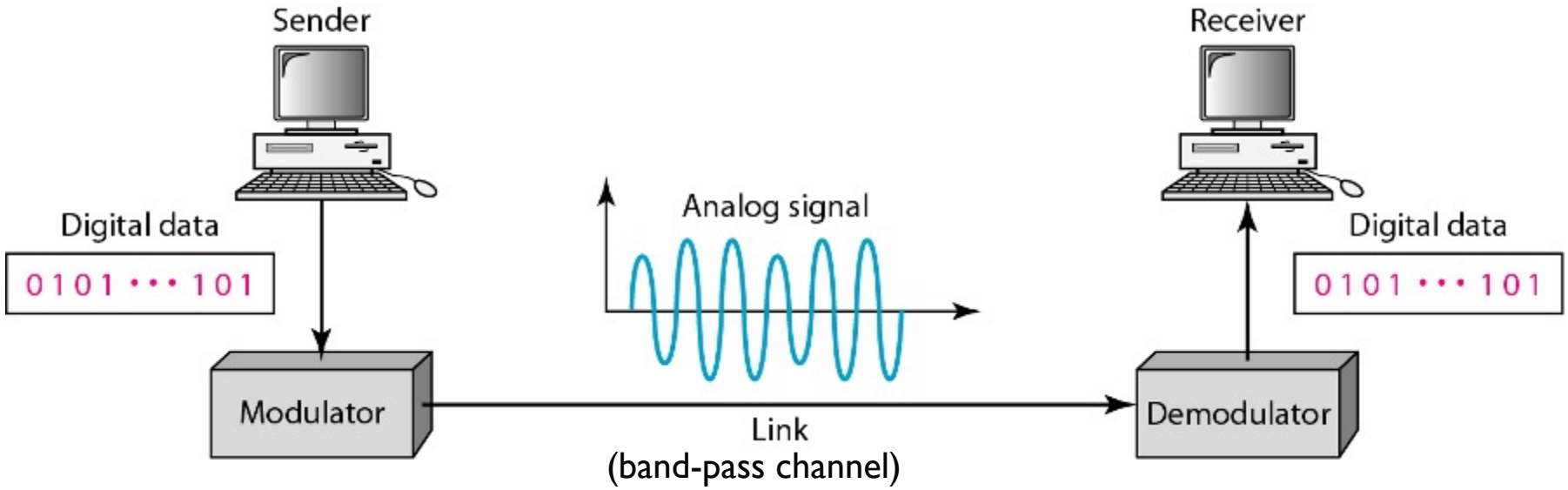
CSE 365: Communication Engineering

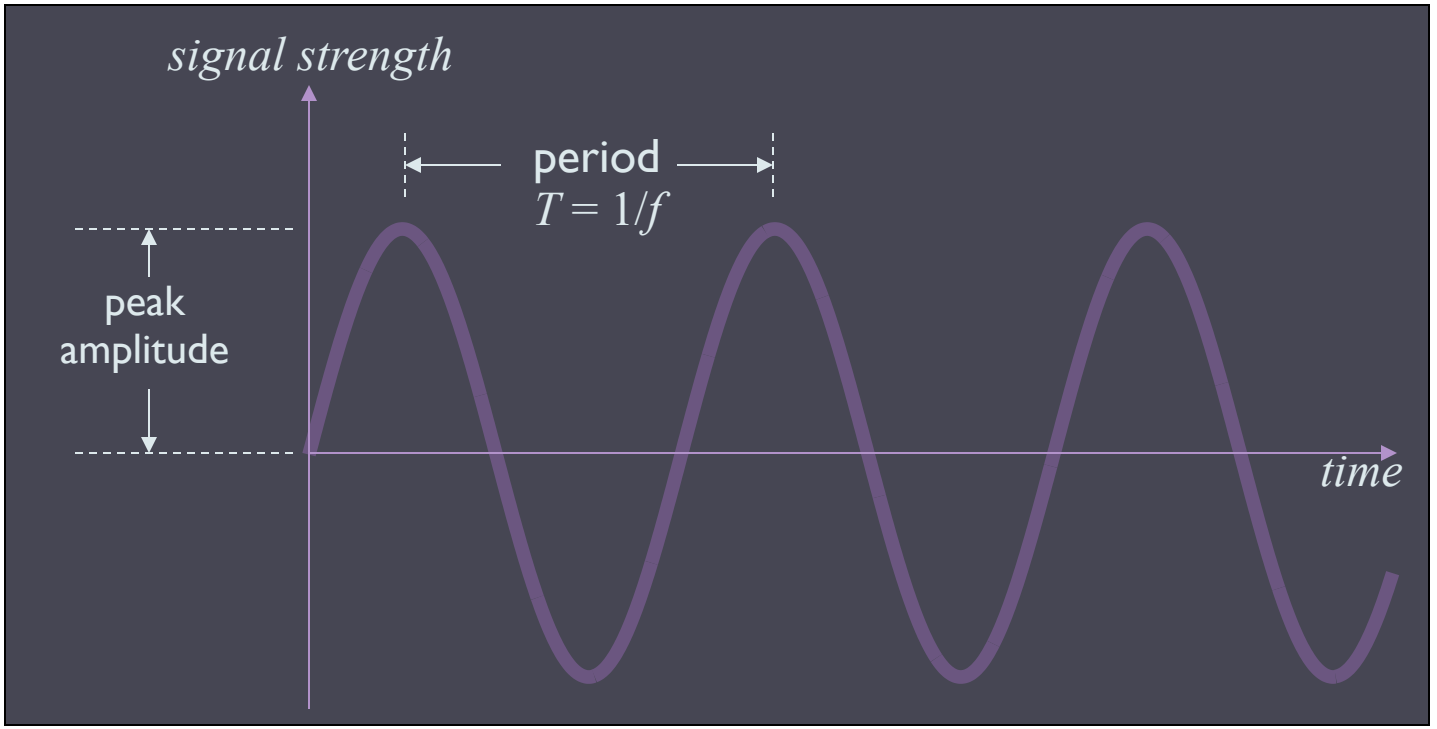
Chapter 5: Analog Transmission

Digital-to-Analog Conversion

- Converting digital data to an analog signal
- Required to send digital data over a band-pass channel
  - Also known as *modulation*

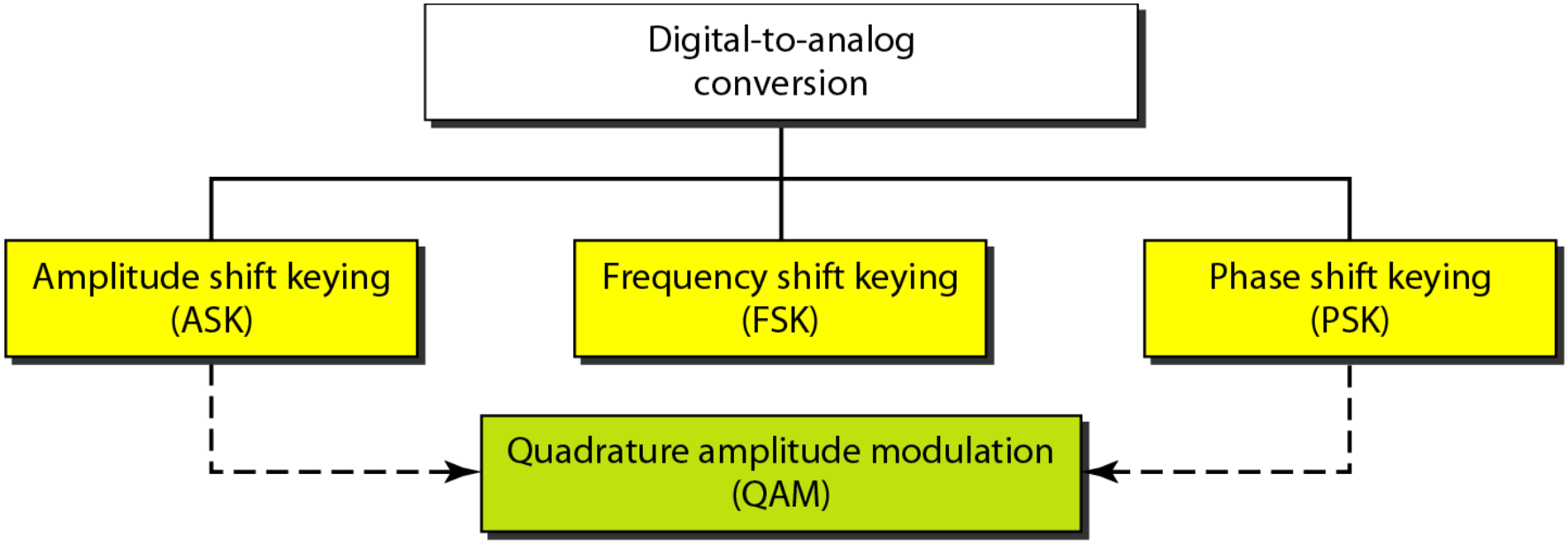


Sine Waves Revisited



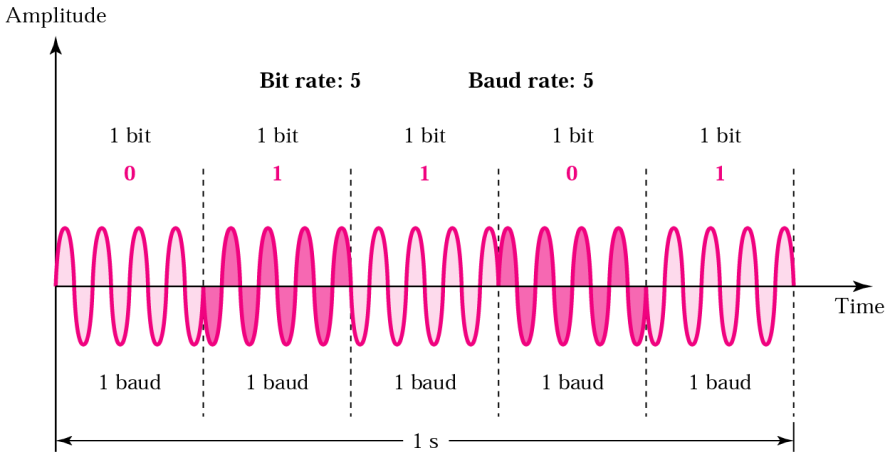
- By changing one characteristic of a simple electric signal, we can use it to represent digital data.

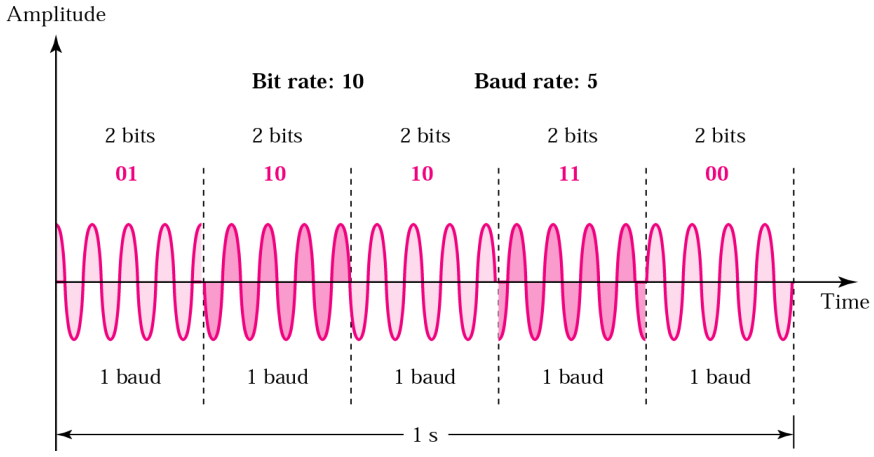
Conversion Techniques



Bit Rate vs. Baud Rate

- *Bit rate* → the number of bits per second
- *Baud rate* → the number of signal elements per second.





- In the analog transmission of digital data, the baud rate is less than or equal to the bit rate

Example 5.2

An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many different signal elements do we need?

Solution

In this example, S = 1000, N = 8000, and r and L are unknown. We find first the value of r and then the value of L.

$$S = N \times \frac{1}{r} \rightarrow r = \frac{N}{S} = \frac{8000}{1000} = 8 \text{ bits/baud}$$

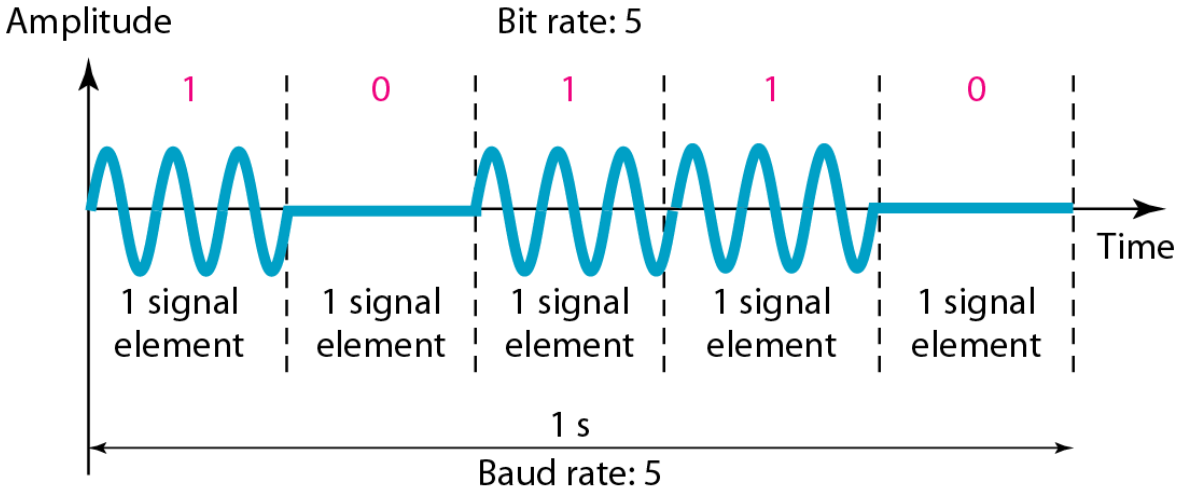
$$r = \log_2 L \rightarrow L = 2^r = 2^8 = 256$$

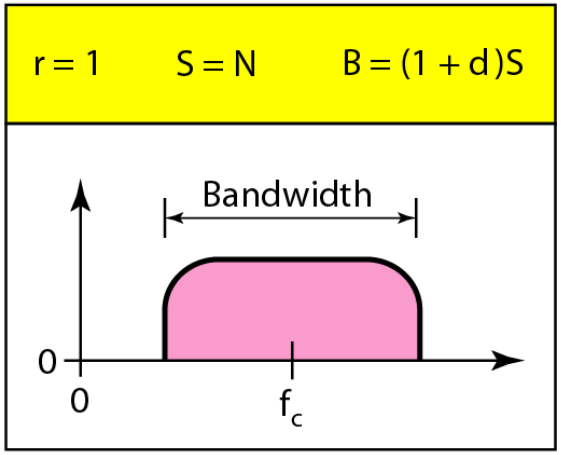
Carrier Signals

- In analog Transmission, the sending device produces a high-frequency signal that acts as a base for the information signal, which is known as Carrier Signal or Carrier Frequency.
- The receiving device is tuned to the frequency of the carrier signal that it expects from the sender.
- Digital information then changes the carrier signal by modifying one or more of its characteristics (amplitude, frequency or phase). This is called *Modulation* or *Shift-Keying*.

Amplitude Shift Keying (ASK)

- In ASK, the amplitude of the carrier signal is varied.
- ASK is normally implemented using only two levels and known as Binary ASK or On-Off Keying (OOK)

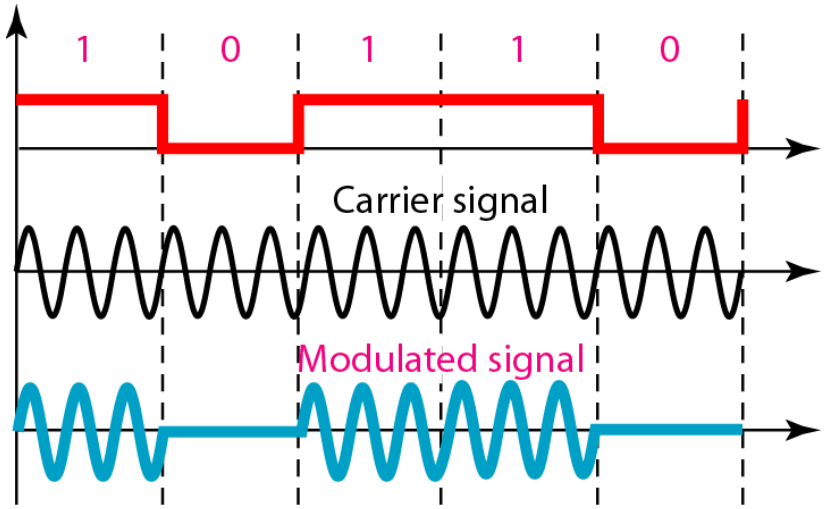


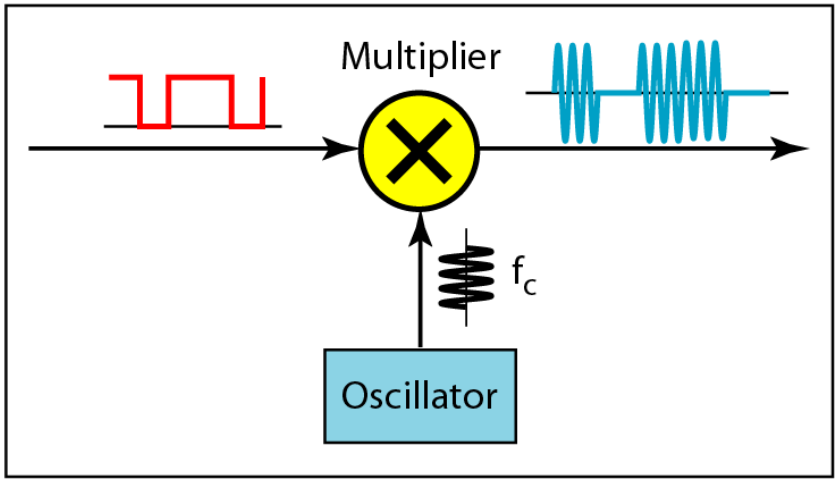


f_c – Carrier frequency

$0 < d < 1$; where d depends on the modulation and filtering process

Implementation of Binary ASK





Example 5.3

We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What are the carrier frequency and the bit rate if we modulated our data by using ASK with d = 1?

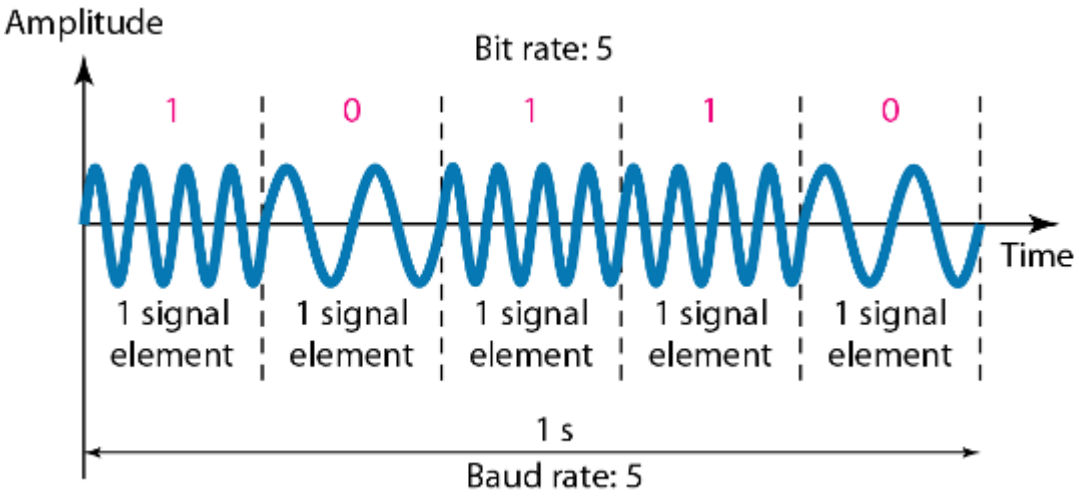
Solution

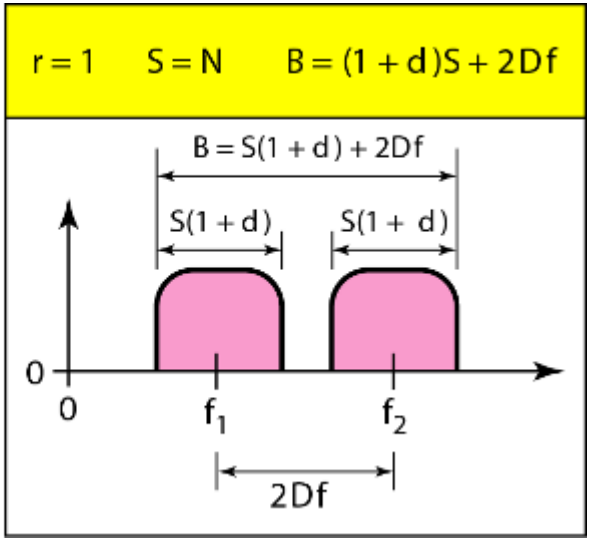
The middle of the bandwidth is located at 250 kHz. This means that our carrier frequency can be at f_c = 250 kHz. We can use the formula for bandwidth to find the bit rate (with d = 1 and r = 1).

$$B = (1+d) \times S = 2 \times N \times \frac{1}{r} = 2 \times N = 100 \text{ kHz} \quad \rightarrow \quad N = 50 \text{ kbps}$$

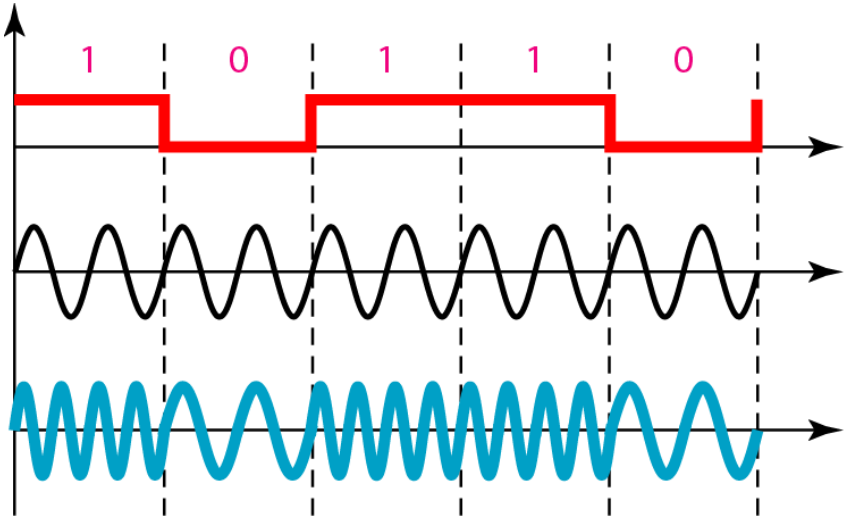
Frequency Shift Keying

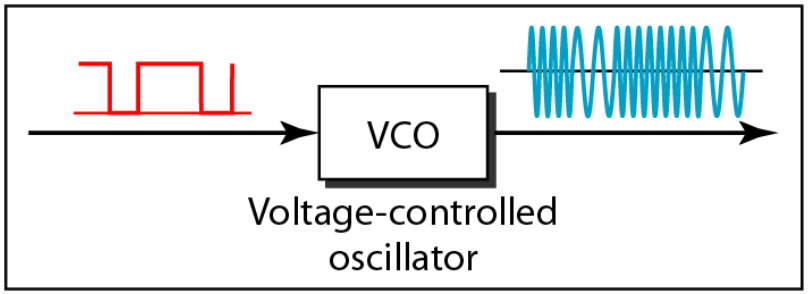
- In FSK, the frequency of the carrier signal is varied.
- Binary FSK (BFSK) considers two carrier frequencies, f_1 and f_2.
- We use the first carrier if the data element is 0 and the second if the data element is 1.





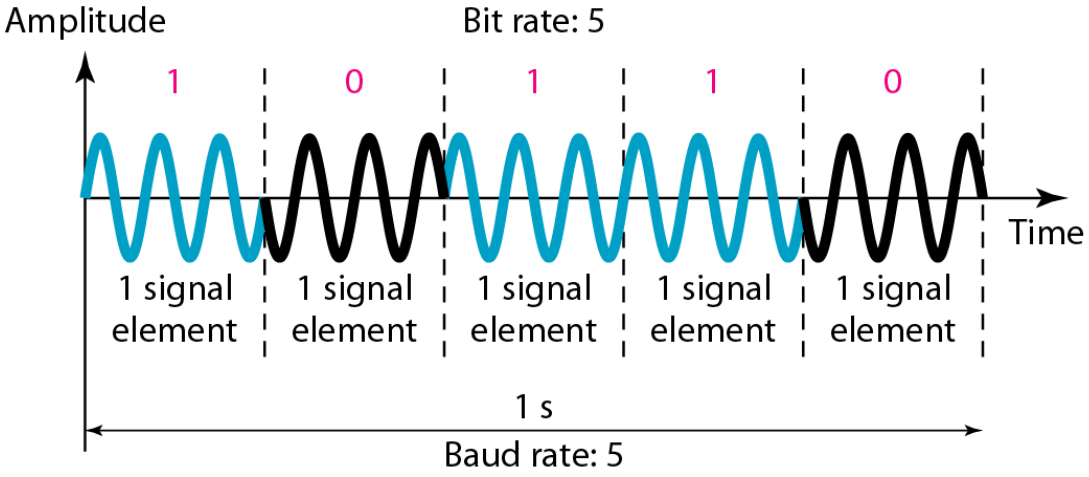
Implementation of Binary FSK

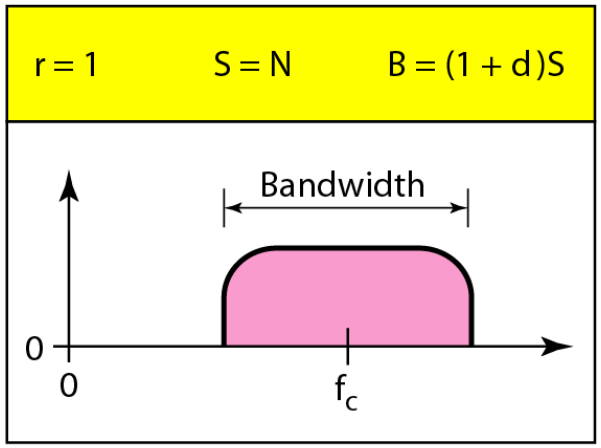




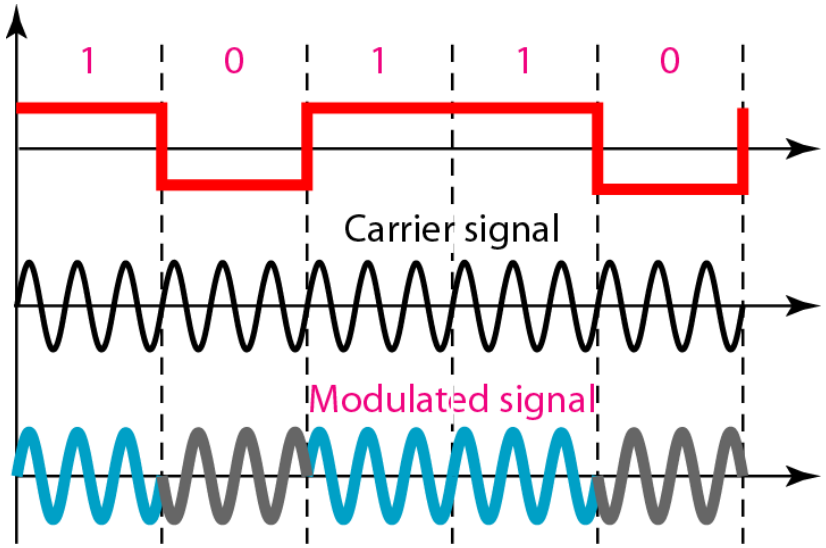
Phase Shift Keying

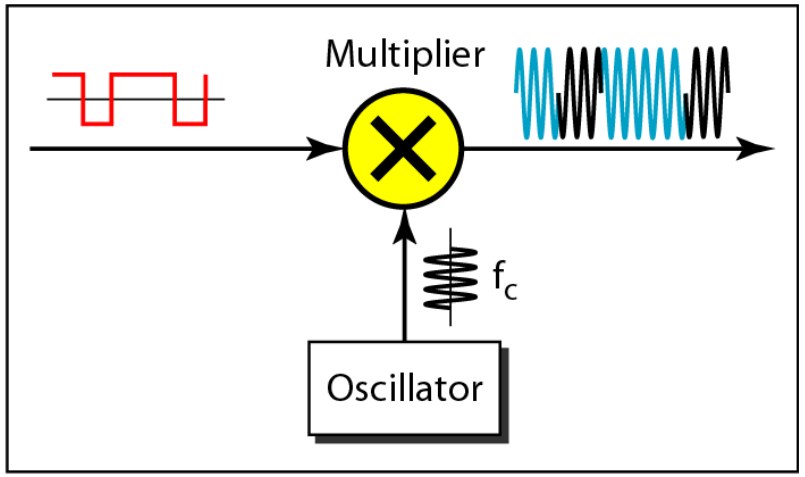
- In PSK, the phase of the carrier signal is varied.
- The simplest PSK is Binary PSK.





Implementation of Binary PSK



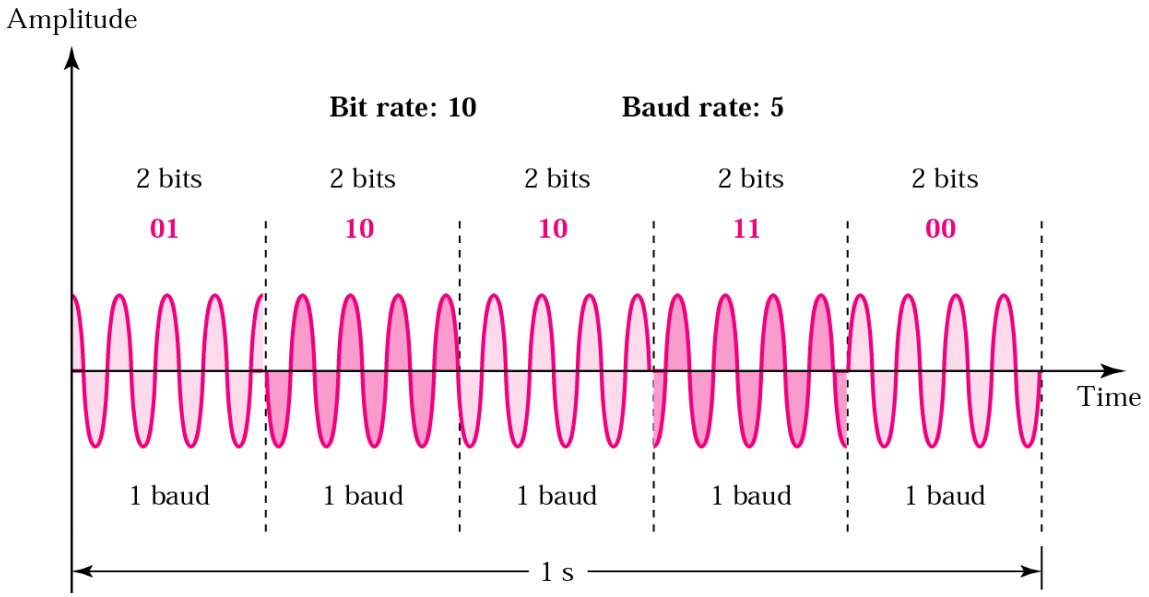


Phase Shift Keying

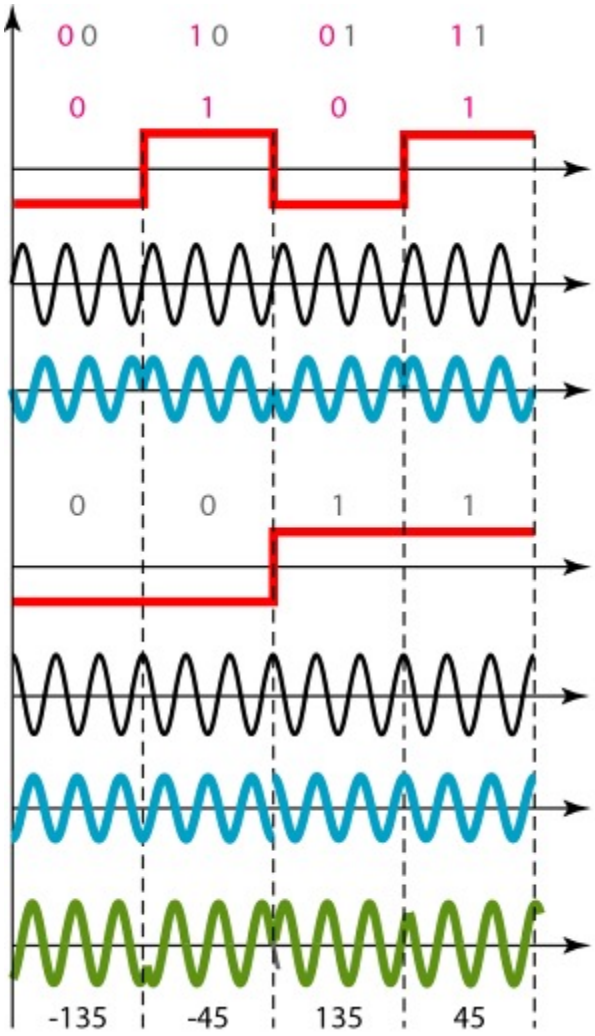
- PSK is much more robust than ASK as it is not that vulnerable to noise, which changes amplitude of the signal.
- PSK is also superior to FSK because it does not need two carrier signals.
- However, PSK needs more sophisticated hardware to be able to distinguish between phases.

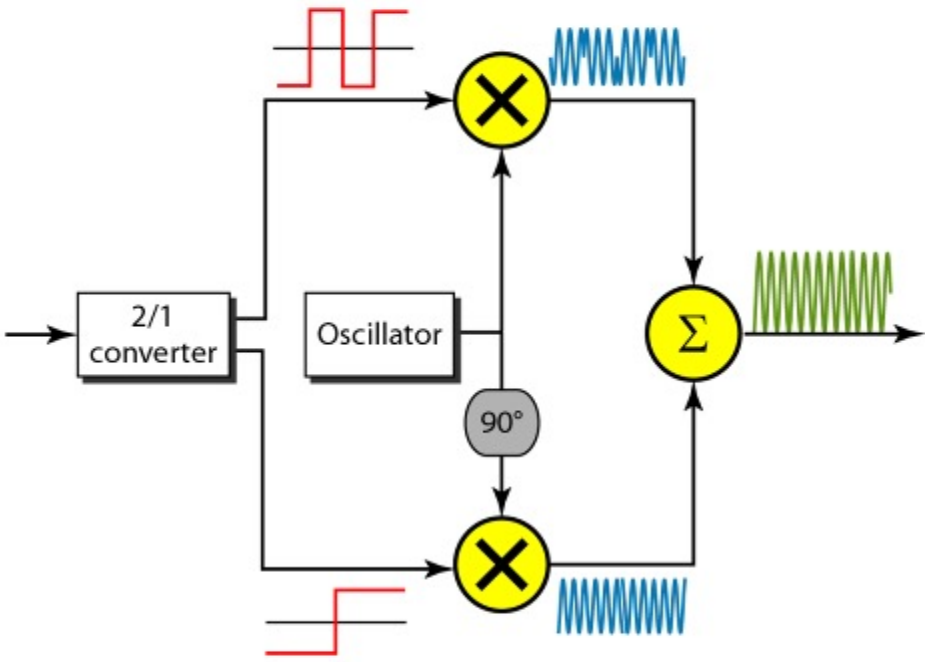
Quadrature PSK

- Each signal element carries 2 bits



Implementation of QPSK





Example 5.7

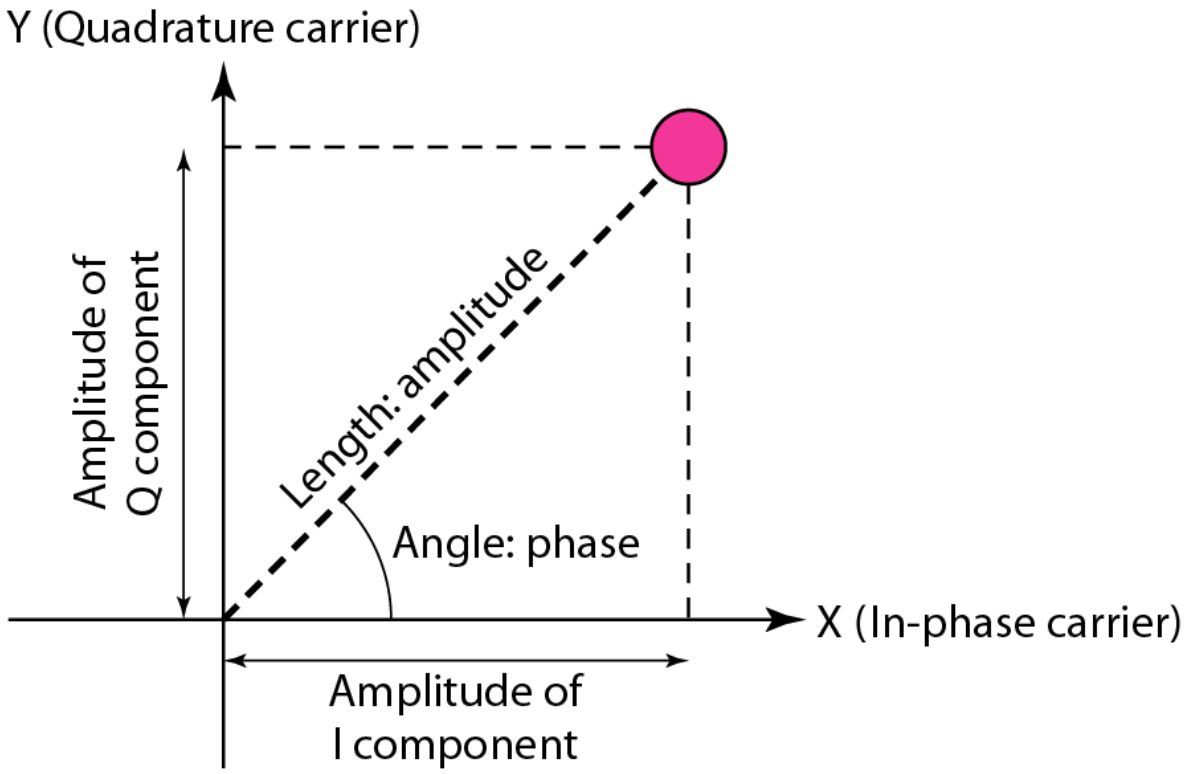
Find the bandwidth for a signal transmitting at 12 Mbps for QPSK. The value of d = 0.

Solution

For QPSK, 2 bits is carried by one signal element. This means that r = 2. So the signal rate (baud rate) is S = N × (1/r) = 6 Mbaud. With a value of d = 0, we have B = S = 6 MHz.

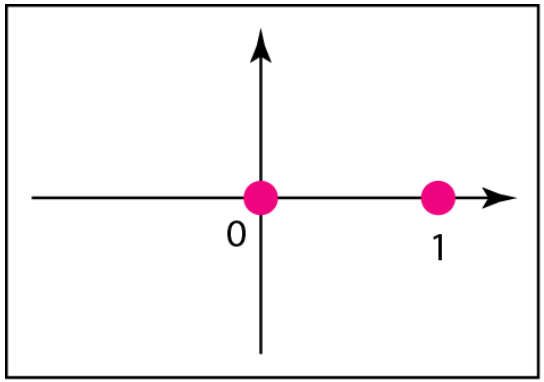
Constellation Diagrams

- A constellation diagram helps define the amplitude and phase of a signal element

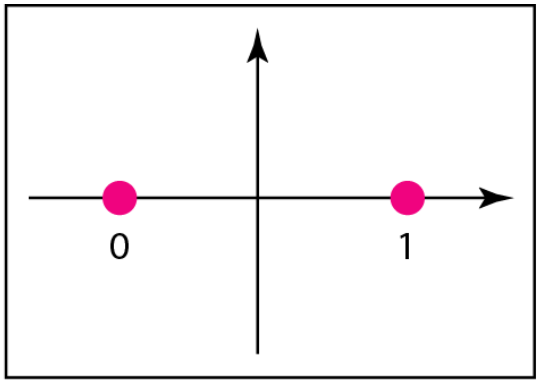


Example 5.8

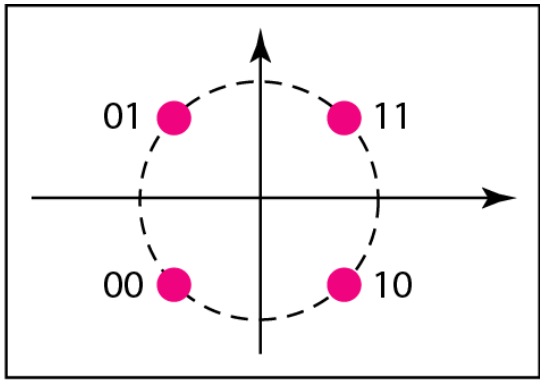
- Show the constellation diagrams for OOK, BPSK, and QPSK modulations



a. ASK (OOK)



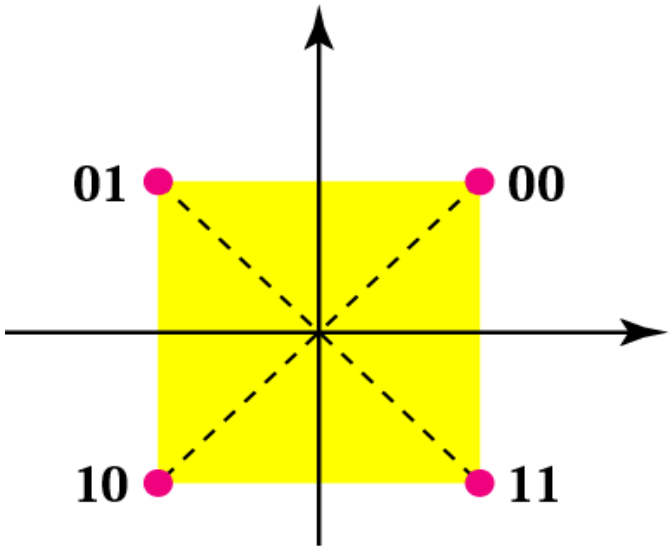
b. BPSK



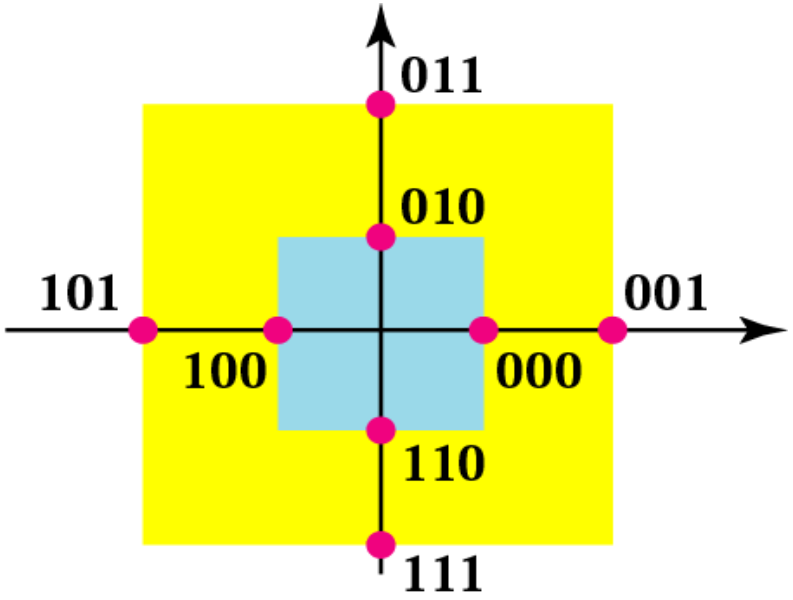
c. QPSK

Quadrature Amplitude Modulation

- Or QAM
- A combination of ASK and PSK



4-QAM
1 amplitude, 4 phases

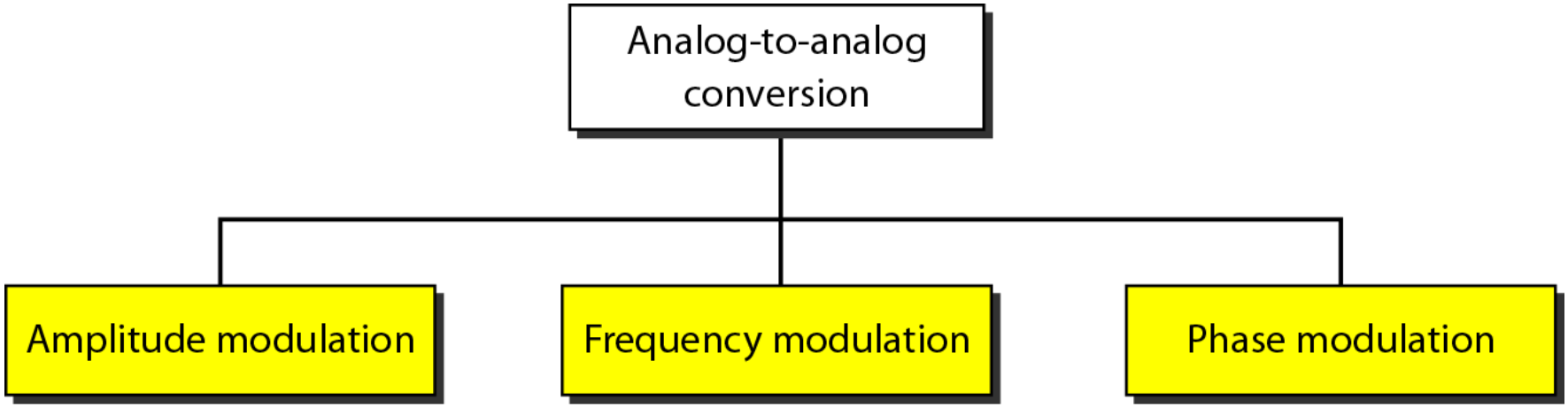


8-QAM
2 amplitudes, 4 phases

Analog-to-Analog Conversion

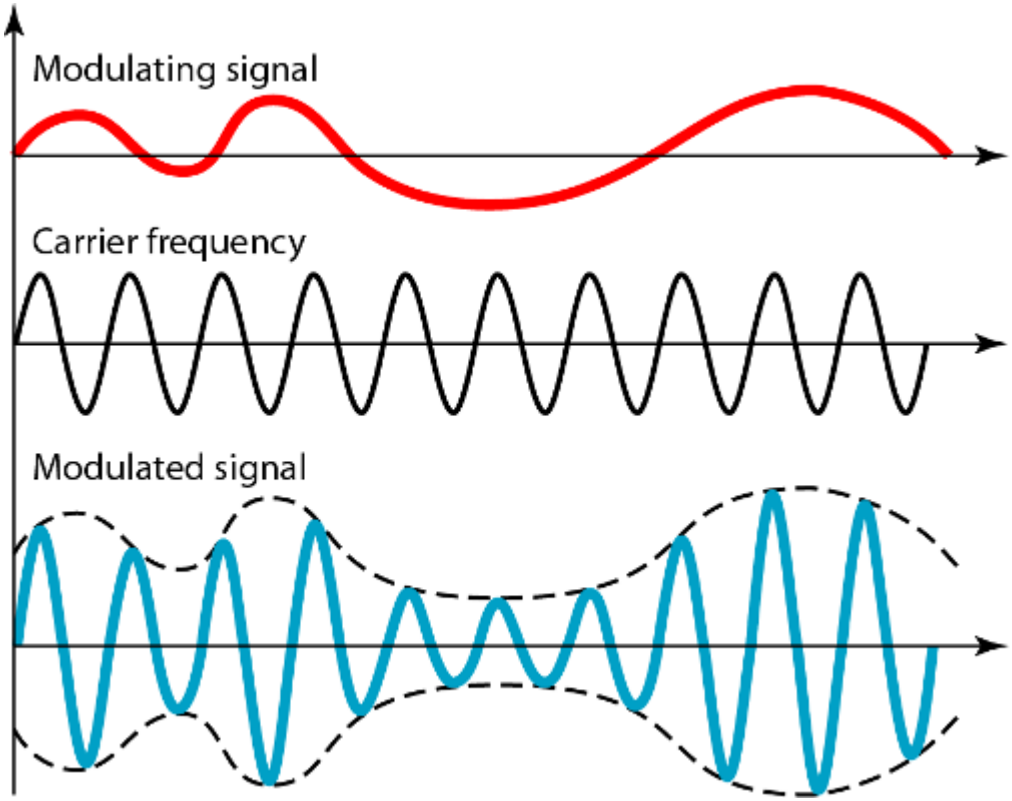
- Process of transmitting analog information by an analog signal
- Although the signal is already analog, modulation is needed if only a band-pass channel is available to us.
- An example is radio. The government assigns a narrow bandwidth to each radio station. The analog signal produced by each station is a low-pass signal, all in the same range. To be able to listen to different stations, the low-pass signals need to be shifted, each to a different range.

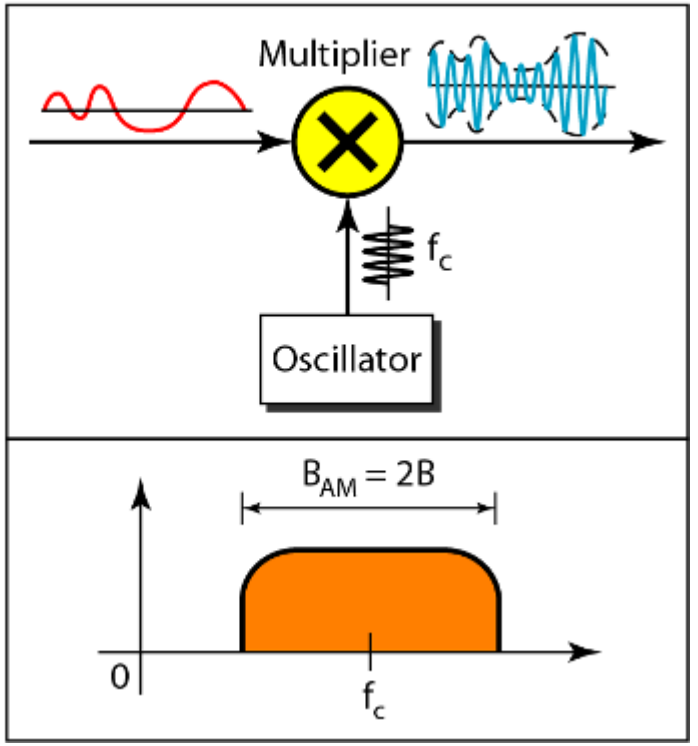
Types of Analog-to-Analog Modulations



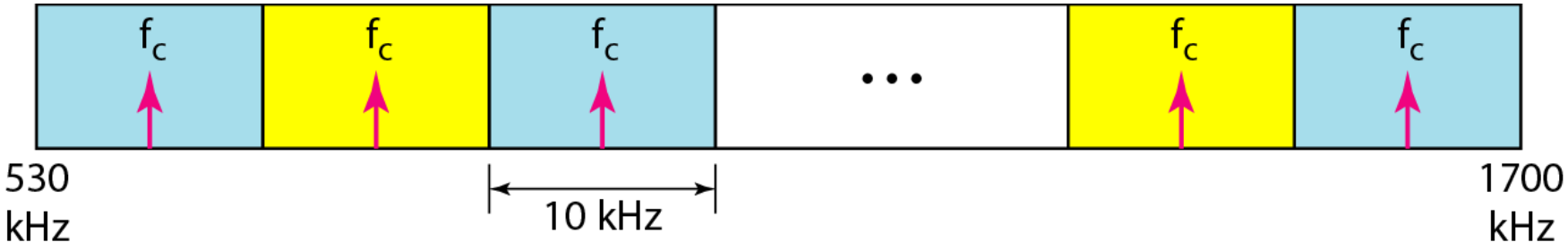
Amplitude Modulation (AM)

- The amplitude of the carrier signal is modulated so that its amplitude varies
- Process of transmitting analog information by an analog signal

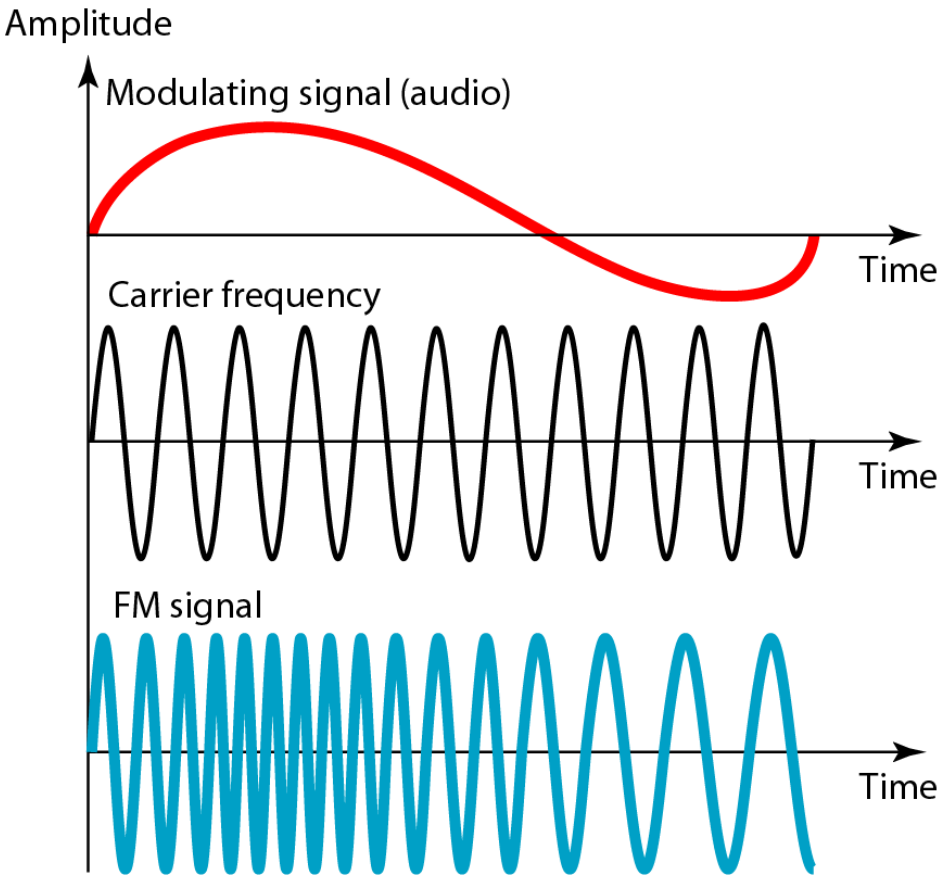


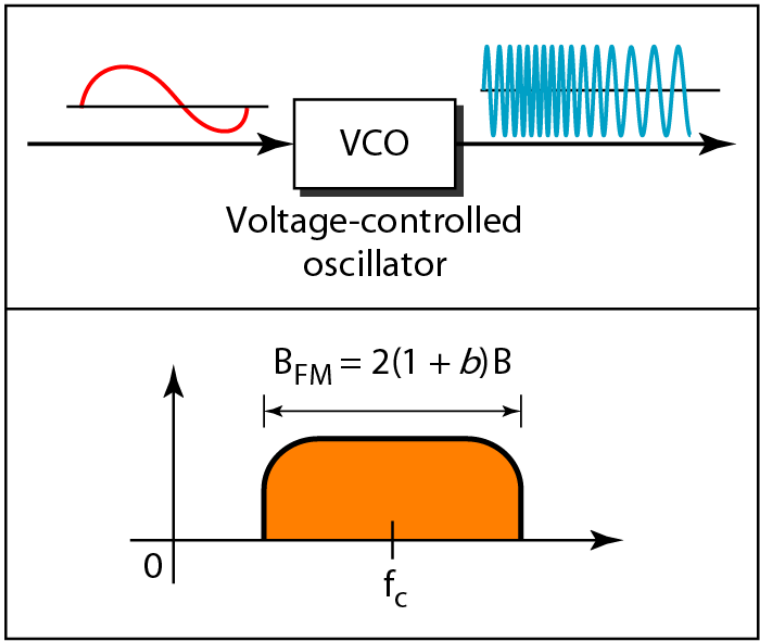


AM Band Allocation

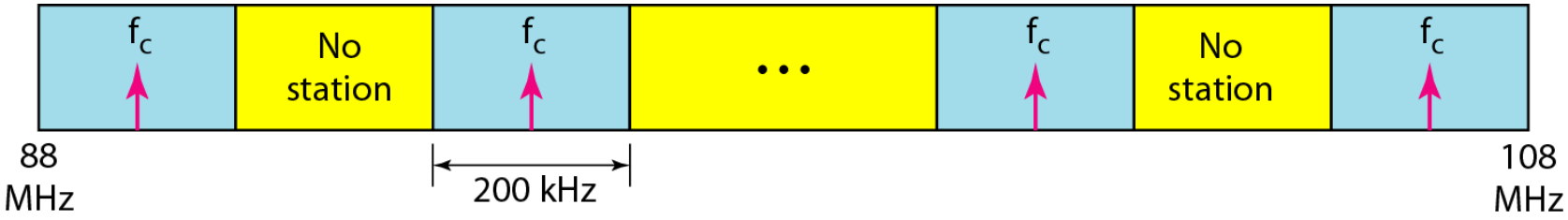


Frequency Modulation (FM)



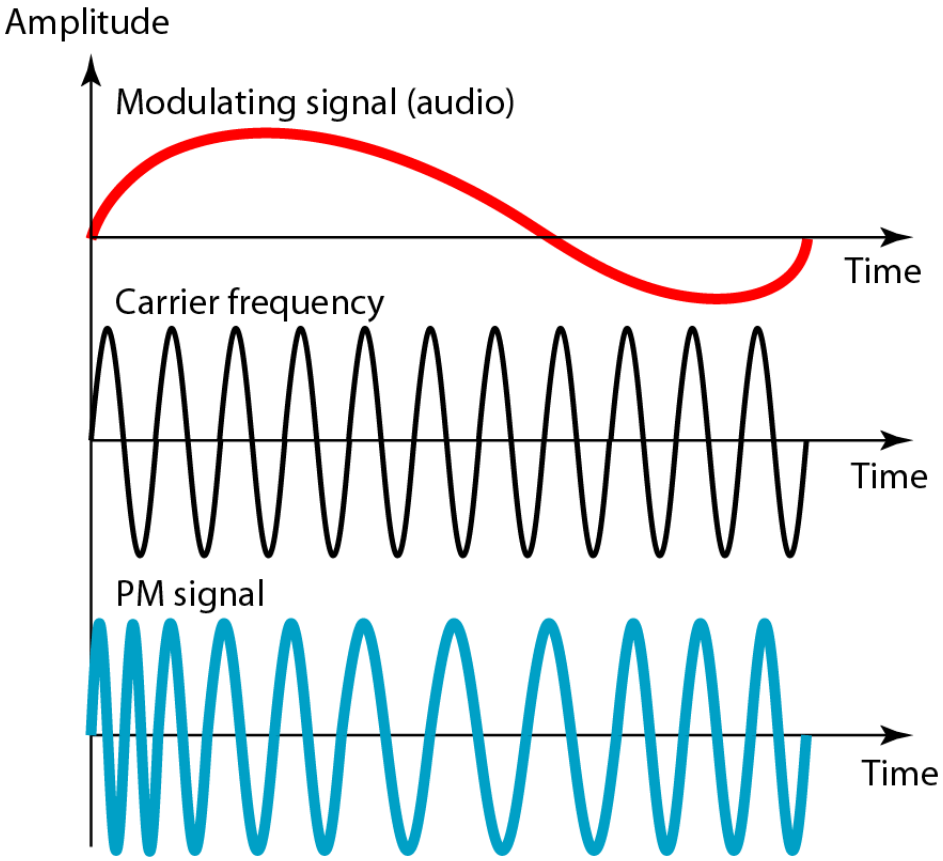


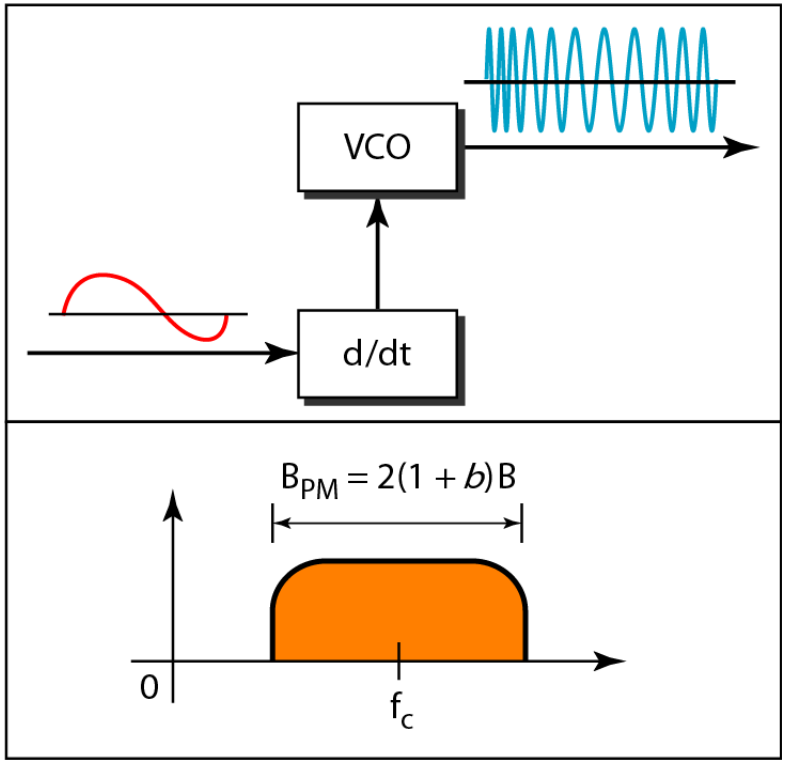
FM Band Allocation



Phase Modulation (PM)

- Considered a variation of FM





Home Work

- Example 5.1-5.7.

A number of slides modified from Chaiporn Jaikaeo and borrowed from the book website