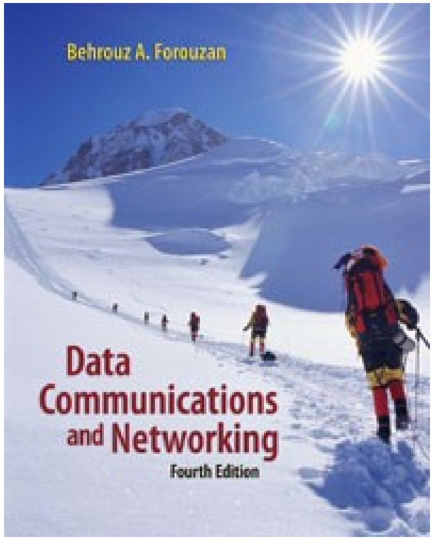
CPE 400 / 600
Computer Communication Networks



Lecture 27

Physical Layer

Ch 5: AnalogTransmission

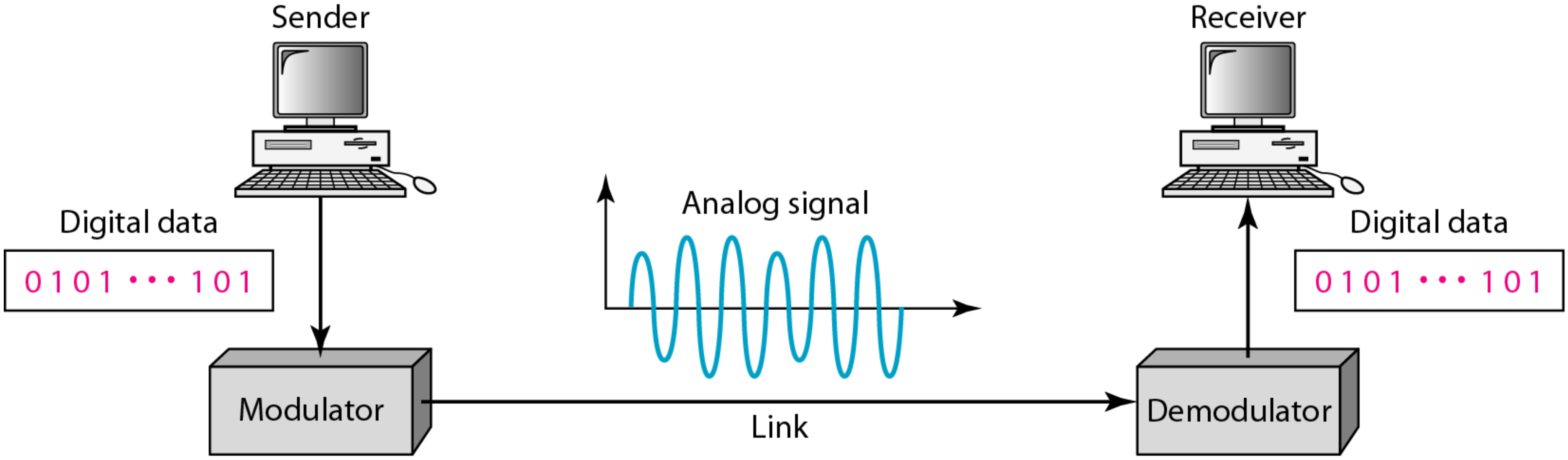
Slides are modified from Behrouz A. Forouzan

Lecture 27: Outline

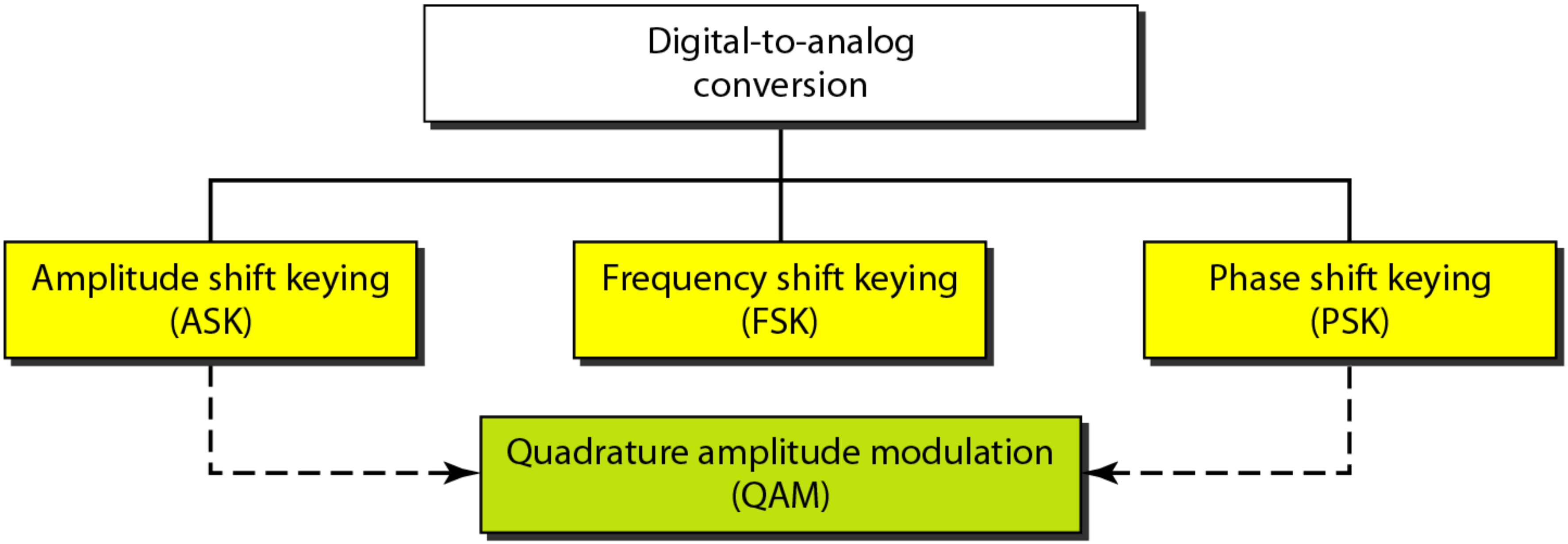
- Chapter 5: Analog Transmission
- 5.1 Digital-to-Analog Conversion
    - Amplitude shift keying
    - Frequency shift keying
    - Phase shift keying
    - Quadrature amplitude modulation
- 5.2 Analog-to-Analog Conversion
    - Amplitude modulation
    - Frequency modulation
    - Phase modulation

5-1 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.



Types of digital-to-analog conversion



- ❑ Bit rate is the number of bits per second.
- ❑ Baud rate is 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

An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate.

Solution

In this case, $r = 4$, $S = 1000$, and N is unknown. We can find the value of N from

$$S = N \times \frac{1}{r} \qquad \text{or} \qquad N = S \times r = 1000 \times 4 = 4000 \text{ bps}$$

Example

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 signal elements do we need?

Solution

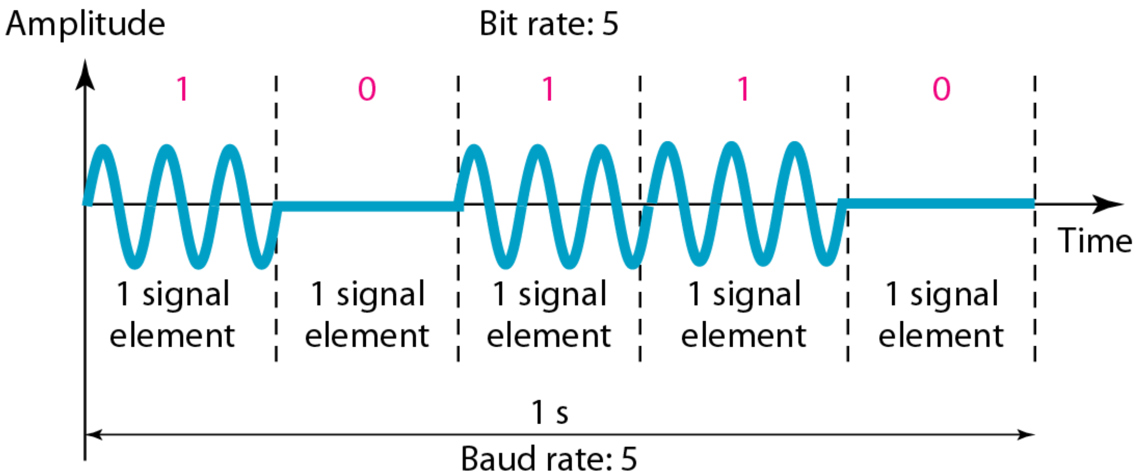
S = 1000, N = 8000, and r and L are unknown.

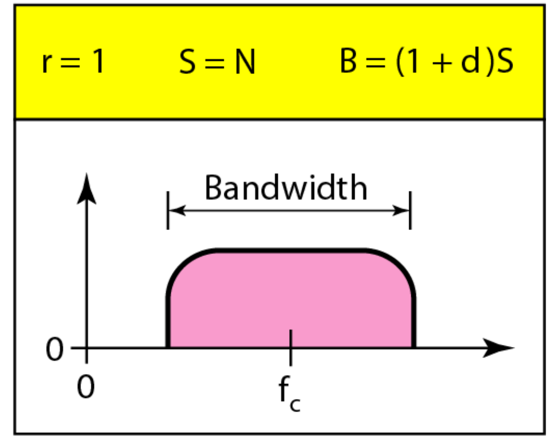
We find first the value of r and then the value of L.

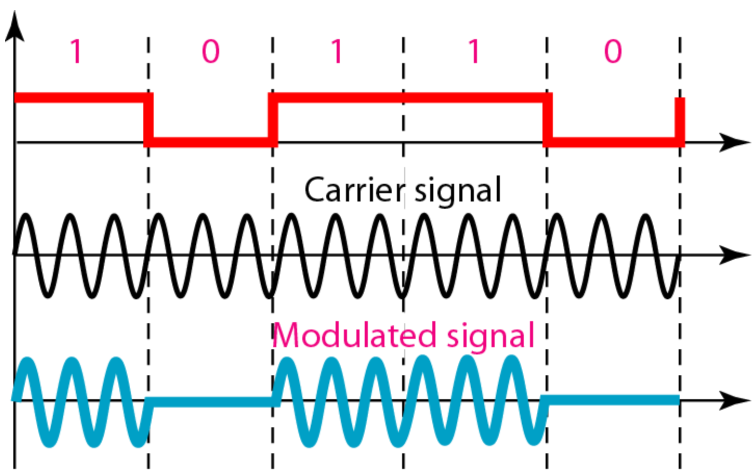
$$S = N \times \frac{1}{r} \quad \Rightarrow \quad r = \frac{N}{S} = \frac{8000}{1000} = 8 \text{ bits/baud}$$

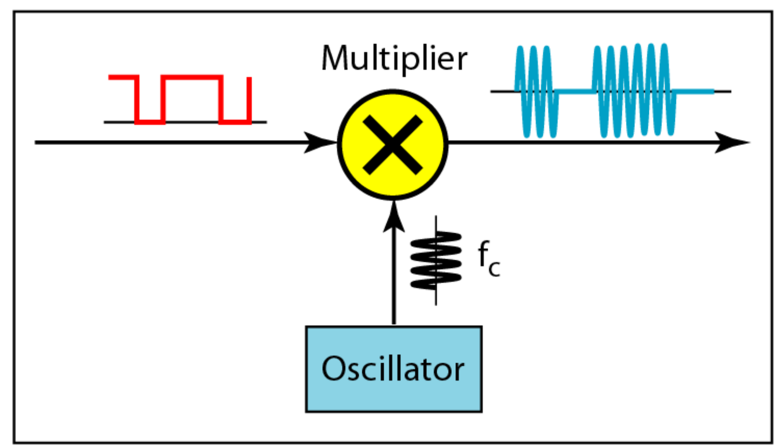
$$r = \log_2 L \quad \Rightarrow \quad L = 2^r = 2^8 = 256$$

Binary amplitude shift keying









Example

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?

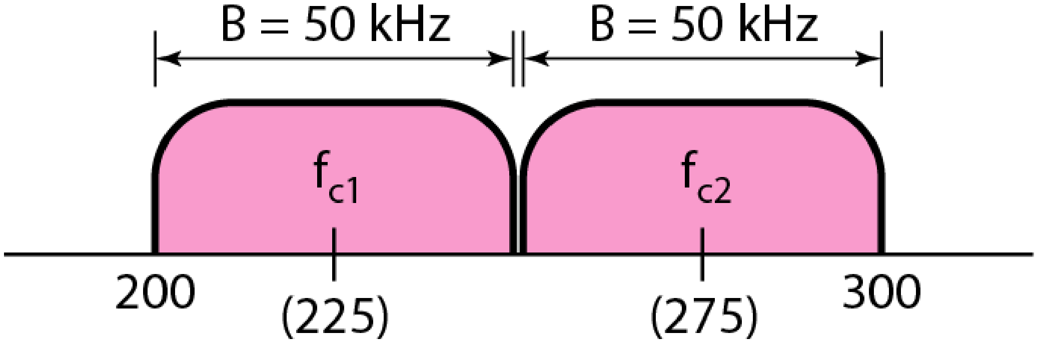
Solution

The middle of the bandwidth is located at 250 kHz.
This means 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).

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

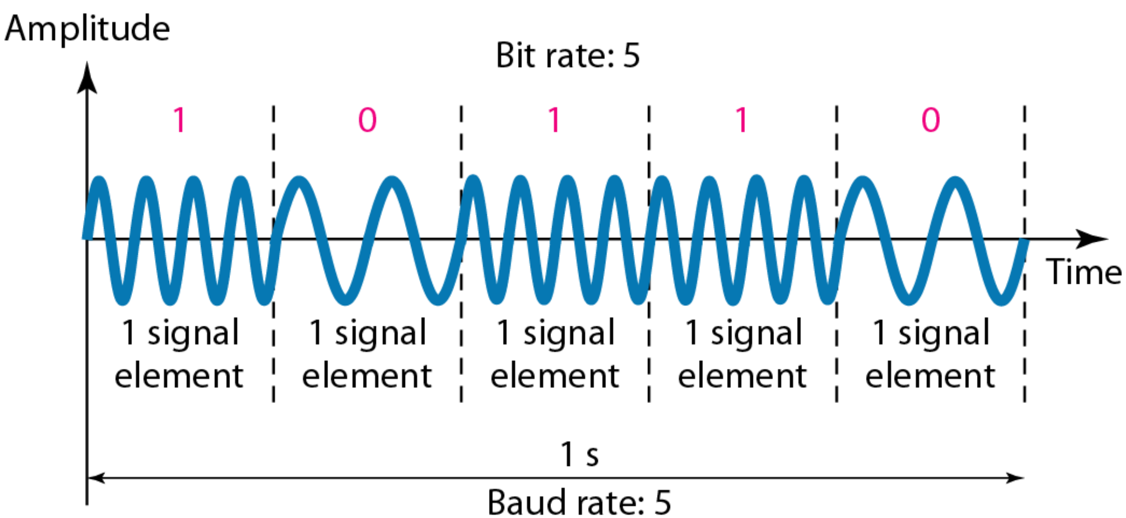
Example

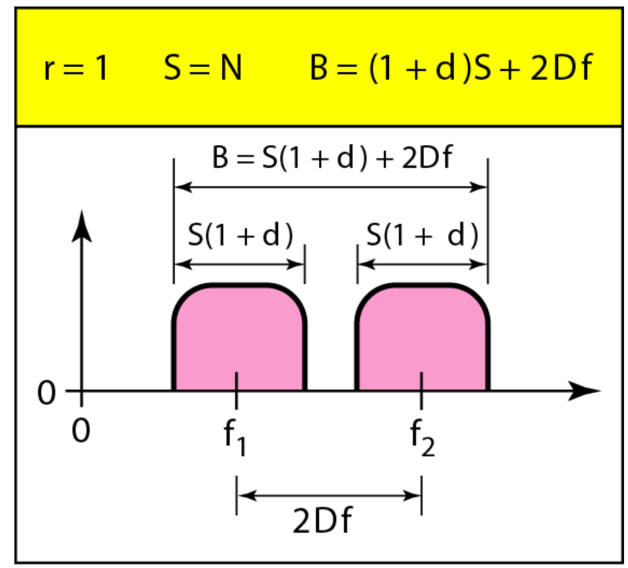
We normally use full-duplex links with communication in both directions.
We need to divide the bandwidth into two with two carrier frequencies.



The available bandwidth for each direction is now 50 kHz, which leaves us with a data rate of 25 kbps in each direction.

Binary frequency shift keying





Example

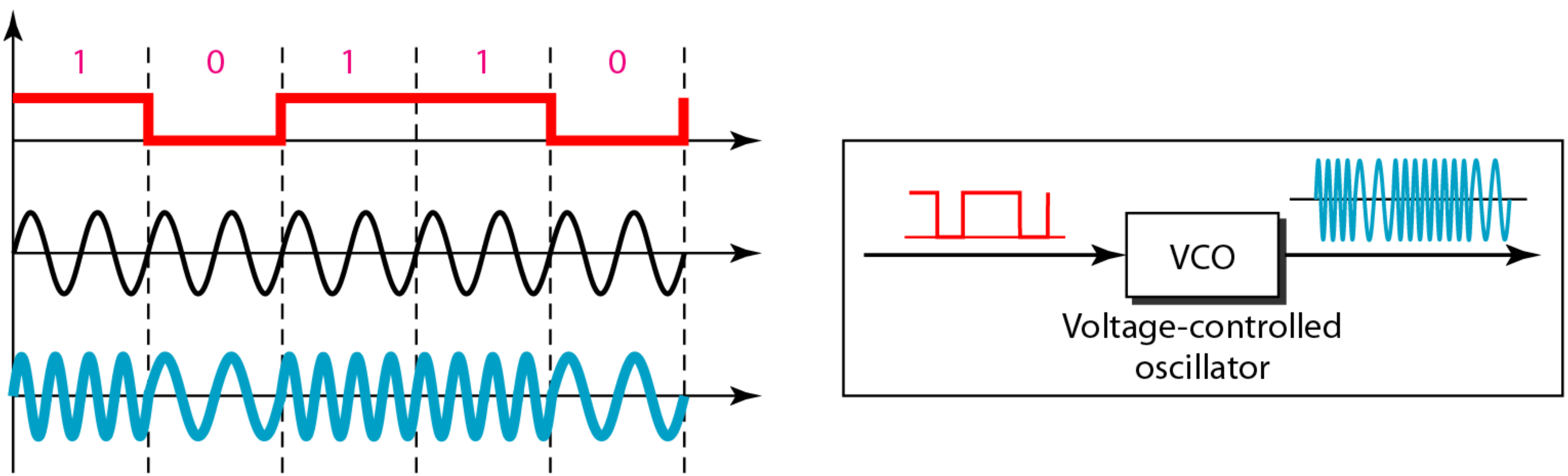
We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with d = 1?

Solution

This problem is similar to Example 5.3, but we are modulating by using FSK. The midpoint of the band is at 250 kHz. We choose 2Δf to be 50 kHz; this means

$$B = (1 + d) \times S + 2\Delta f = 100 \quad \Rightarrow \quad 2S = 50 \text{ kHz} \quad S = 25 \text{ kbaud} \quad N = 25 \text{ kbps}$$

Bandwidth of MFSK used in Example 5.6



Example

We need to send data 3 bits at a time at a bit rate of 3 Mbps. The carrier frequency is 10 MHz. Calculate the number of levels (different frequencies), the baud rate, and the bandwidth.

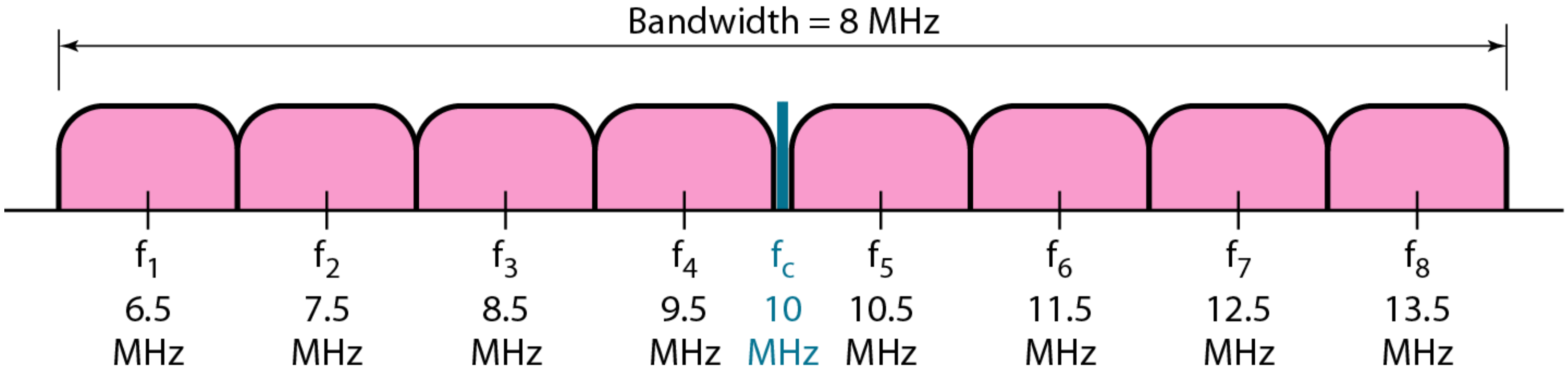
Solution

We can have L = 23 = 8.

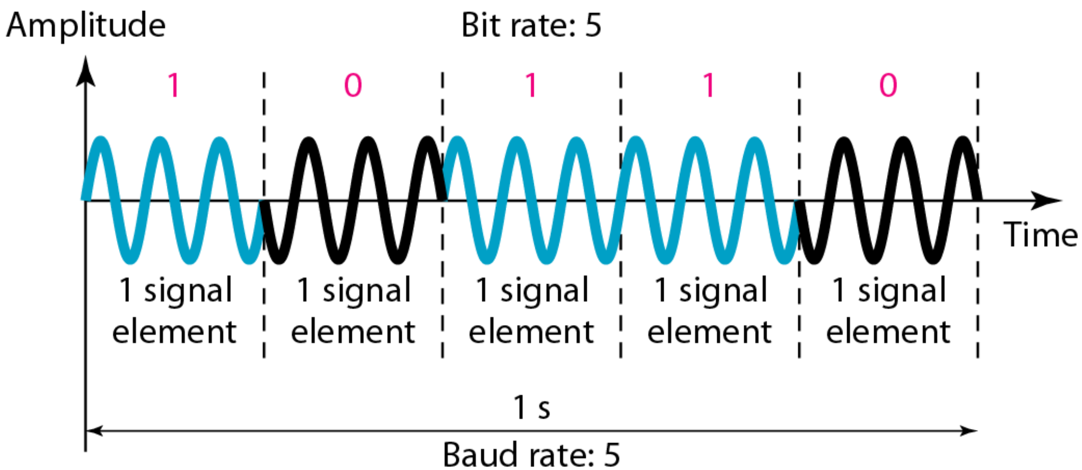
The baud rate is S = 3 MHz/3 = 1000 Mbaud.

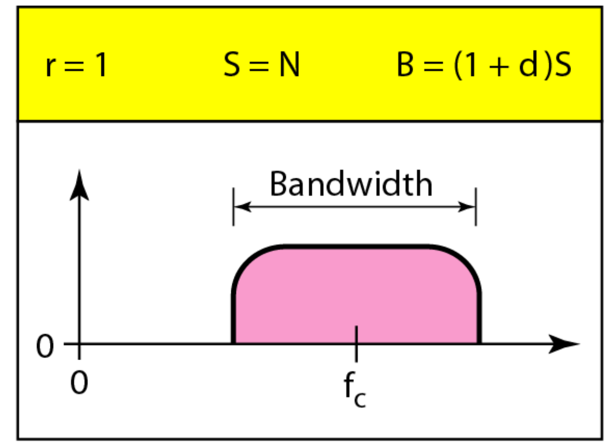
This means that the carrier frequencies must be 1 MHz apart (2Δf = 1 MHz).

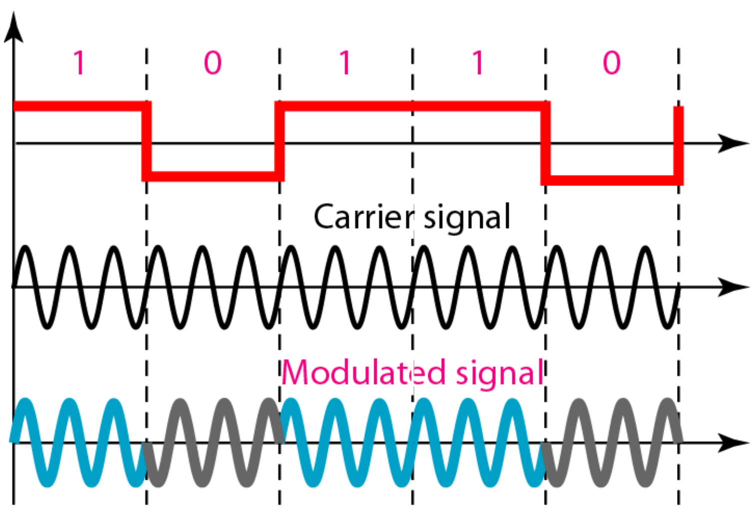
The bandwidth is B = 8 × 1000 = 8000.

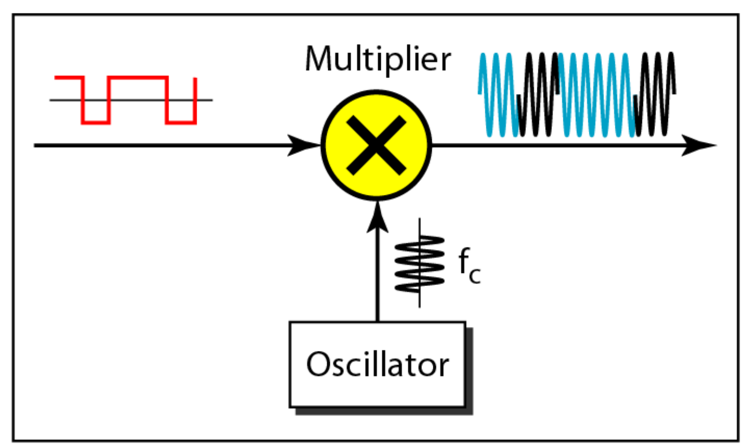


Binary phase shift keying

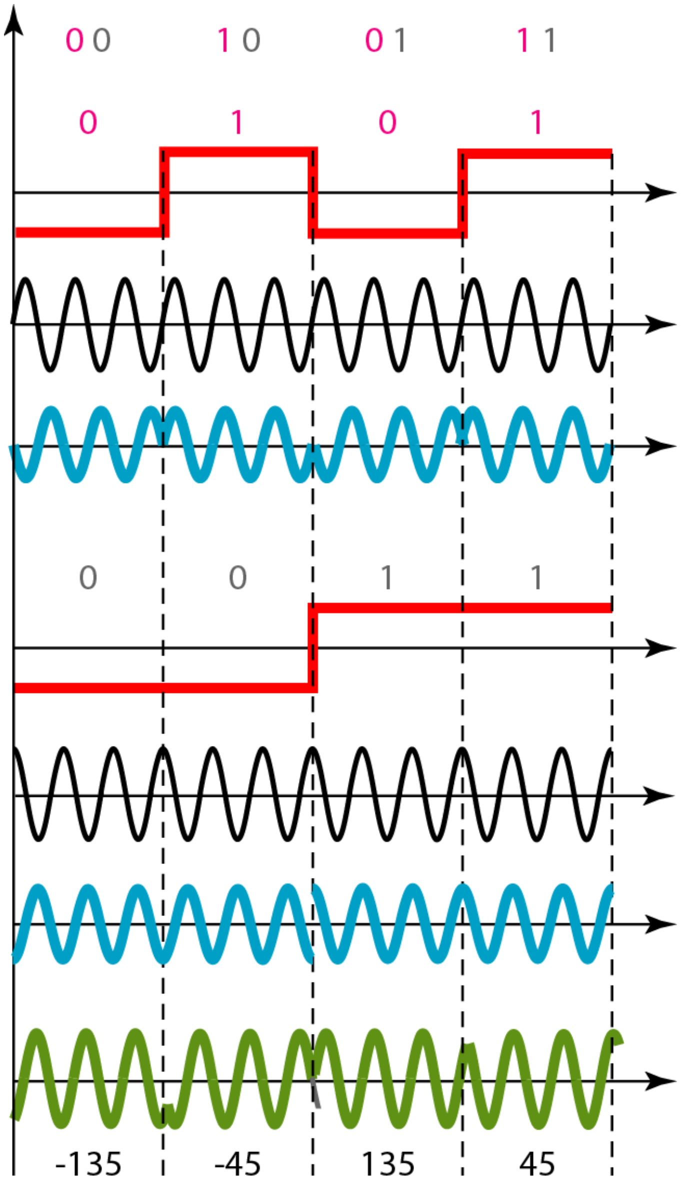


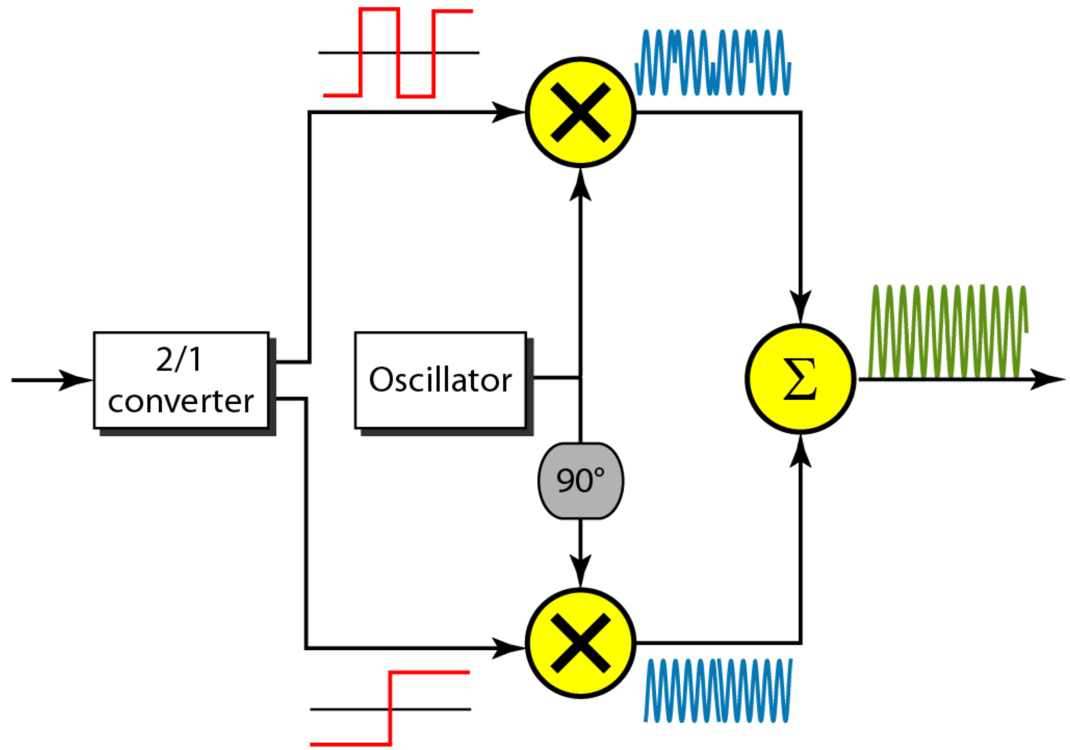






QPSK and its implementation





Example

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

Solution

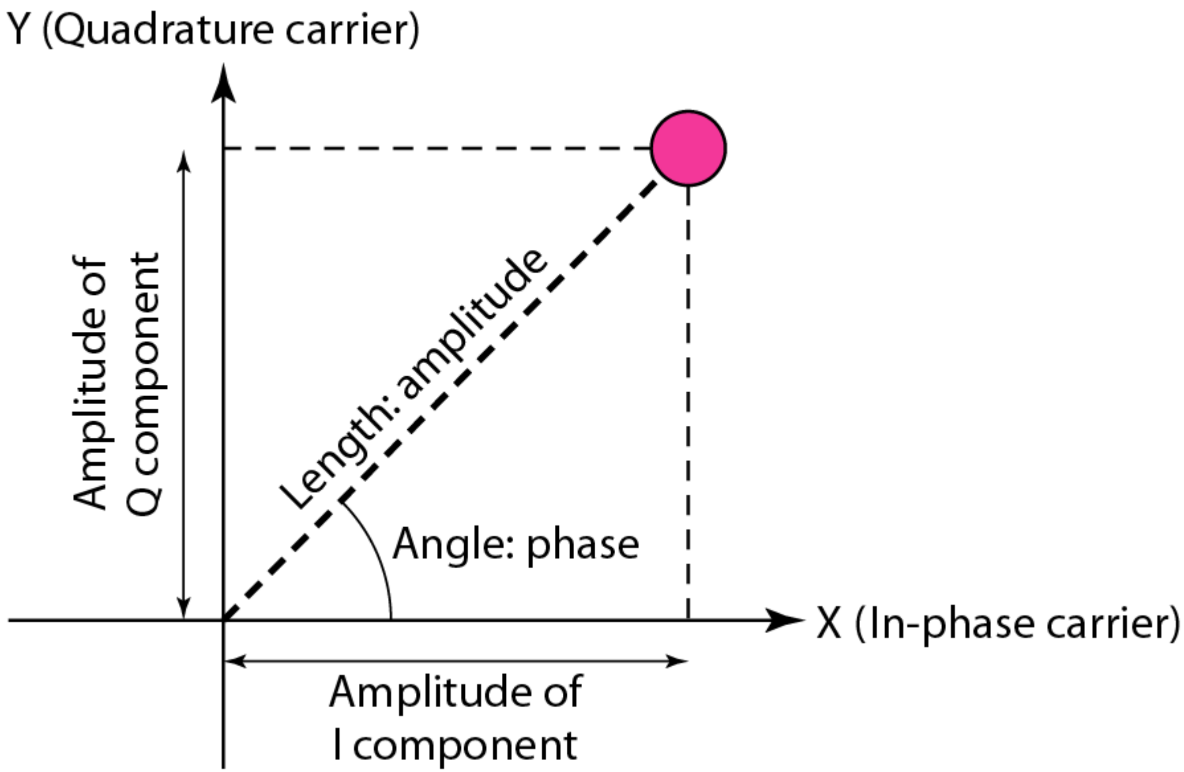
For QPSK, 2 bits is carried by one signal element.

This means that r = 2.

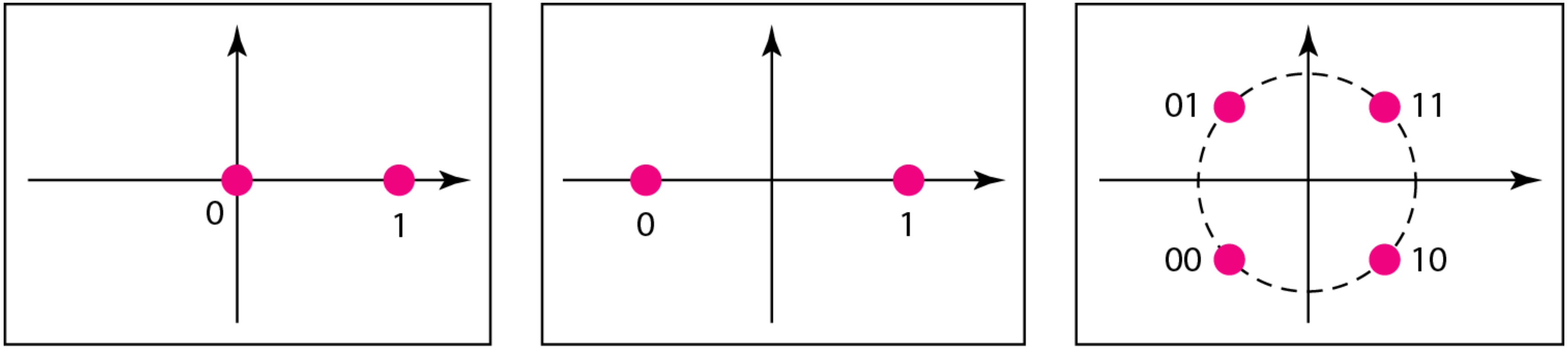
So the signal rate (baud rate) is $S = N \times (1/r) = 6$ Mbaud.

With a value of d = 0, we have B = S = 6 MHz.

Concept of a constellation diagram



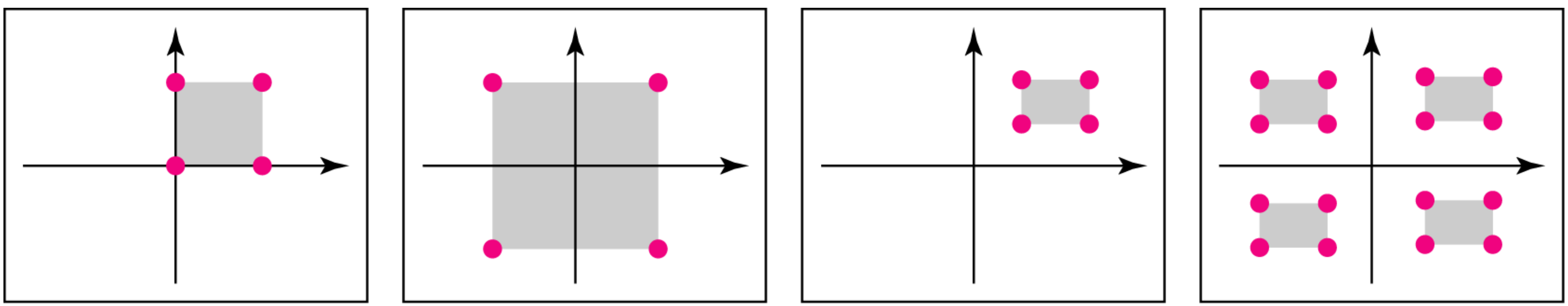
Constellation diagrams for ASK (OOK), BPSK, and QPSK



a. ASK (OOK) b. BPSK c. QPSK

Constellation diagrams for some QAMs

Quadrature amplitude modulation is a combination of ASK and PSK.



a. 4-QAM b. 4-QAM c. 4-QAM d. 16-QAM

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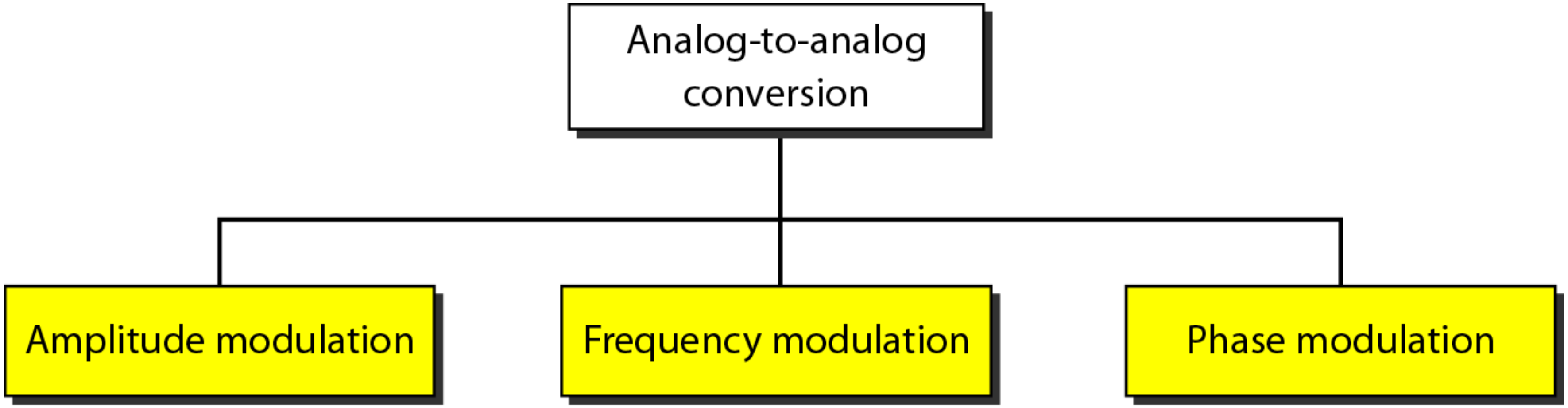
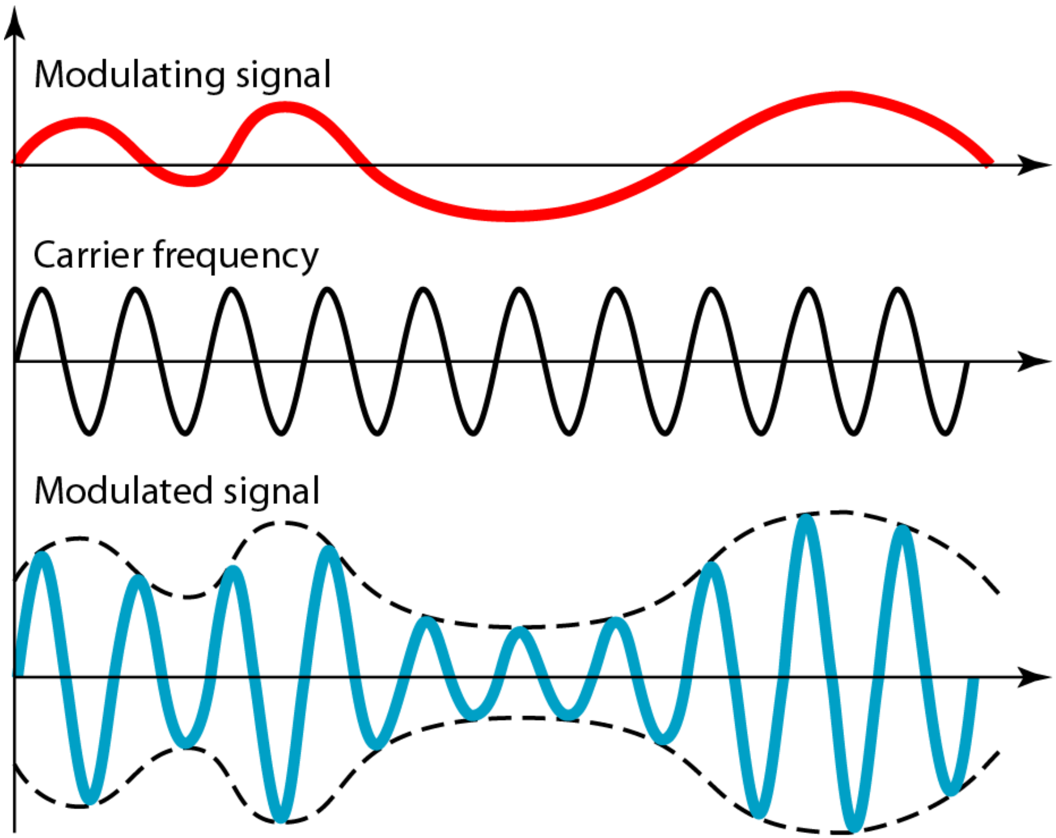
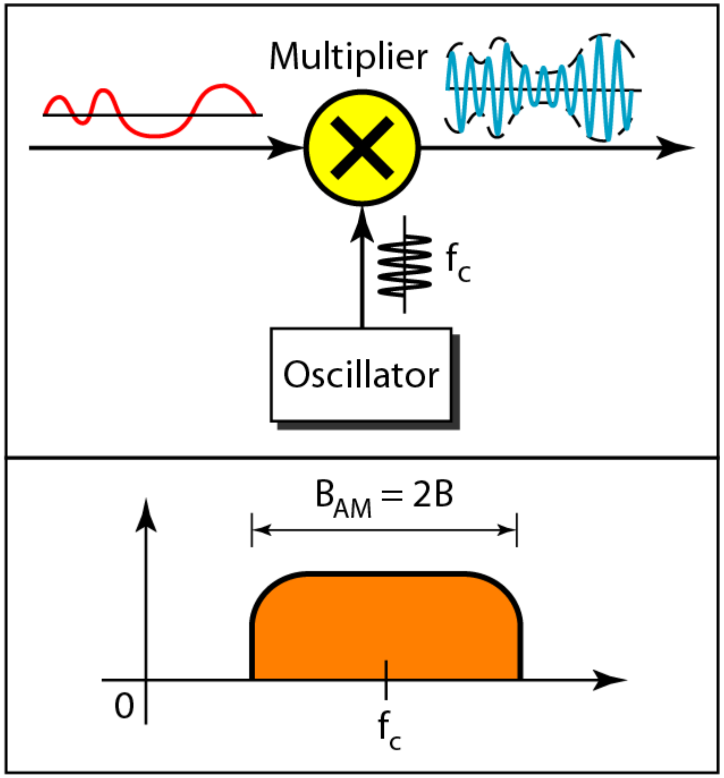
5-2 ANALOG AND DIGITAL

- 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.



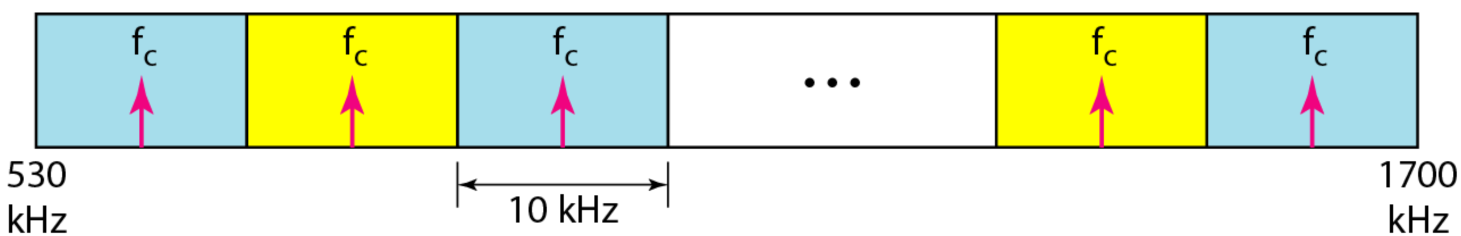
Amplitude modulation



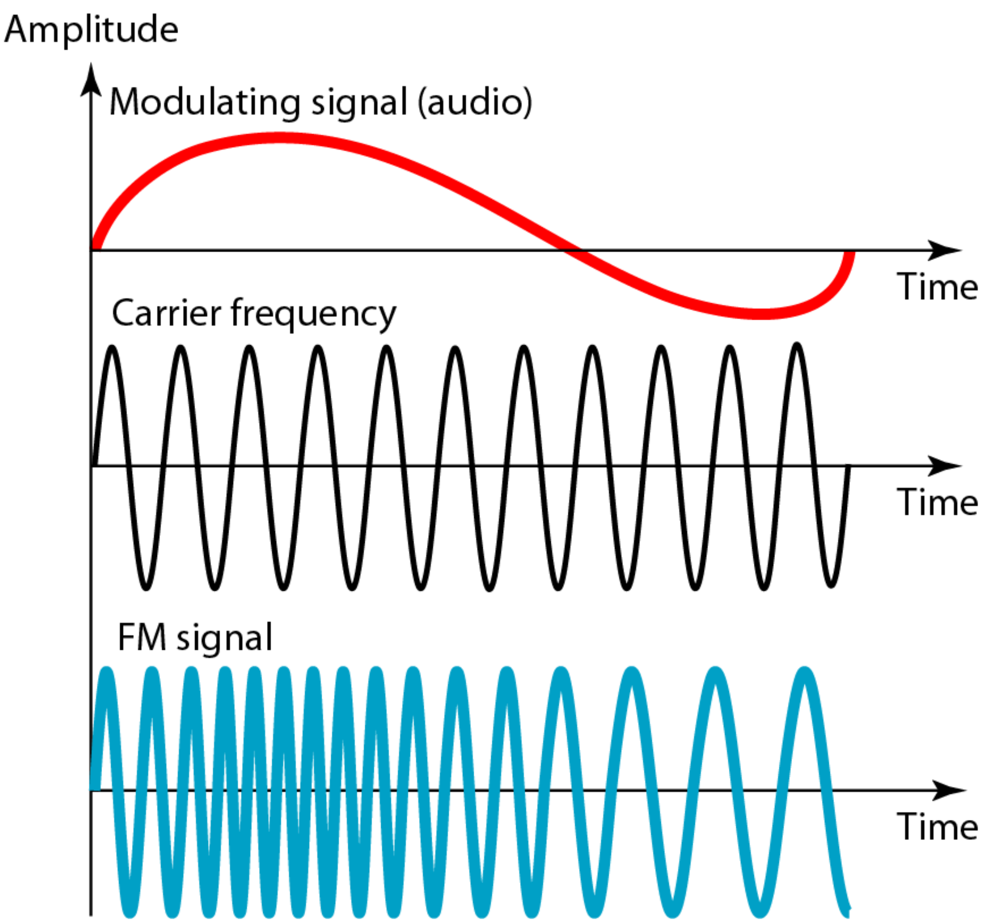


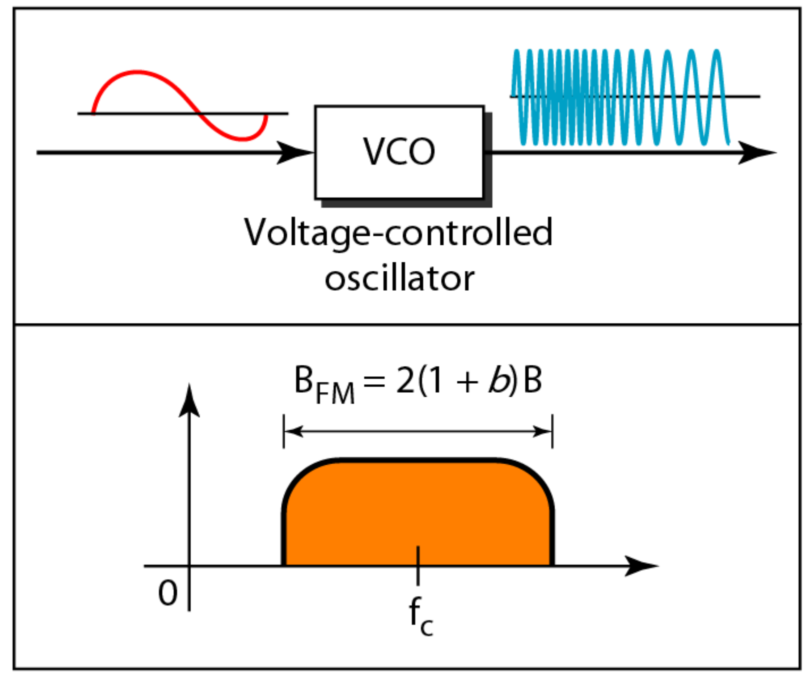
AM band allocation

The total bandwidth required for AM can be determined from the bandwidth of the audio signal: $B_{AM} = 2B$.



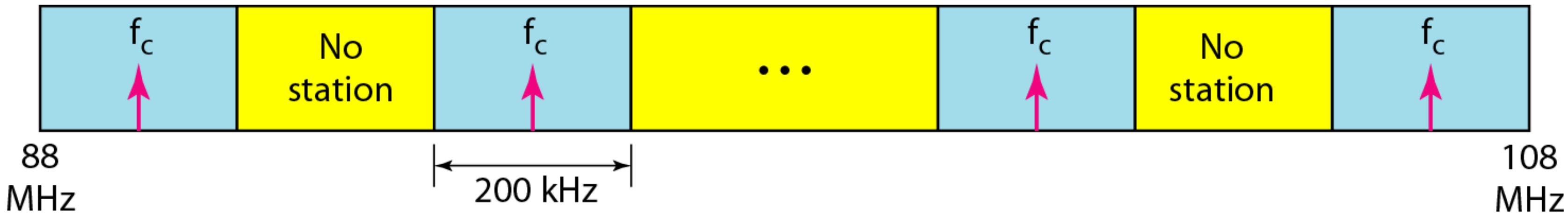
Frequency modulation



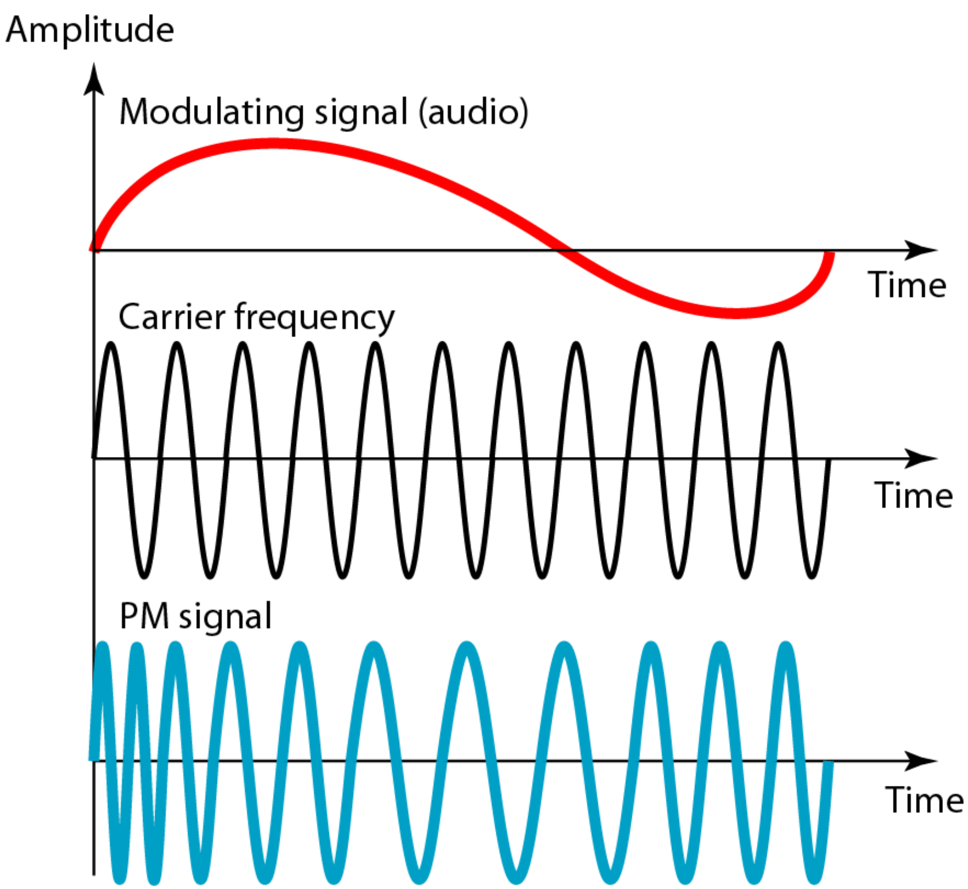


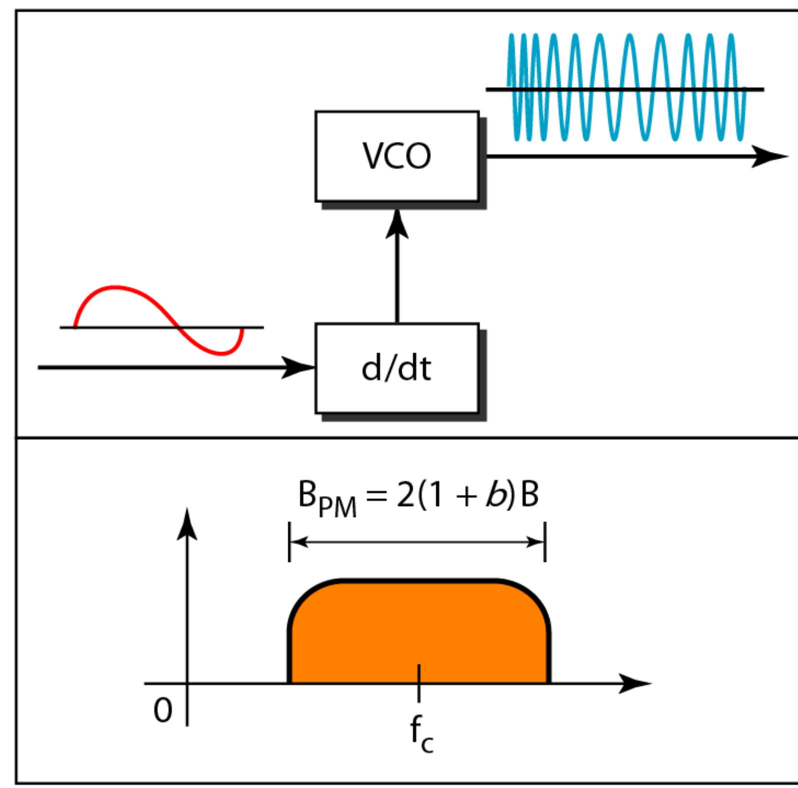
FM band allocation

The total bandwidth required for FM can be determined from the bandwidth of the audio signal: $B_{FM} = 2(1 + \beta)B$.



Phase modulation





PM band allocation

The total bandwidth required for PM can be determined from the bandwidth and maximum amplitude of the modulating signal:

$$B_{PM} = 2(1 + \beta)B.$$