Data Communication

#9 Analog Transmission

Digital to Analog Conversion

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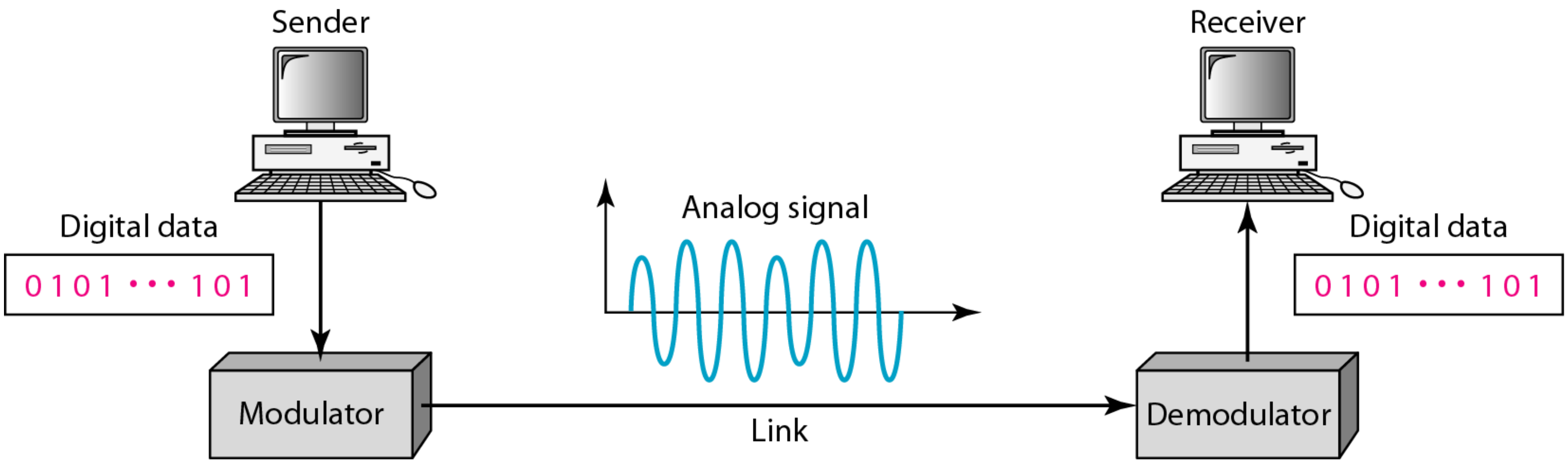
Analog Transmission

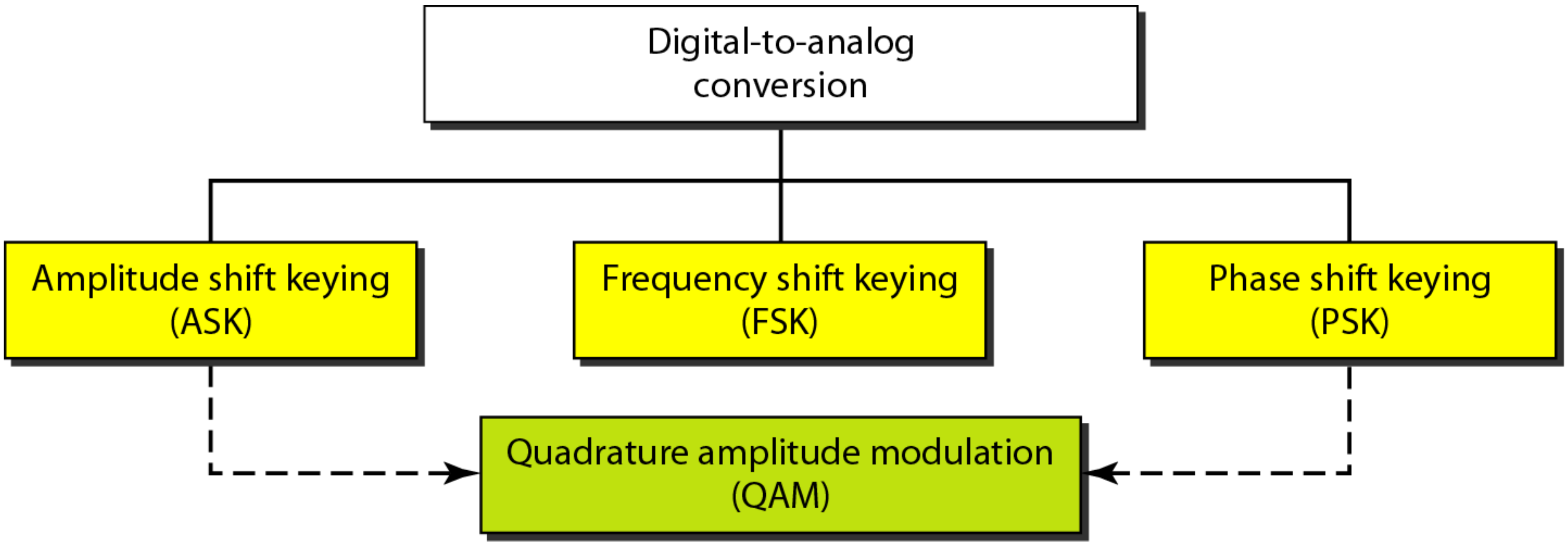
- In chapter 3, we discussed the advantages and disadvantage of digital and analog transmission. We saw that while digital transmission is very desirable, a low-pass channel is needed. We also saw that analog transmission is the only choice if we have a bandpass channel. Digital transmission was discussed in Chapter 4; we discuss analog transmission in this chapter.
- Converting digital data to a bandpass analog signal.is traditionally called digital- to-analog conversion. Converting a low-pass analog signal to a bandpass analog signal is traditionally called analog-to-analog conversion. In this chapter, we discuss these two types of conversions.

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



Aspects of Digital to Analog Conversion

- Data Element vs Signal Element
    - Data Element is a smallest piece of information to be exchanged, the bit
    - Signal Element is the smallest unit of a signal that is constant.
- Data Rate vs Signal Rate
    - Bit rate is the number of bits per second. Baud Rate is the number of signal element per second.
    - In the analog transmission of digital data, the baud rate is less than or equal to the bit rate.
    - Relationship between Data Rate and Signal Rate:

$$S = N \times \frac{1}{r} \quad baud$$

Examples

- 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

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

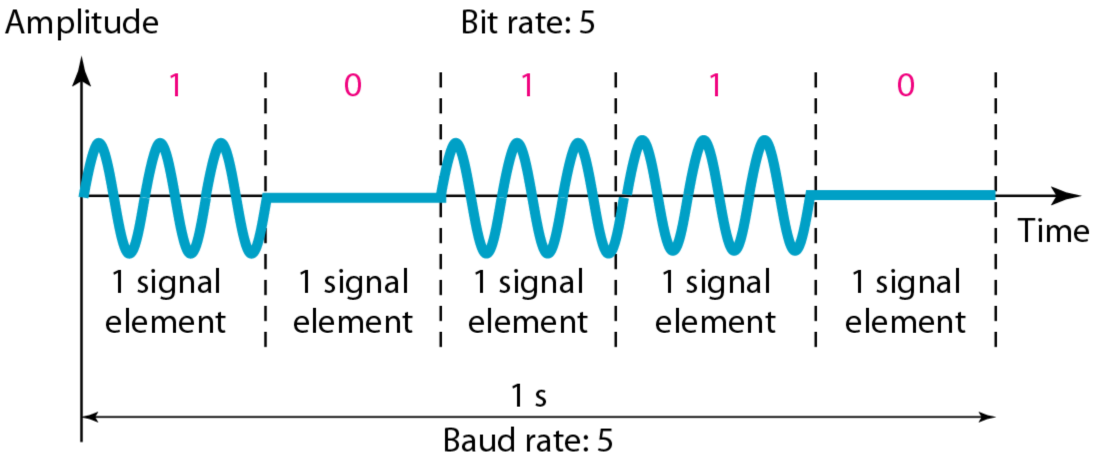
- An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?
- Solution
    - In this example, S = 1000, N = 8000, and r and L are unknown. We find first the value of r and then the value of L.

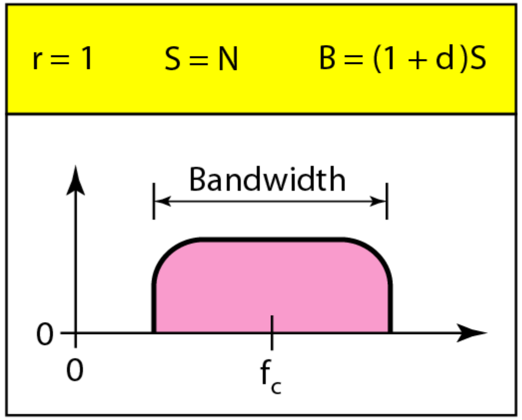
$$S = N \times \frac{1}{r} \quad \rightarrow \quad r = \frac{N}{S} = \frac{8000}{1000} = 8 \text{ bits/baud}$$

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

Amplitude Shift Keying (ASK)

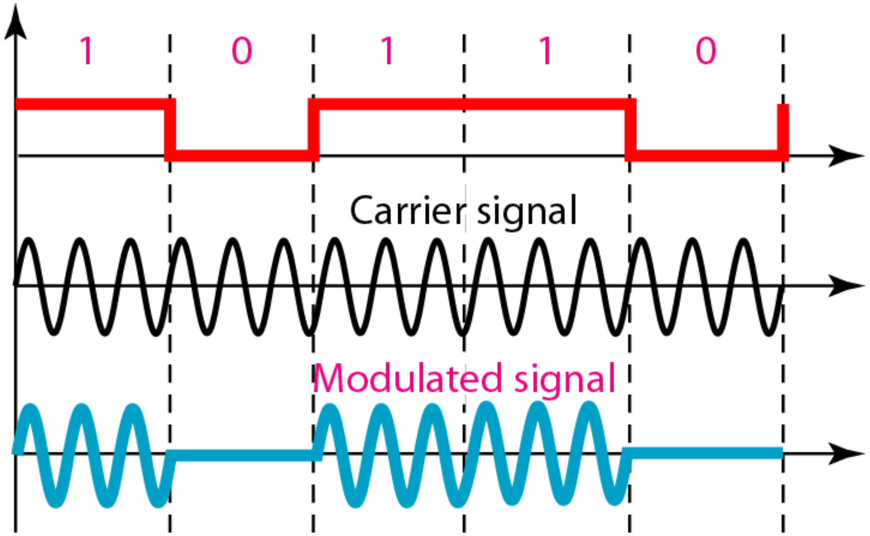
- Binary Amplitude Shift Keying (BASK)

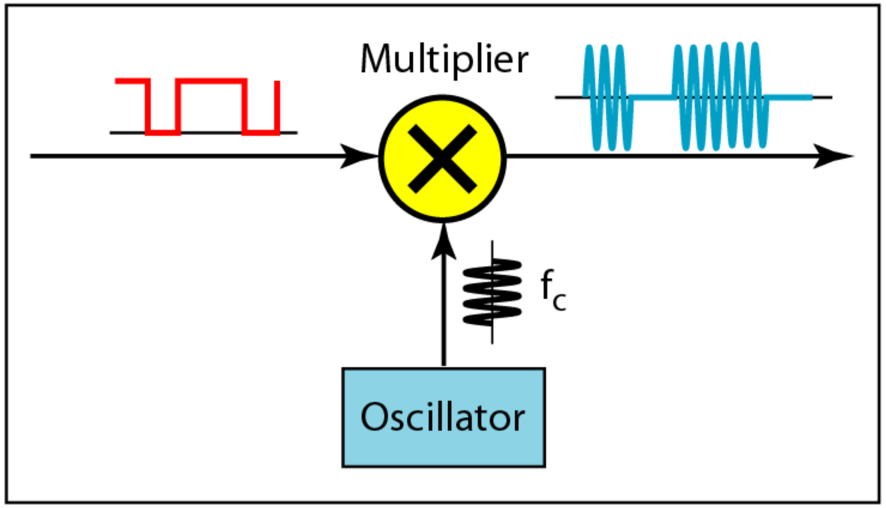




- d ≥ 0 ➔ related to the condition of the line

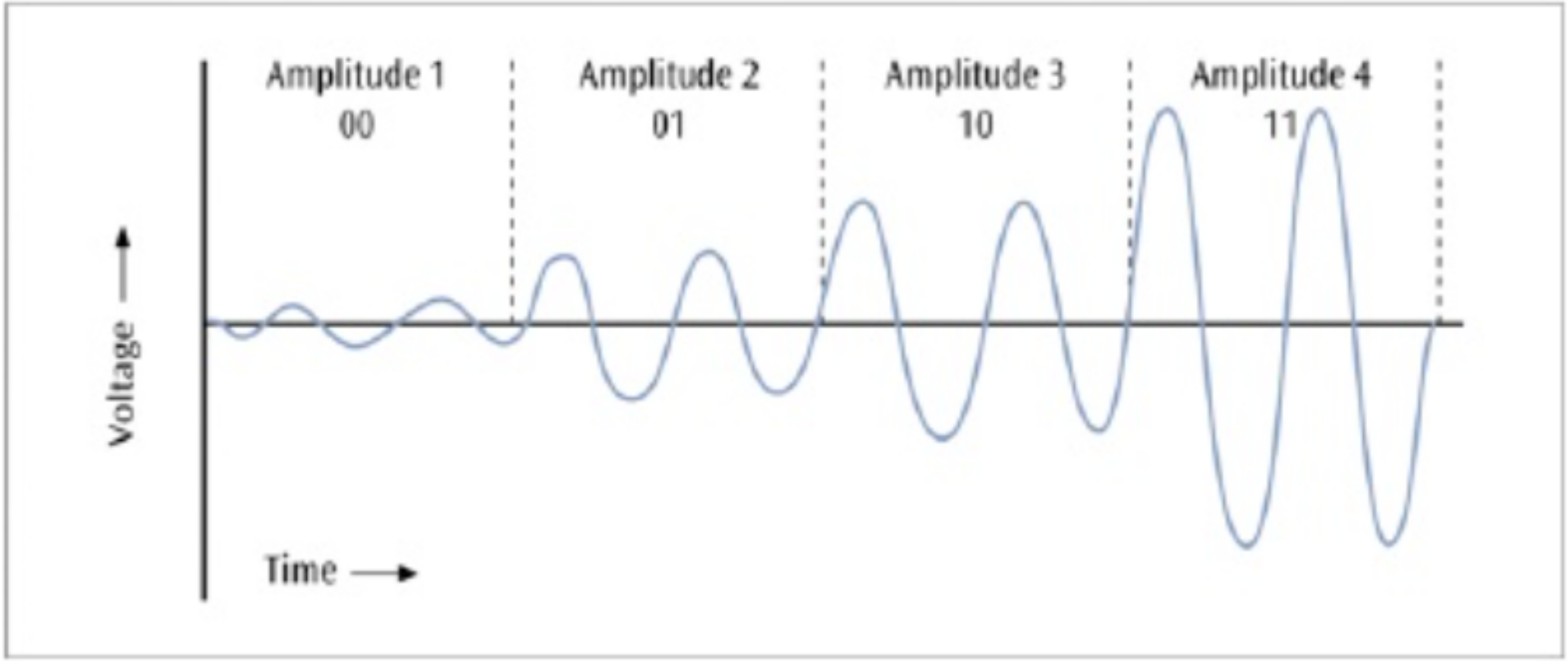
Implementation of Binary ASK





OOK and MASK

- OOK (On Off Keying)
  - 0 silence
  - Sensor networks: battery life, simple implementation
- MASK : Multiple Amplitude Levels



Pro, Con and Applications

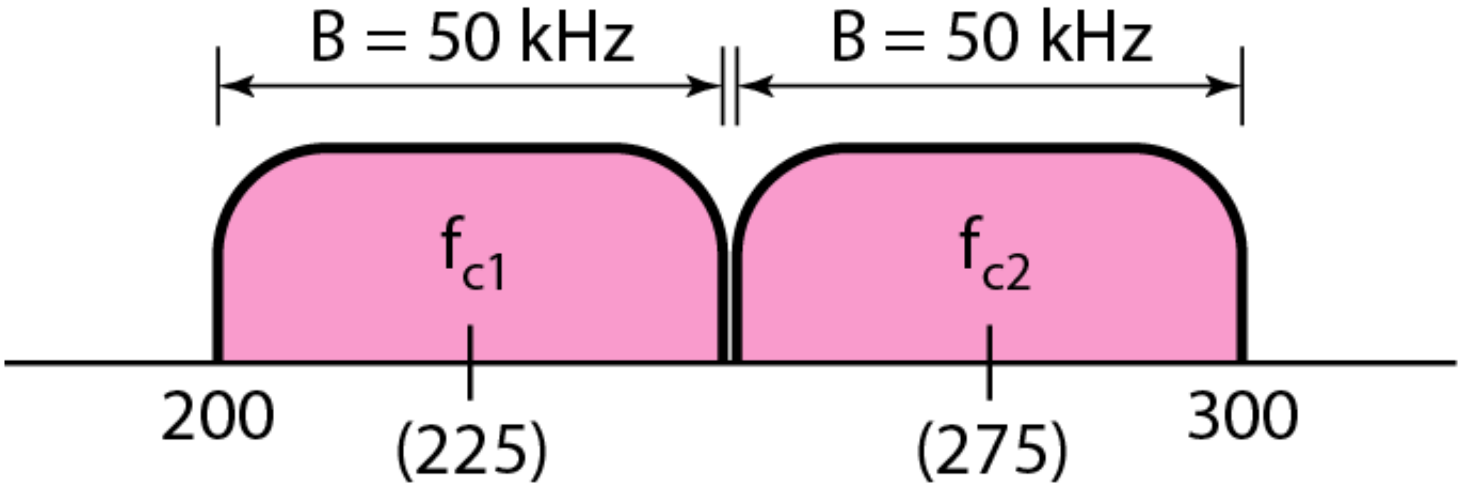
- Pro
  - Simple implementation
- Con
  - Major disadvantage is that telephone lines are very susceptible to variation in transmission quality that can affect amplitude.
  - Susceptible to sudden gain changes
  - Inefficient modulation technique for data.
- Applications:
  - On voice grade lines, used up to 1200 bps
  - Used to transmit digital data over optical fibre
  - Morse code
  - Laser transmitters

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 that our carrier frequency can be at fc = 250 kHz. We can use the formula for bandwidth to find the bit rate (with d = 1 and r = 1).

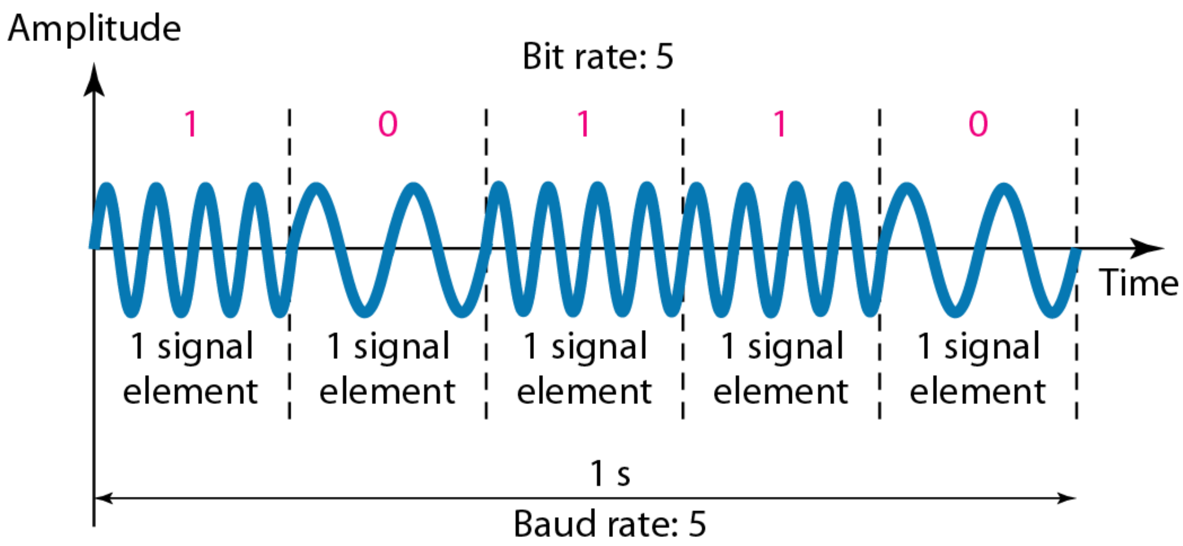
$$B = (1 + d) \times S = 2 \times N \times \frac{1}{r} = 2 \times N = 100 \text{ kHz} \rightarrow N = 50 \text{ kbps}$$

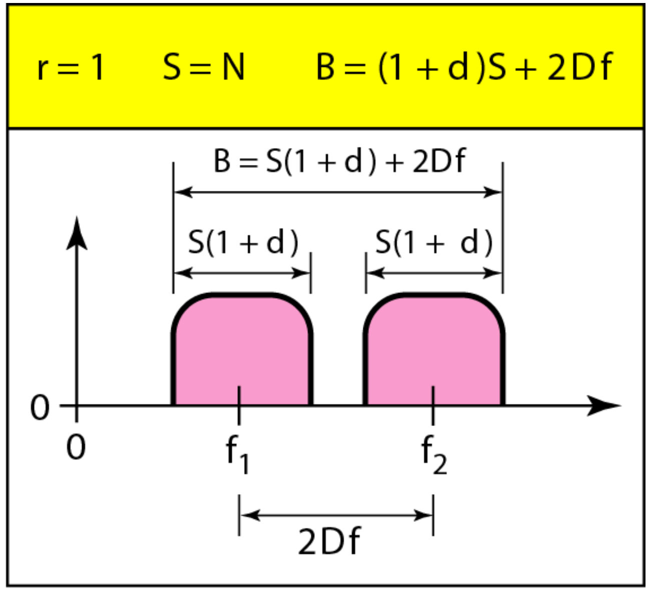
- In data communications, we normally use full-duplex links with communication in both directions. We need to divide the bandwidth into two with two carrier frequencies, as shown in Figure 5.5. The figure shows the positions of two carrier frequencies and the bandwidths. The available bandwidth for each direction is now 50 kHz, which leaves us with a data rate of 25 kbps in each direction.



Frequency Shift Keying (FSK)

- Binary Frequency Shift Keying





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

- Limiting factor: Physical capabilities of the carrier
- Not susceptible to noise as much as ASK
- Applications:
  - On voice grade lines, used up to 12000bps
  - Used fr high frequency (3 to 20 MHz) radio transmission
  - Used at higher frequencies on LANs that use coaxial cable

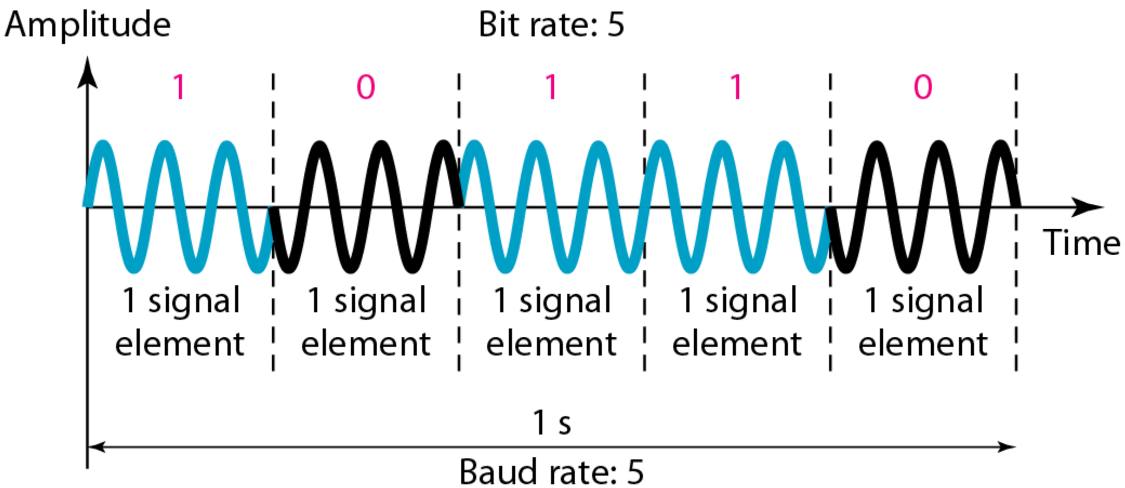
Example

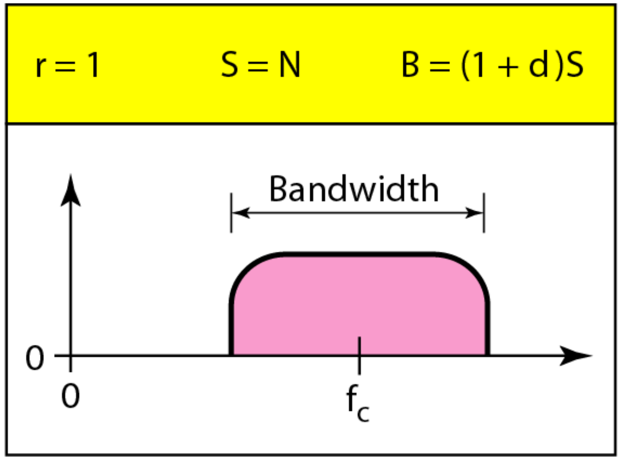
- We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with d = 1?
- Solution
  - This problem is similar to Example 5.3, but we are modulating by using FSK. The midpoint of the band is at 250 kHz. We choose 2Δf to be 50 kHz; this means

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

Phase Shift Keying (PSK)

- In phase shift keying, the phase of the carrier is varied to represent two or more different signal elements. Both peak amplitude and frequency remain constant as the phase changes. Today, PSK is more common than ASK or FSK

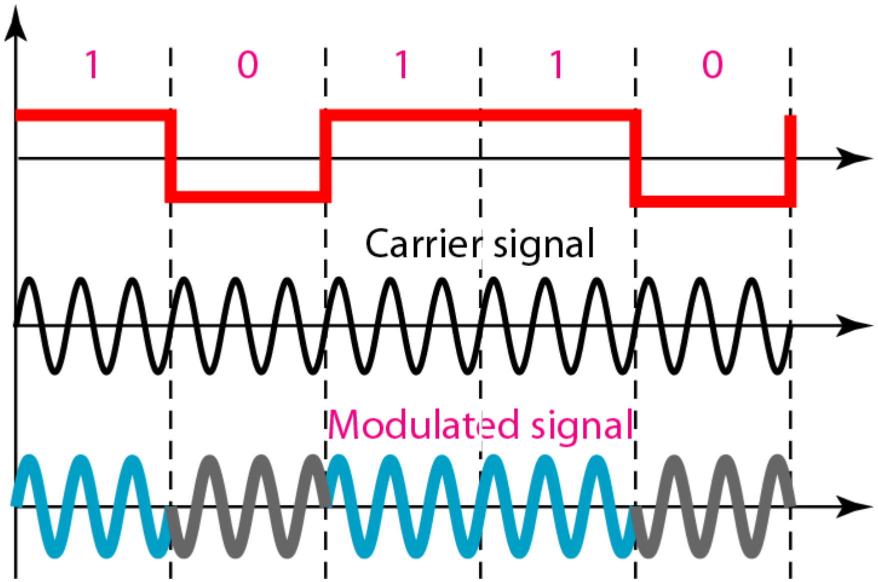


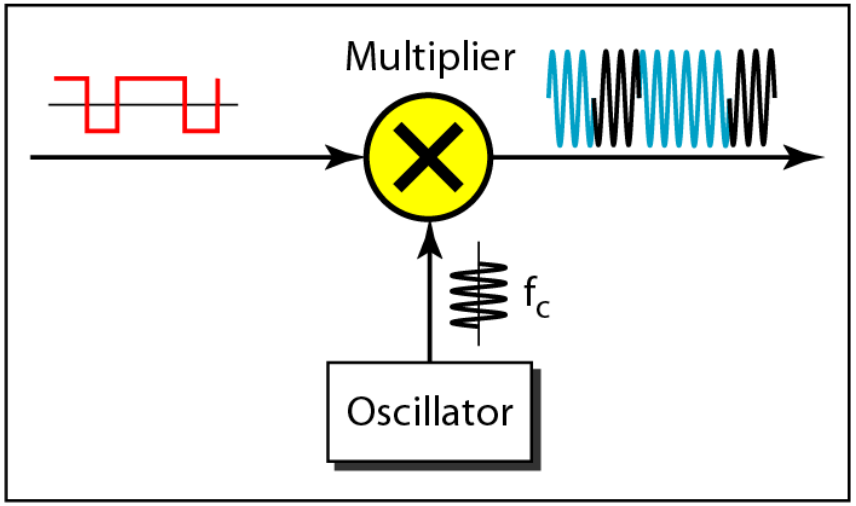


$$s(t) = \begin{cases} A\cos(2\pi f_1 t) & \text{binary 1} \\ A\cos(2\pi f_2 t) & \text{binary 0} \end{cases}$$

Implementation BPSK

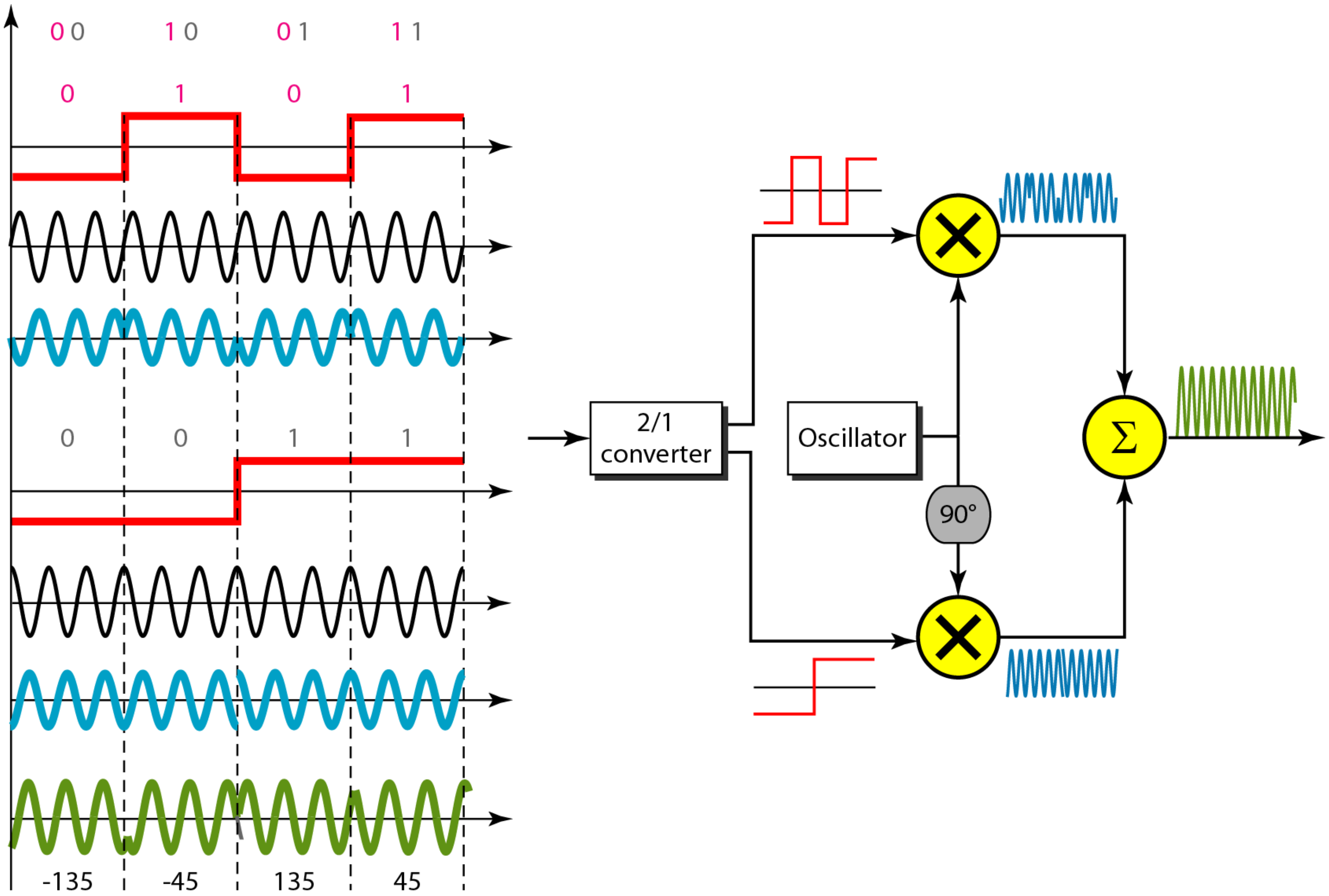
- Binary PSK is as simple as binary ASK with one big advantage-it is less susceptible to noise. In ASK, the criterion for bit detection is the amplitude of the signal; in PSK, it is the phase. Noise can change the amplitude easier than it can change the phase. In other words, PSK is less susceptible to noise than ASK. PSK is superior to FSK because we do not need two carrier signals.





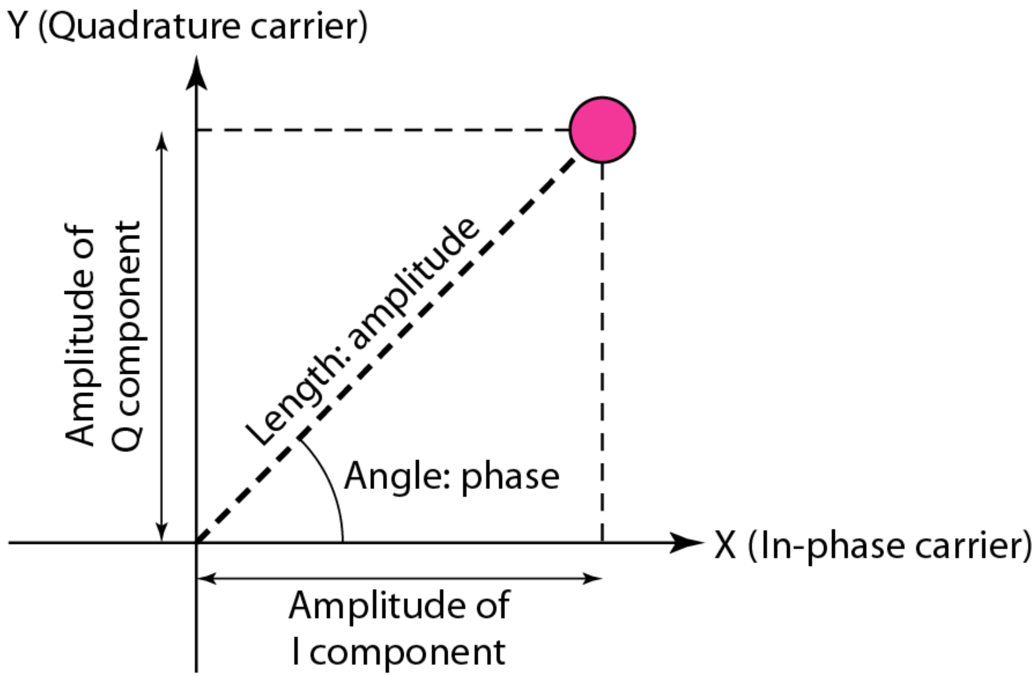
- The implementation of BPSK is as simple as that for ASK. The reason is that the signal element with phase 180° can be seen as the complement of the signal element with phase 0°. This gives us a clue on how to implement BPSK. We use the same idea we used for ASK but with a polar NRZ signal instead of a unipolar NRZ signal, as shown in Figure 5.10. The polar NRZ signal is multiplied by the carrier frequency; the 1 bit (positive voltage) is represented by a phase starting at 0°; the 0 bit (negative voltage) is represented by a phase starting at 180°.

Quadrature Phase Shift Keying (QPSK)



Concept of a Constellation Diagram

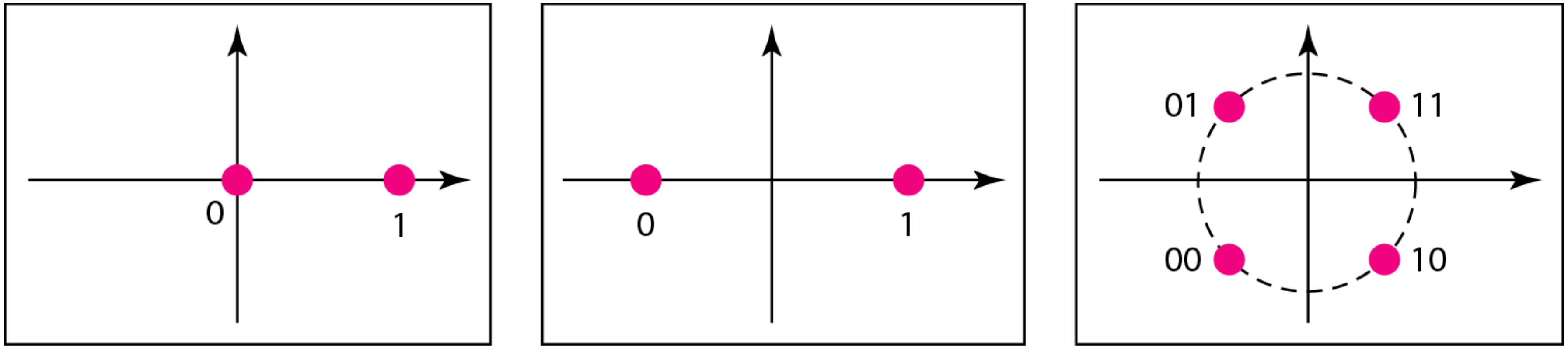
- A constellation diagram can help us define the amplitude and phase of a signal element, particularly when we are using two carriers (one in-phase and one quadrature), The diagram is useful when we are dealing with multilevel ASK, PSK, or QAM (see next section). In a constellation diagram, a signal element type is represented as a dot. The bit or combination of bits it can carry is often written next to it.



Quadrature Amplitude Modulation

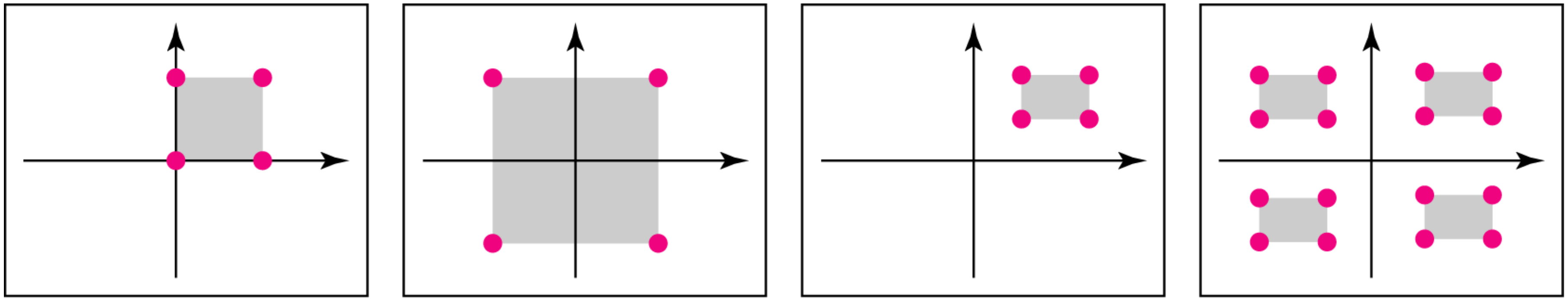
- PSK is limited by the ability of the equipment to distinguish small differences in phase. This factor limits its potential bit rate. So far, we have been altering only one of the three characteristics of a sine wave at a time; but what if we alter two? Why not combine ASK and PSK? The idea of using two carriers, one in-phase and the other quadrature, with different amplitude levels for each carrier is the concept behind quadrature amplitude modulation (QAM).

- Show the constellation diagrams for an ASK (OOK), BPSK, and QPSK signals.



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

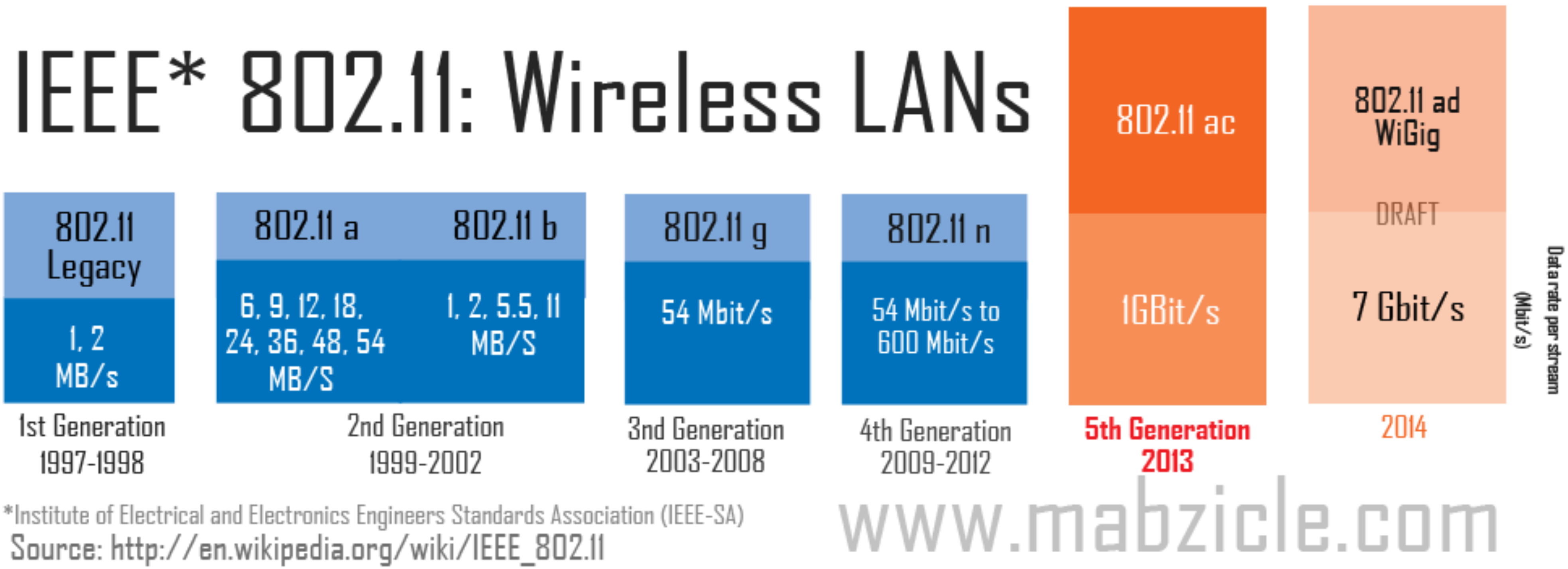
- The possible variations of QAM are numerous. Figure below shows some of these schemes. Figure a shows the simplest 4-QAM scheme (four different signal element types) using a unipolar NRZ signal to modulate each carrier. This is the same mechanism we used for ASK (OOK). Part b shows another 4-QAM using polar NRZ, but this is exactly the same as QPSK. Part c shows another QAM-4 in which we used a signal with two positive levels to modulate each of the two carriers. Finally, Figure d shows a 16-QAM constellation of a signal with eight levels, four positive and four negative.



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

QAM Implementation

- A variety of communication protocols implement quadrature amplitude modulation (QAM). Current protocols such as 802.11b wireless Ethernet (Wi-Fi) and digital video broadcast (DVB), for example, both utilize 64-QAM modulation. In addition, emerging wireless technologies such as Worldwide Interoperability for Microwave Access (WiMAX), 802.11n, and HSDPA/HSUPA (a new cellular data standard) will implement QAM as well. Thus, understanding QAM is important because of its widespread use in current and emerging technologies.
- source: http://www.ni.com/white-paper/3896/en/


IEEE* 802.11: Wireless LANs
802.11 Legacy
1, 2 MB/s
1st Generation 1997-1998
802.11 a
6, 9, 12, 18, 24, 36, 48, 54 MB/S
802.11 b
1, 2, 5.5, 11 MB/S
2nd Generation 1999-2002
802.11 g
54 Mbit/s
3nd Generation 2003-2008
802.11 n
54 Mbit/s to 600 Mbit/s
4th Generation 2009-2012
802.11 ac
1GBit/s
5th Generation 2013
802.11 ad WiGig
DRAFT
7 Gbit/s
2014
Data rate per stream (Mbit/s)
*Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA)
Source: http://en.wikipedia.org/wiki/IEEE_802.11
www.mabzicle.com

	802.11ac	802.11ad	802.11af "White-Fi"	802.11ah
Bands	5 GHz	60 GHz	TV White Spaces 54 to 790 MHz	< 1 GHz (ISM Bands vary by country)
Modulation Schemes	BPSK to 256-QAM	BPSK to 64-QAM	BPSK to 256-QAM	BPSK to 256-QAM
Channel Architecture	OFDM	OFDM and Single Carrier	OFDM	OFDM
Channel Bandwidth	20, 40, 80, 80 + 80, and 160 MHz	2.16 GHz	6, 7, and 8 MHz	1, 2, 4, 8, and 16 MHz
Year Introduced	Draft in 2011 Finalized in 2014	2012 Wi-Gig in 2016	2013	Will be Finalized In Early 2016