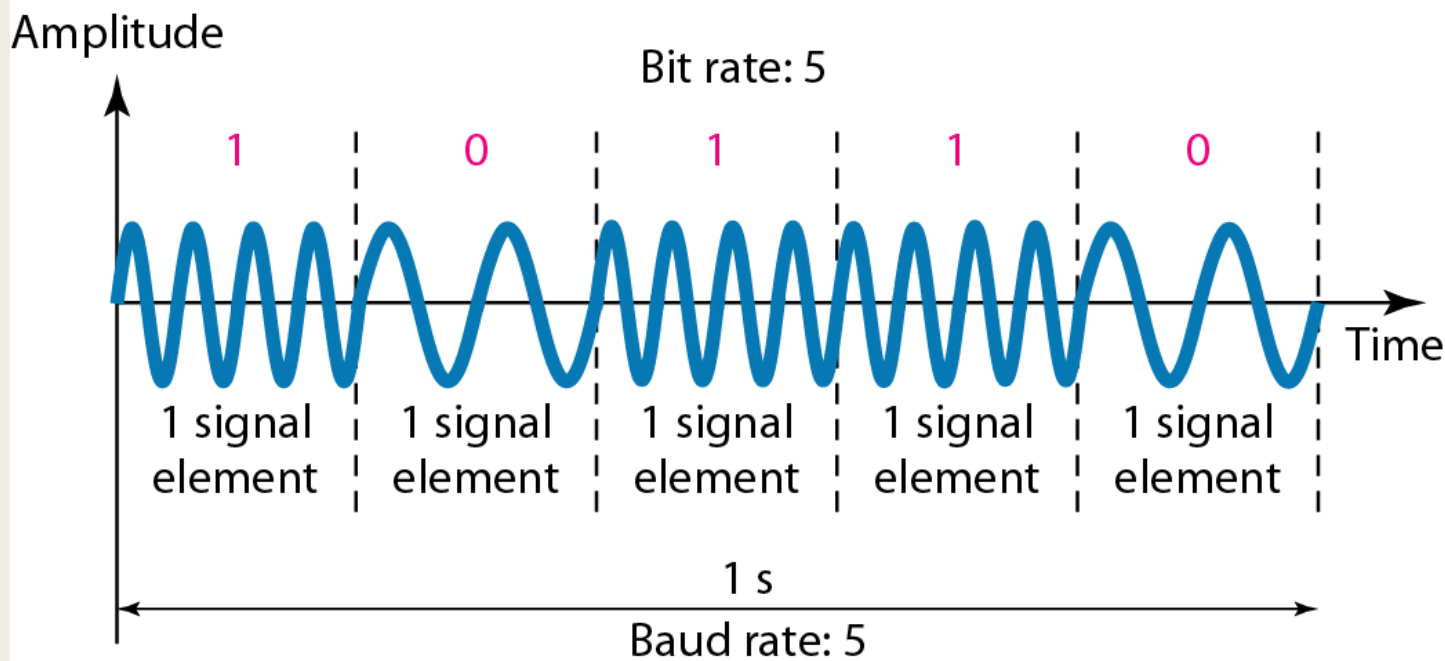
# Binary Amplitude Shift Keying

- Normally implemented using only two levels.
- Referred to as binary amplitude shift keying or *on-off keying* (OOK).
- The peak amplitude of one signal level is 0; the other is the same as the amplitude of the carrier frequency.



# Frequency Shift Keying (FSK)

- The digital data stream changes the frequency of the carrier signal,  $f_c$ .



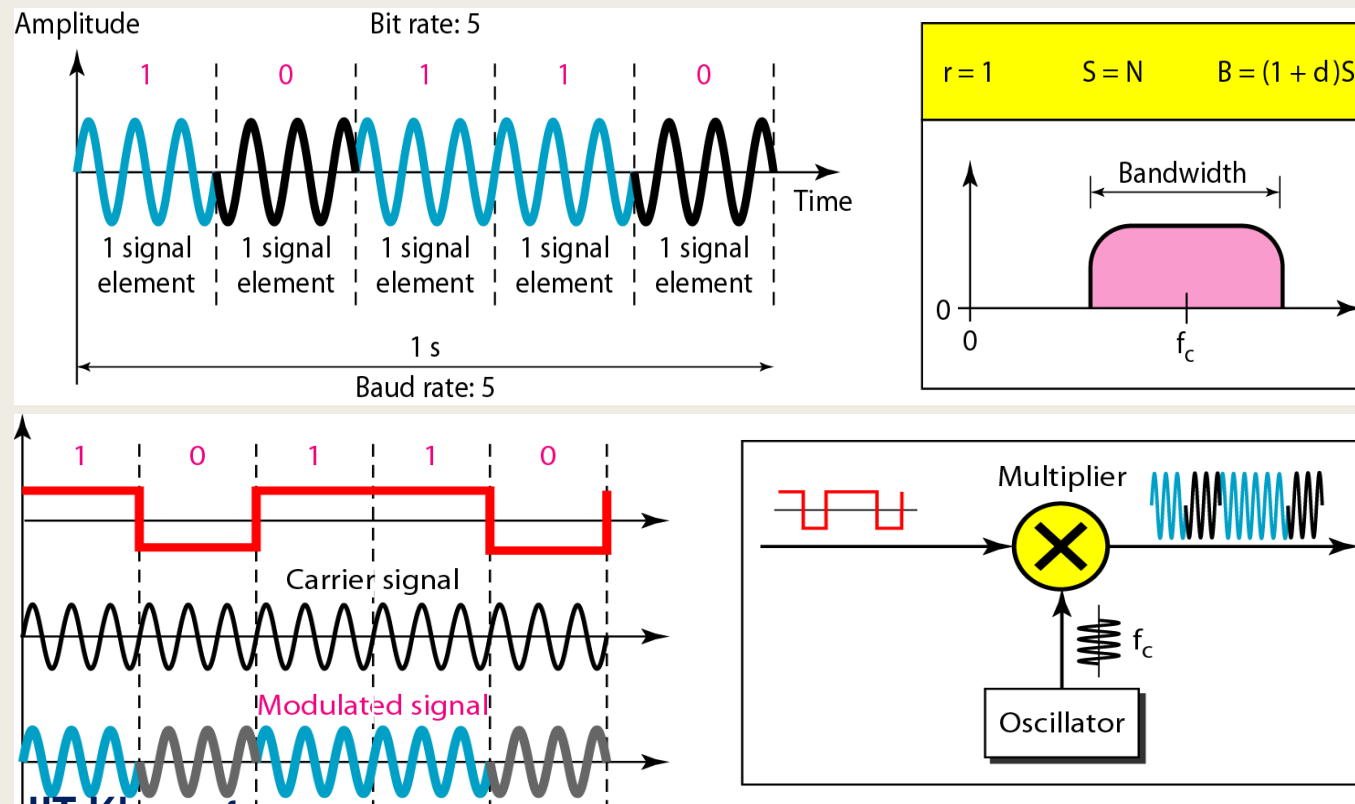


# Coherent and Non Coherent (FSK)

- In a non-coherent FSK scheme, when we change from one frequency to the other, we do not adhere to the current phase of the signal.
- In coherent FSK, the switch from one frequency signal to the other only occurs at the same phase in the signal.

# Phase Shift Keying

- We vary the phase shift of the carrier signal to represent digital data.
- PSK is much more robust than ASK as it is not that vulnerable to noise, which changes amplitude of the signal.



Source: B. A. Forouzan, "Data Communications and Networking," McGraw-Hill Forouzan Networking Series, 5E.

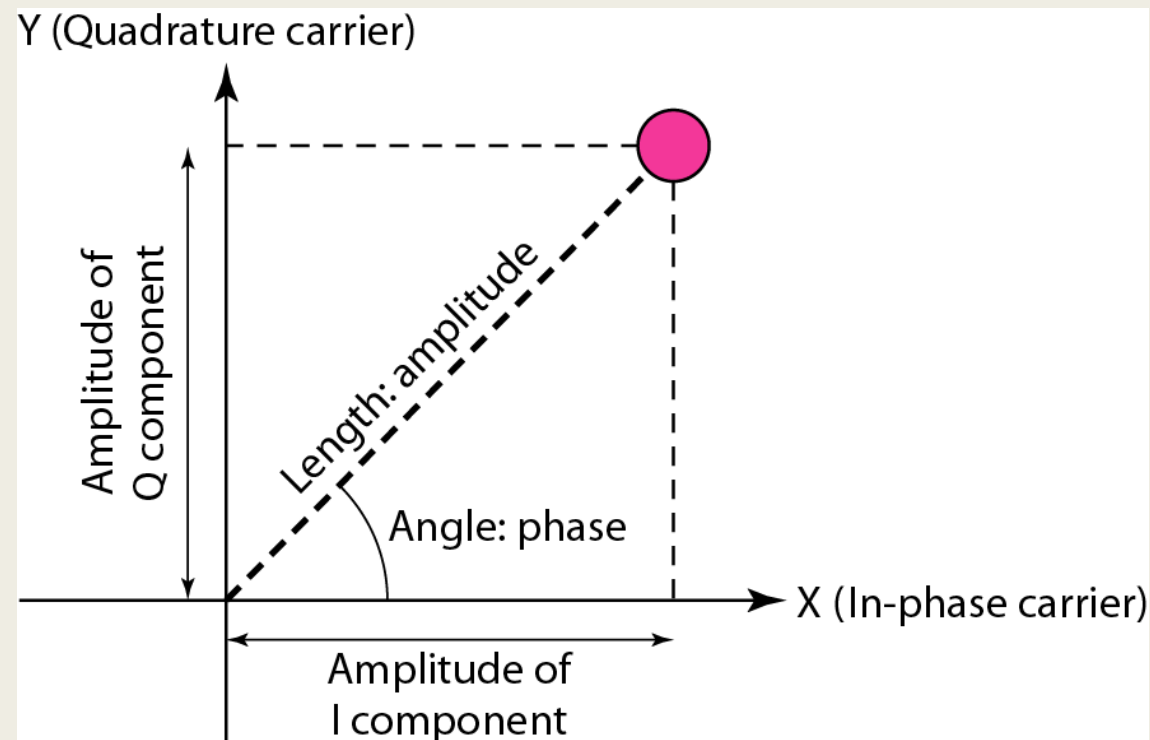
# Binary Phase Shift Keying



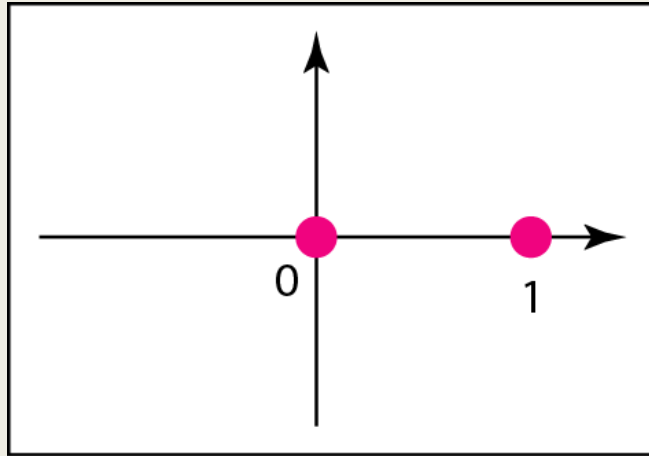
- Binary Phase-shift keying (BPSK) is a digital modulation scheme that conveys data by changing, or modulating, two different phases of a reference signal (the carrier wave).
- This gives maximum phase-separation between adjacent points and thus the best immunity to corruption.
- Used in various wireless standards such as CDMA, WiMAX (16d, 16e), WLAN 11a, 11b, 11g, 11n, Satellite, DVB, Cable modem etc.

# Constellation Diagrams

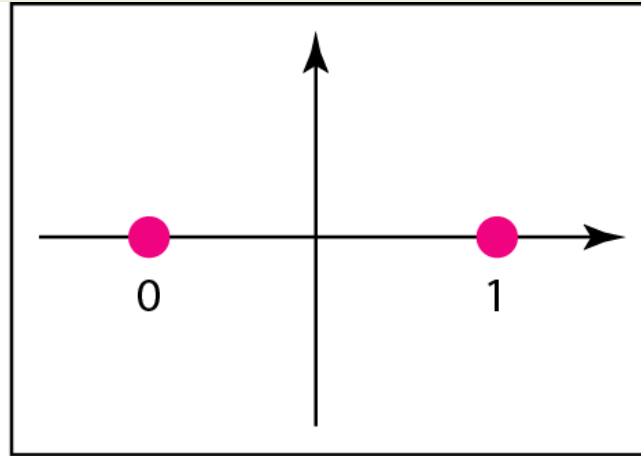
- A constellation diagram helps us to define the amplitude and phase of a signal when we are using two carriers, one in quadrature of the other.
- The X-axis represents the in-phase carrier and the Y-axis represents quadrature carrier.



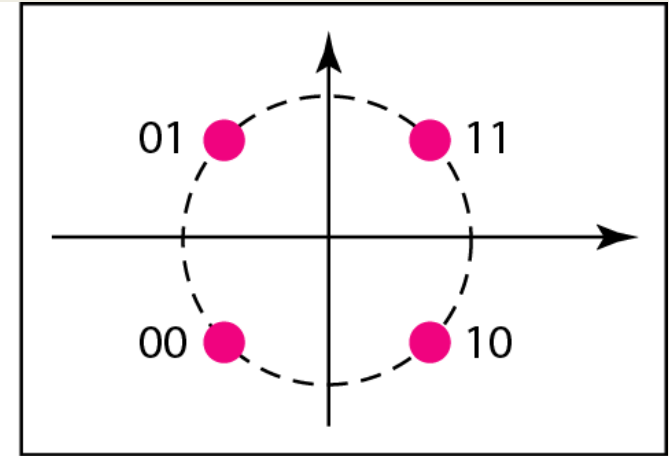
# Cont...



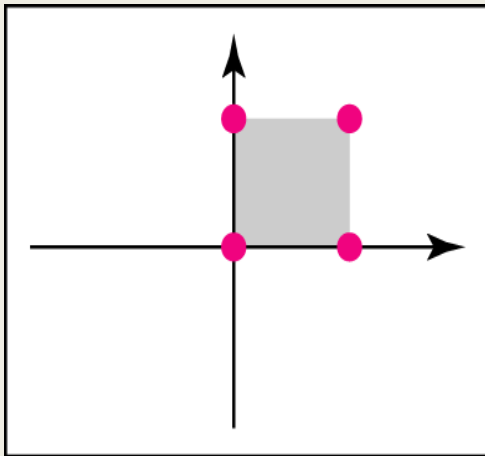
a. ASK (OOK)



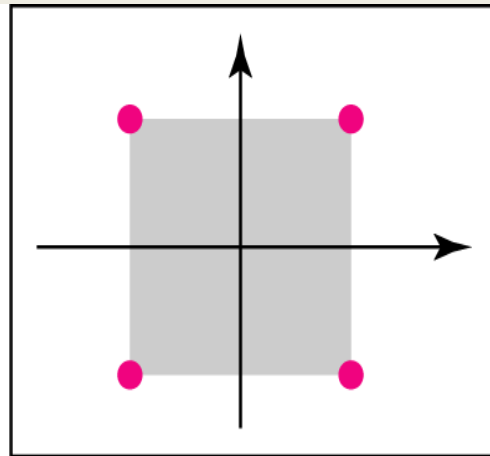
b. BPSK



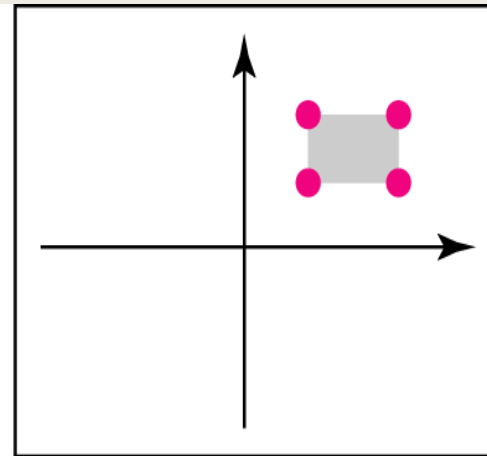
c. QPSK



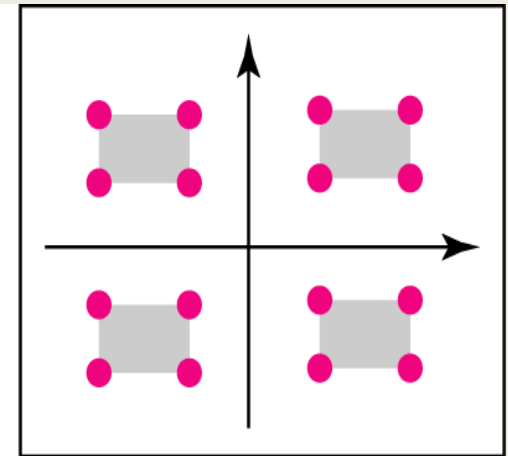
a. 4-QAM



b. 4-QAM



c. 4-QAM

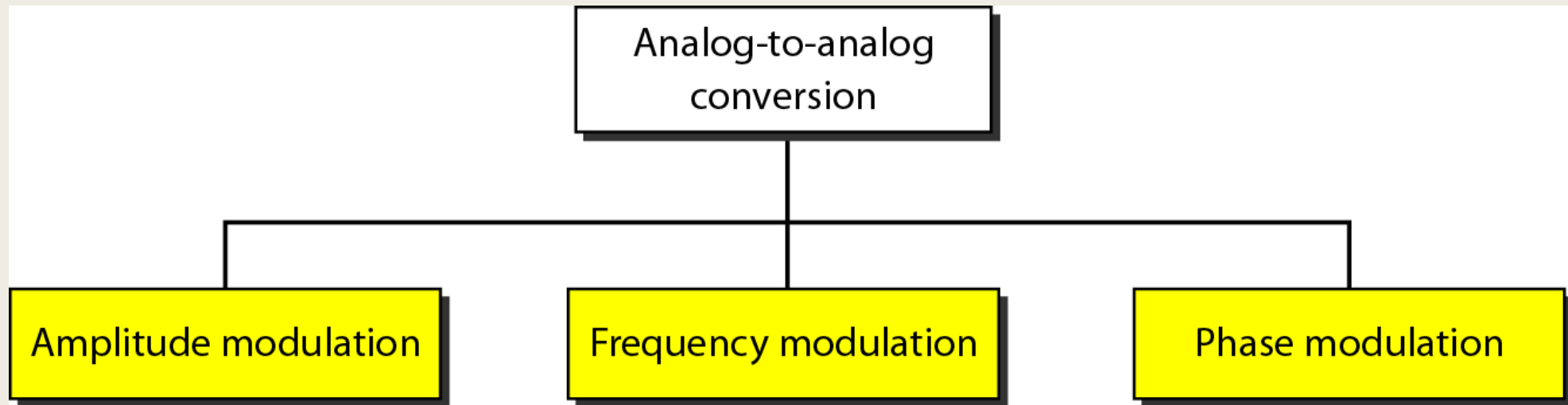


d. 16-QAM

# Analog to Analog Conversion

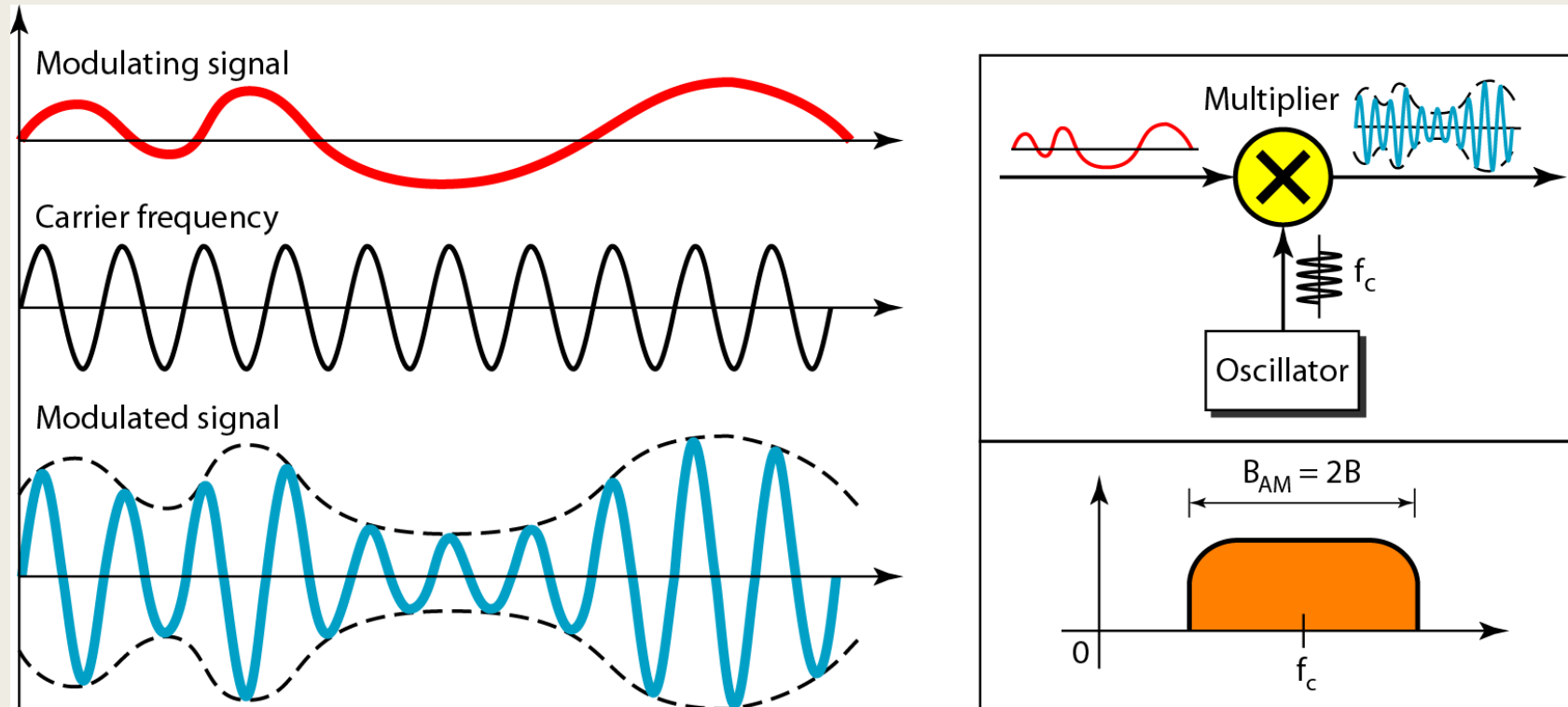


- Analog-to-analog conversion is the representation of analog information by an analog signal.
- One may ask why we need to modulate an analog signal; it is already analog.
- Modulation is needed if the medium is bandpass in nature or if only a bandpass channel is available to us.



# Amplitude Modulation

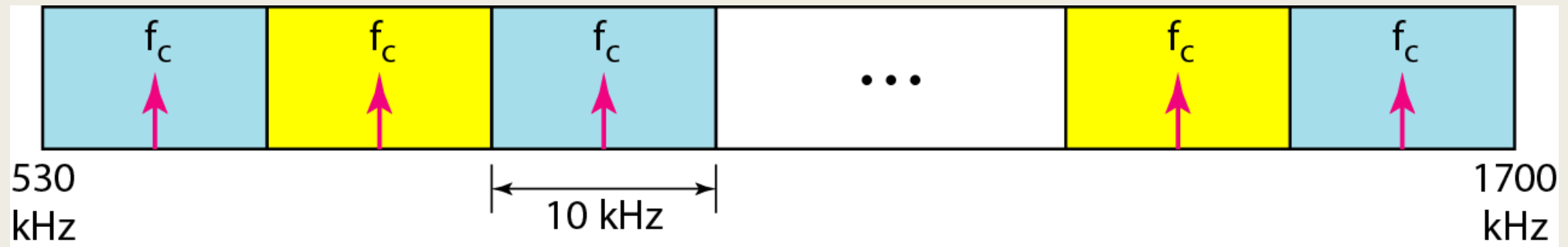
- A carrier signal is modulated only in amplitude value.
- The modulating signal is the envelope of the carrier.
- The required bandwidth is  $2B$ , where  $B$  is the bandwidth of the modulating signal.



# Cont...



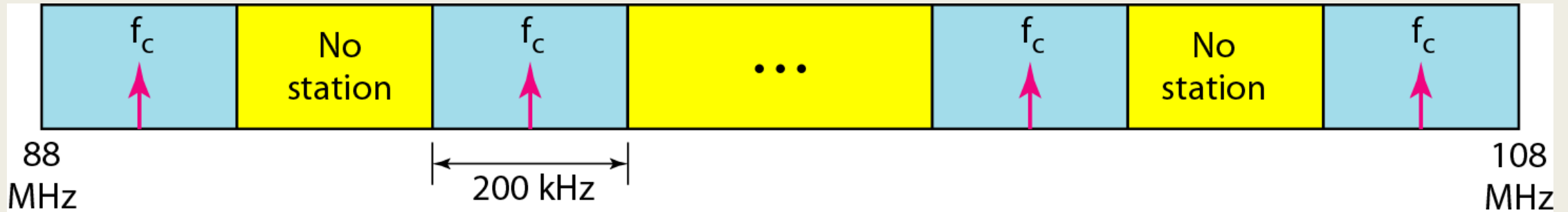
- Since on both sides of the carrier frequency  $f_c$ , the spectrum is identical, we can discard one half, thus requiring a smaller bandwidth for transmission.
- The band allocation is as:



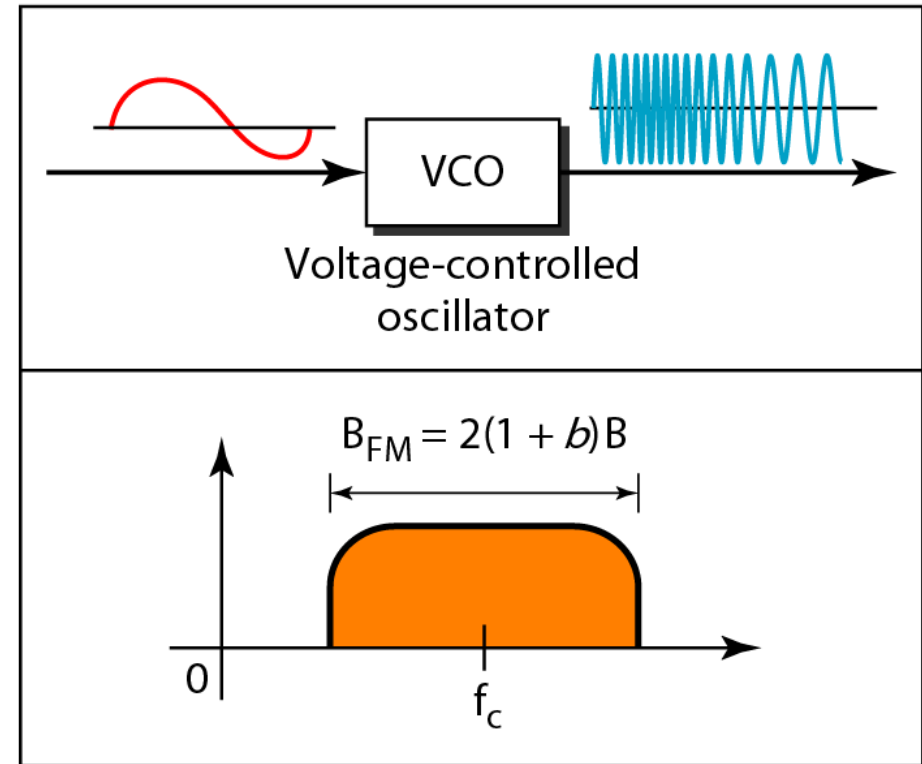
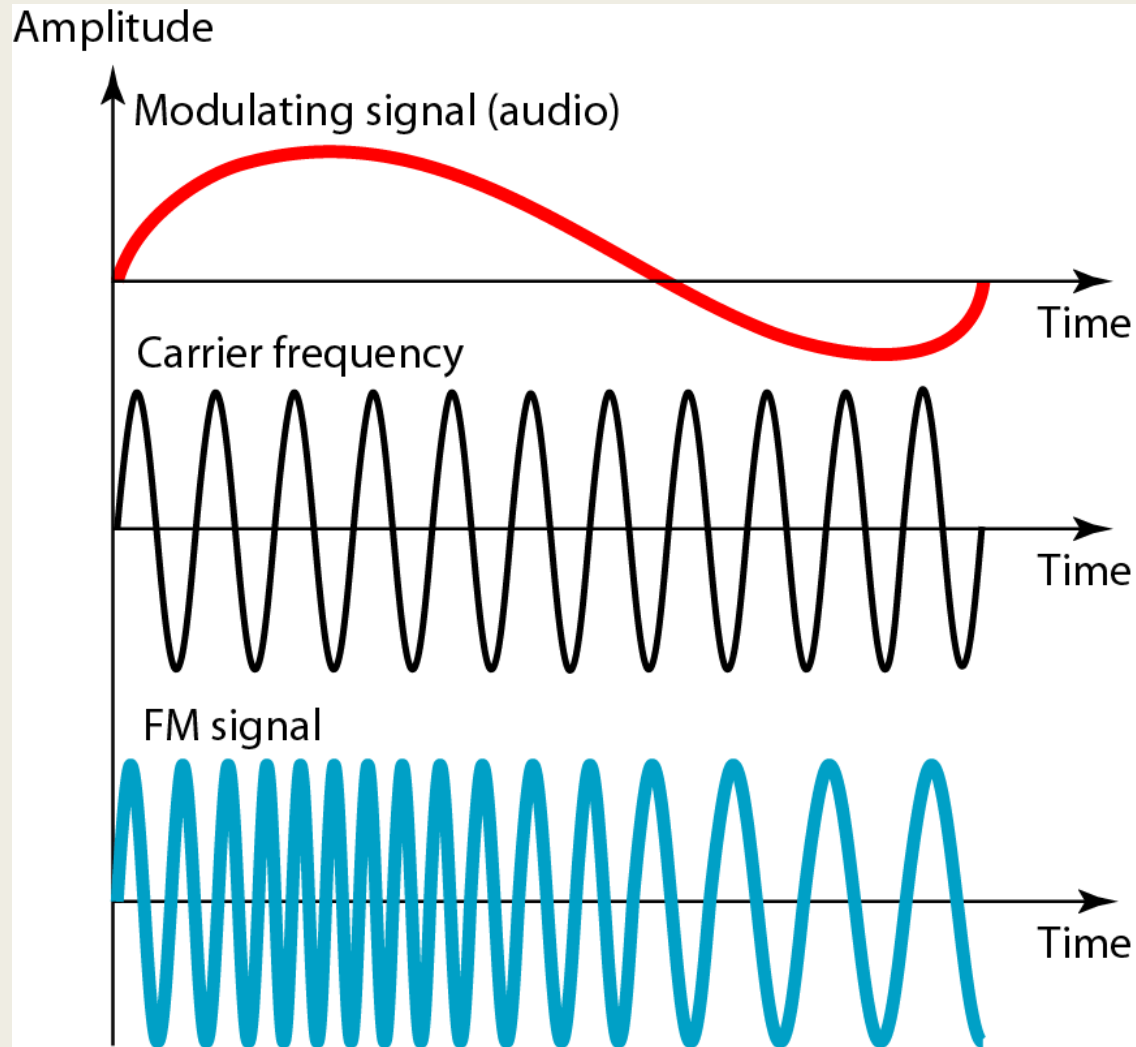


# Frequency Modulation

- The modulating signal changes the freq.  $f_c$  of the carrier signal.
- The bandwidth for FM is high.
- It is approx. 10x the signal frequency.
- The FM band allocation is:

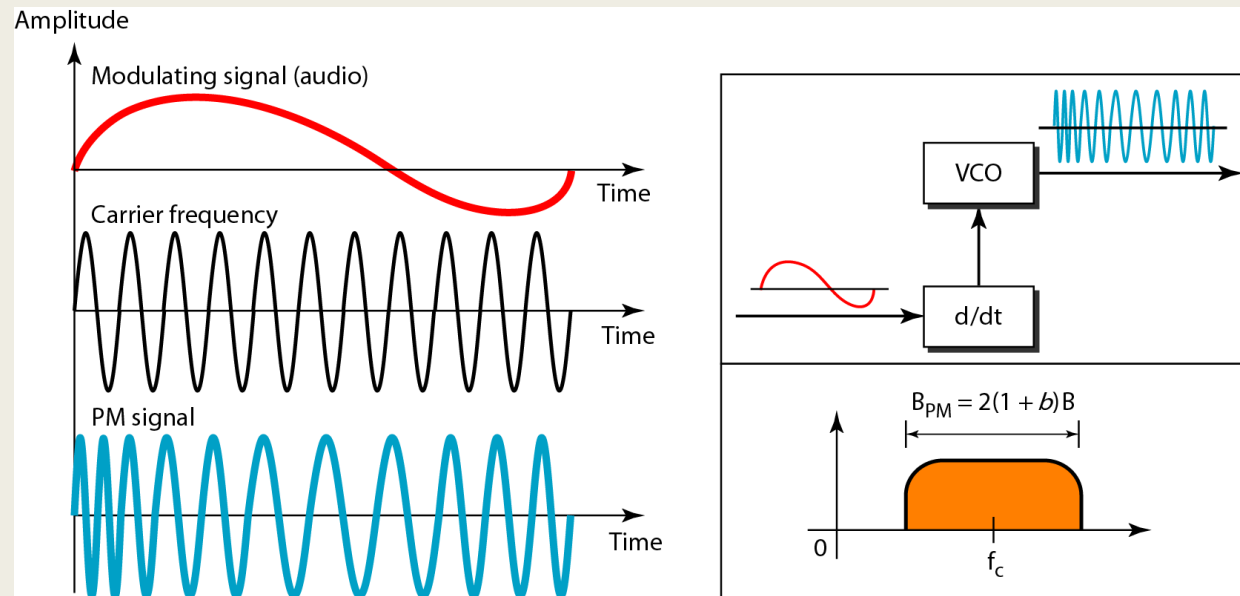


# Cont...



# Phase Modulation

- The modulating signal only changes the phase of the carrier signal.
- The phase change manifests itself as a frequency change but the instantaneous frequency change is proportional to the derivative of the amplitude.
- The bandwidth is higher than for AM.



Source: B. A. Forouzan, "Data Communications and Networking," McGraw-Hill Forouzan Networking Series, 5E.



**Thank You!!!**