Chapter 5: Analog Transmission

Outline

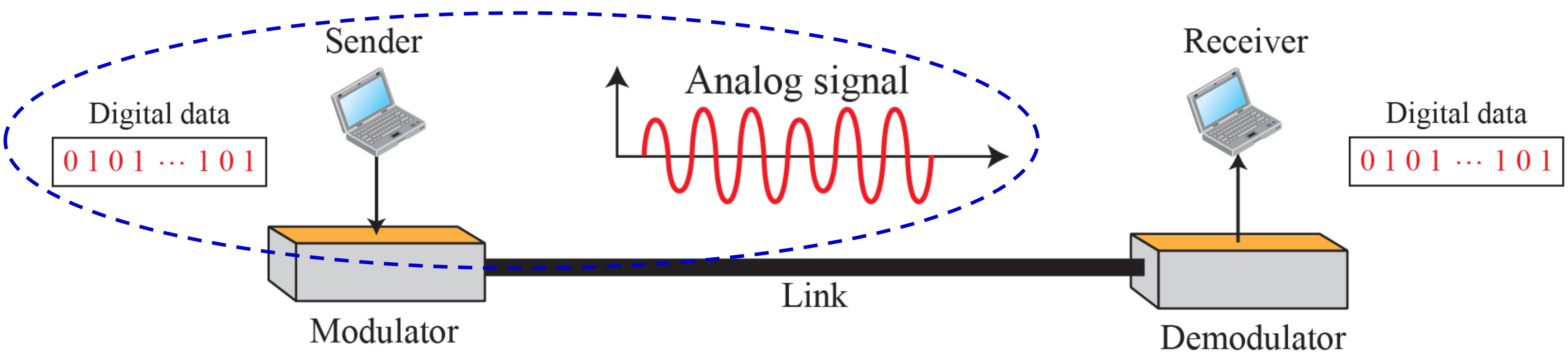
5.1 DIGITAL-TO-ANALOG CONVERSION

5.2 ANALOG-TO-ANALOG CONVERSION

5-1 DIGITAL-TO-ANALOG CONVERSION

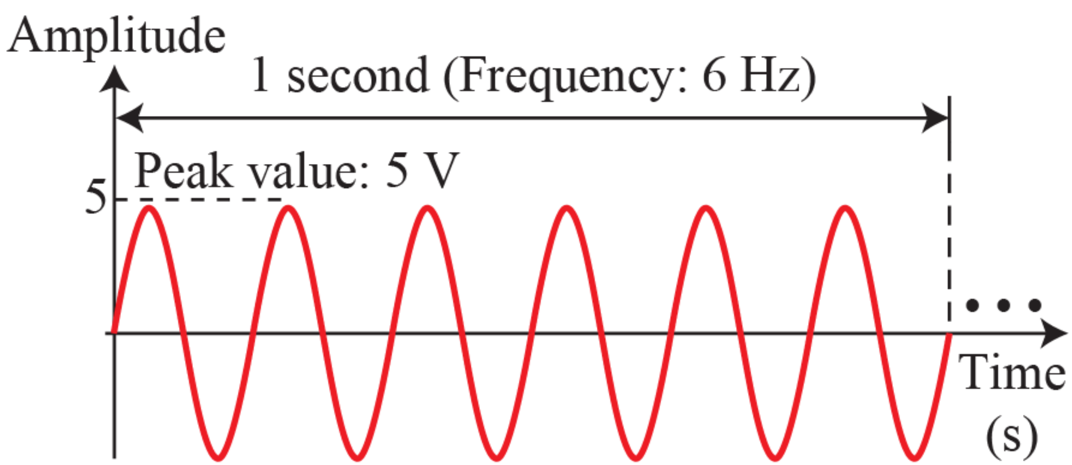
Digital-to-analog ***conversion is the process of*** ***changing*** ***one of the*** ***characteristics*** ***of an*** ***analog signal*** ***based on*** ***the information in*** ***digital data***.

The relationship between the ***digital data***, ***the*** ***digital-to-analog*** ***modulating process and the resultant*** ***analog signal*** ***is shown below:***



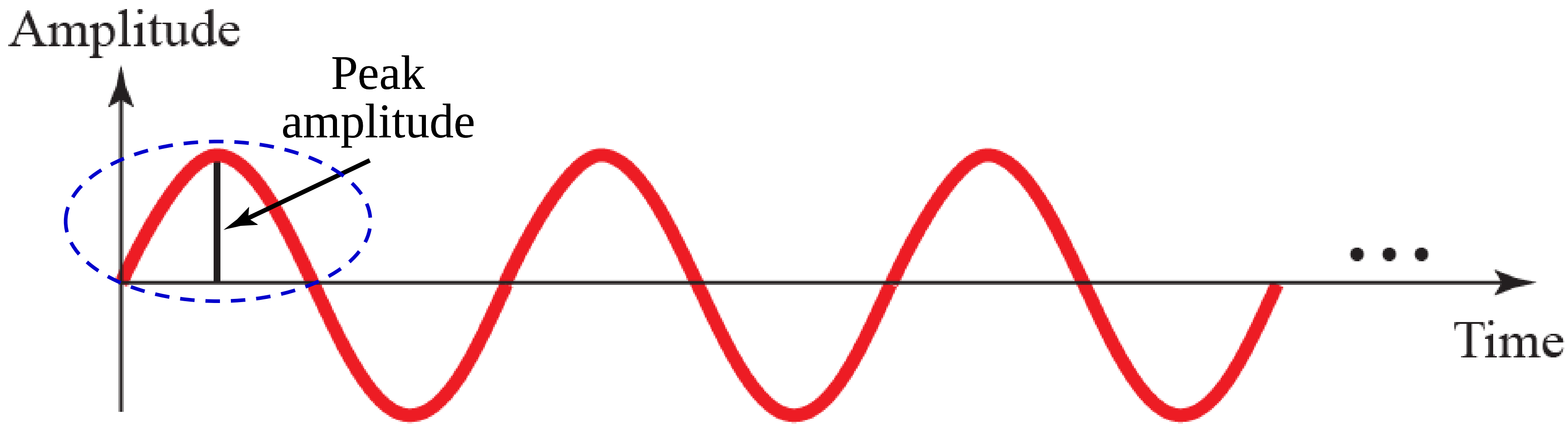
3.2.1 Sine Wave

Recall that the sine wave is the most fundamental form of a periodic analog signal. It is comprehensively defined by its peak amplitude, frequency, and phase. The time-domain plot shows changes in signal amplitude with respect to time.

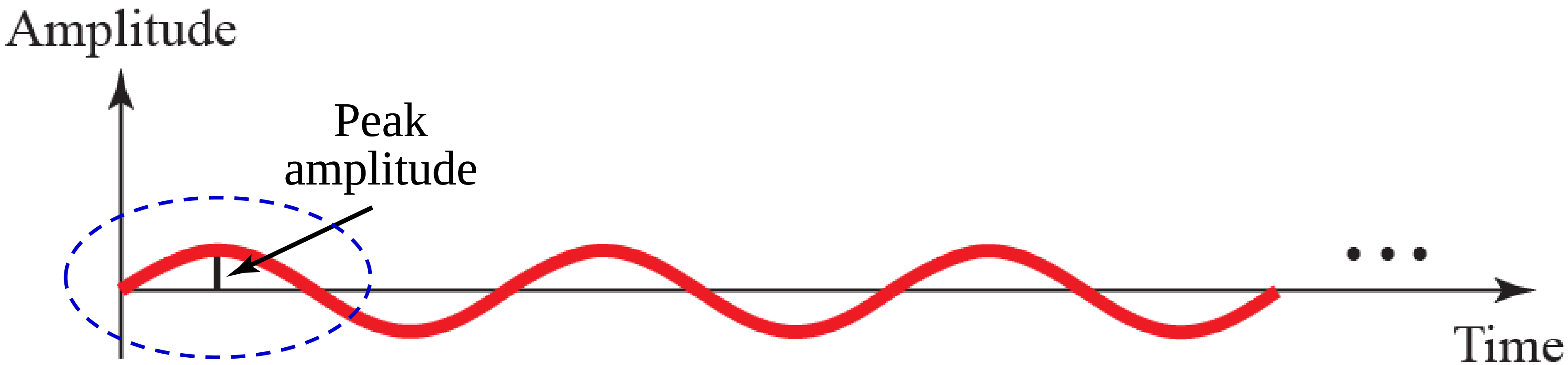


a. A sine wave in the time domain

Figure 3.4: ***Two signals with <u>different amplitudes</u>***

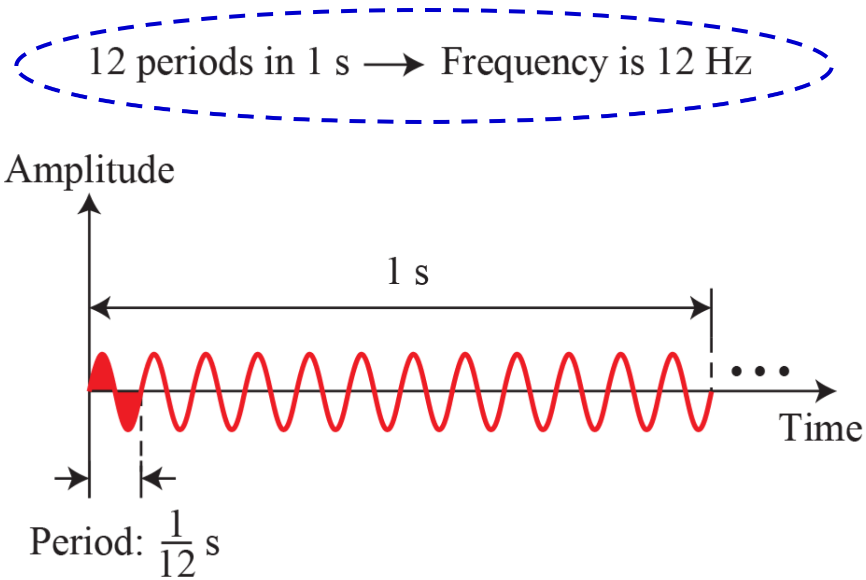


a. A signal with high peak amplitude

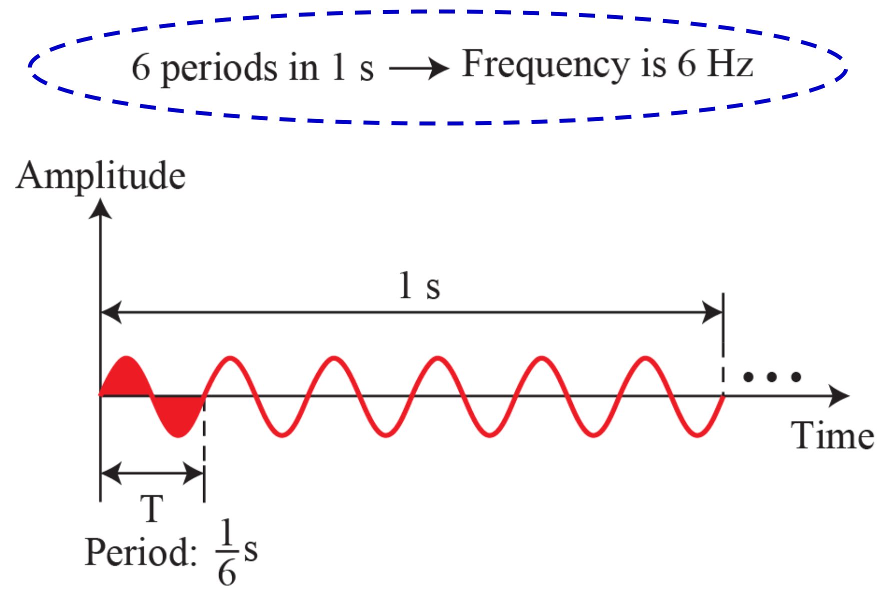


b. A signal with low peak amplitude

Figure 3.5: Two signals with <u>different frequencies</u>



a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

Figure 3.6: Three signals with different phases

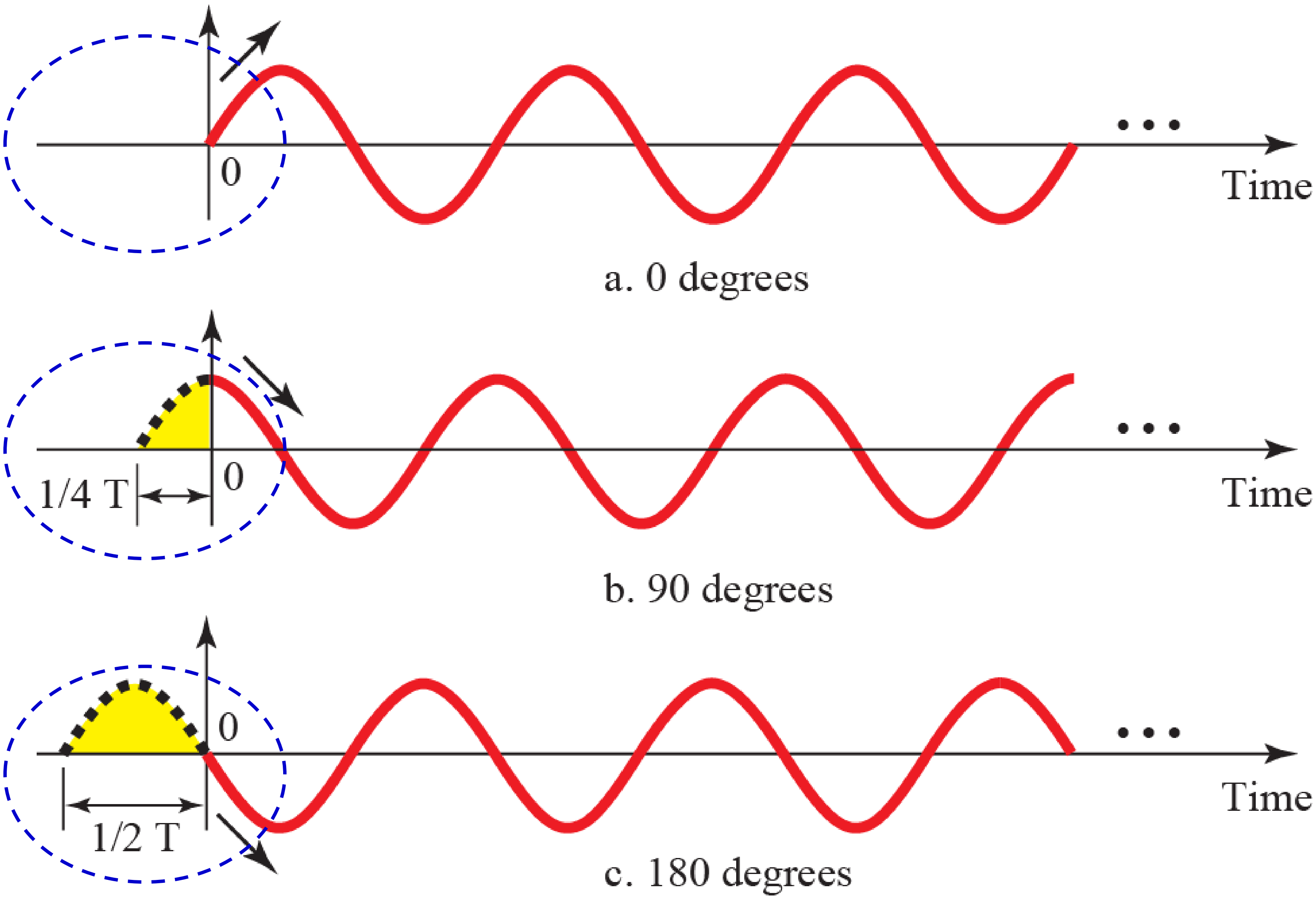
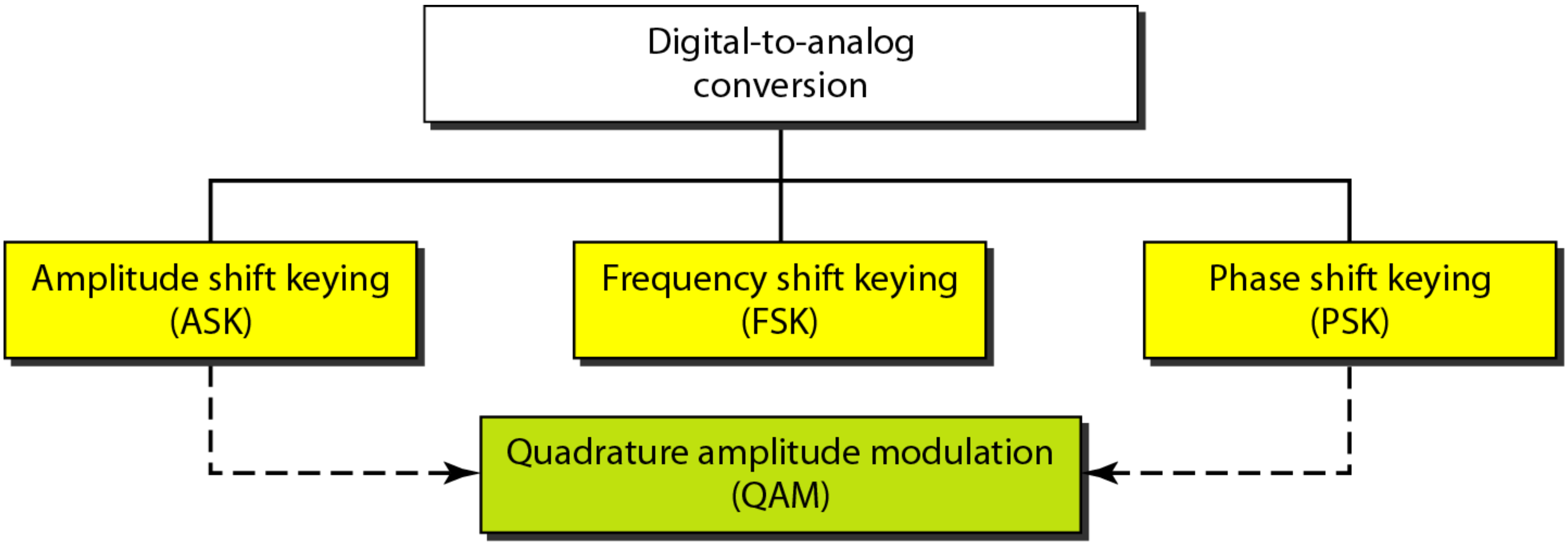
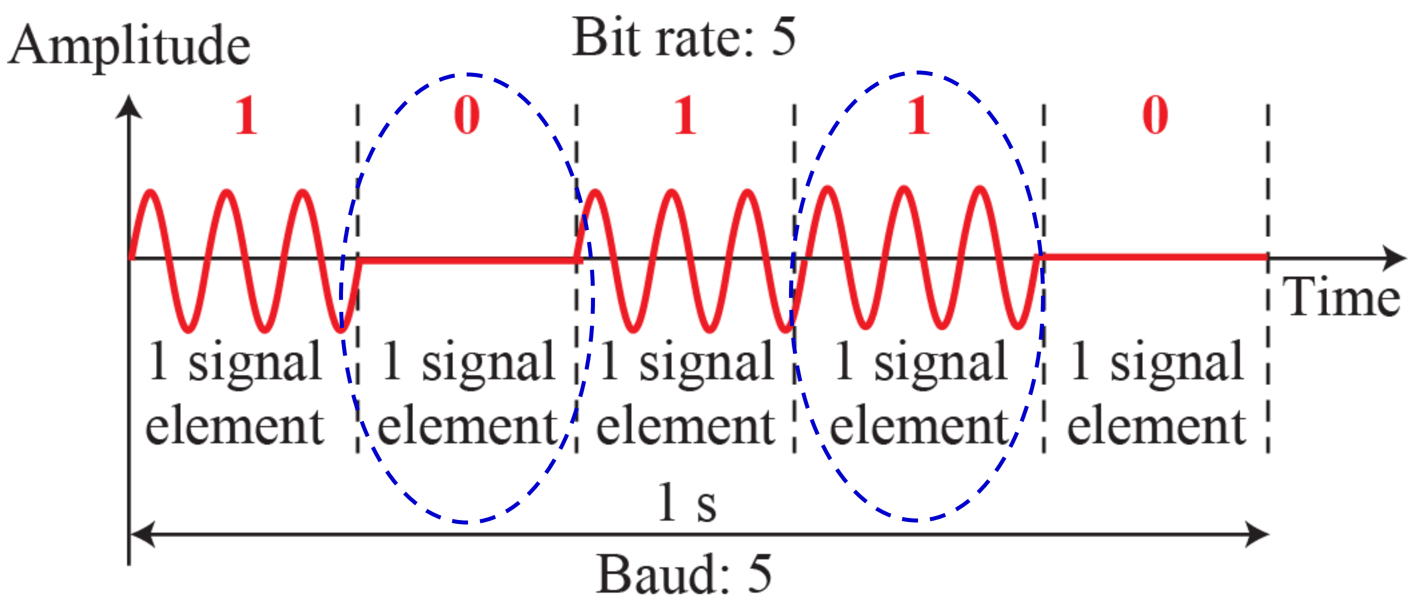


Figure 5.2: Types of digital to analog conversion



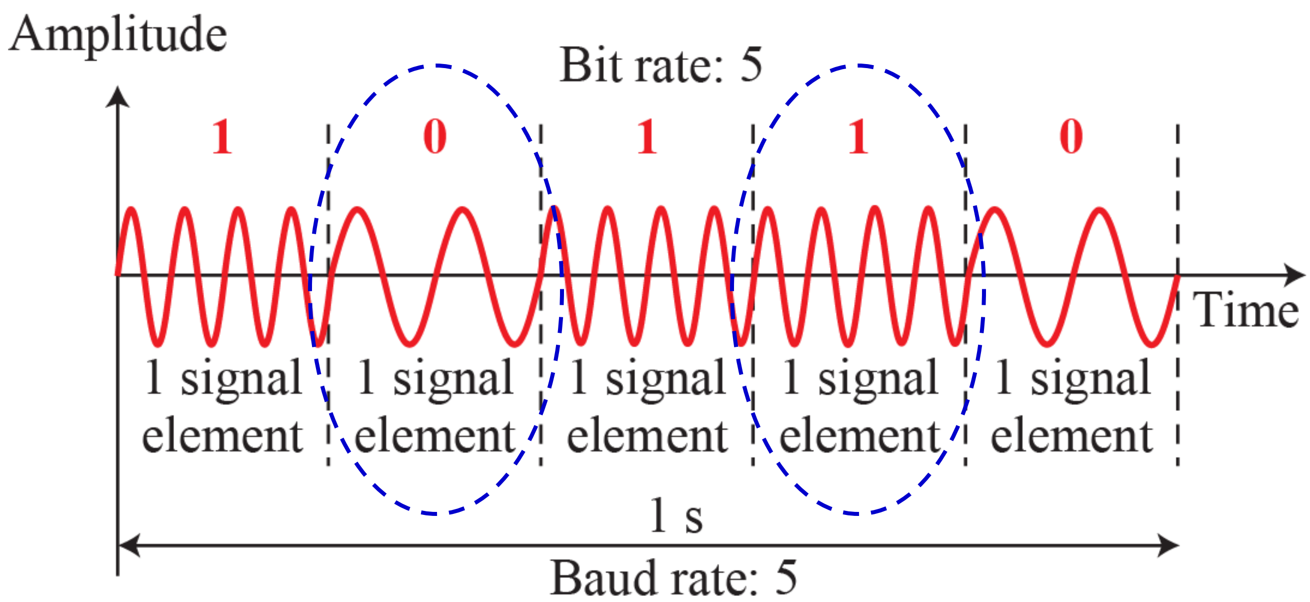
5.1.2 Amplitude Shift Keying (ASK)

In amplitude shift keying (ASK), the amplitude of the carrier signal is varied to create signal elements. Both the frequency and phase remain constant while the amplitude changes.



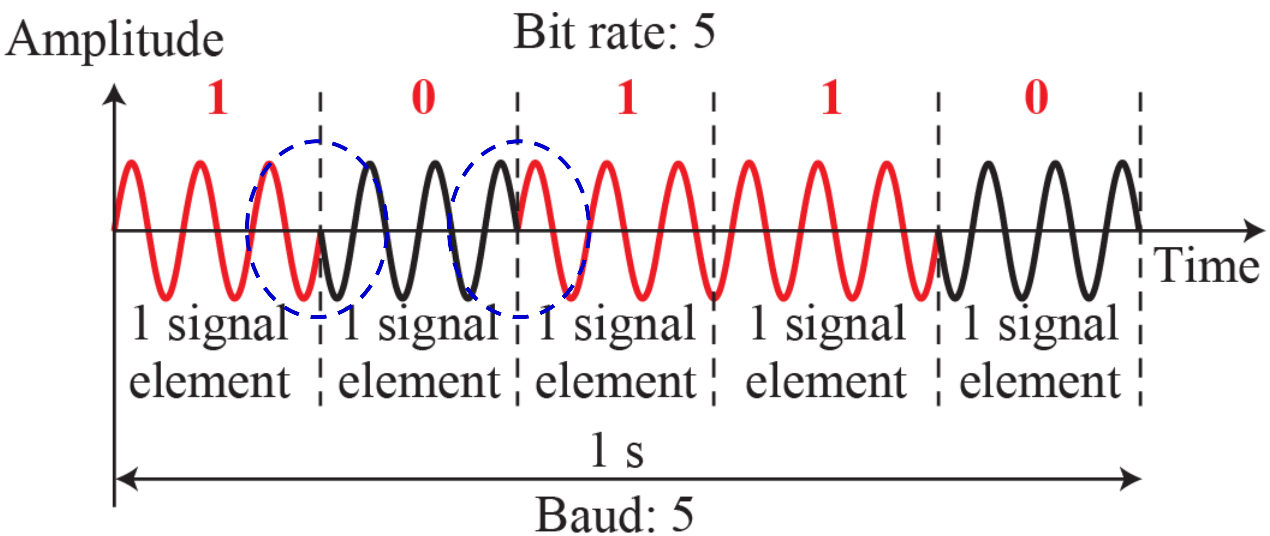
5.1.3 Frequency Shift Keying (FSK)

In frequency shift keying (FSK), the <u>frequency</u> of the carrier signal is <u>varied</u> to represent data. Both the peak amplitude and phase remain constant for all signal elements.



5.1.4 Phase Shift Keying (PSK)

In phase shift keying (PSK), the <u>phase</u> of the carrier is <u>varied</u> to represent two or more different signal elements. Both the peak amplitude and frequency remain constant as the phase changes.



Advantages:

1) **PSK is <u>less susceptible to noise</u> than ASK (noise changes amplitude easier than it can change the phase)**
2) **PSK <u>does not require multiple carrier signals</u> as compared to FSK.**

Disadvantage:

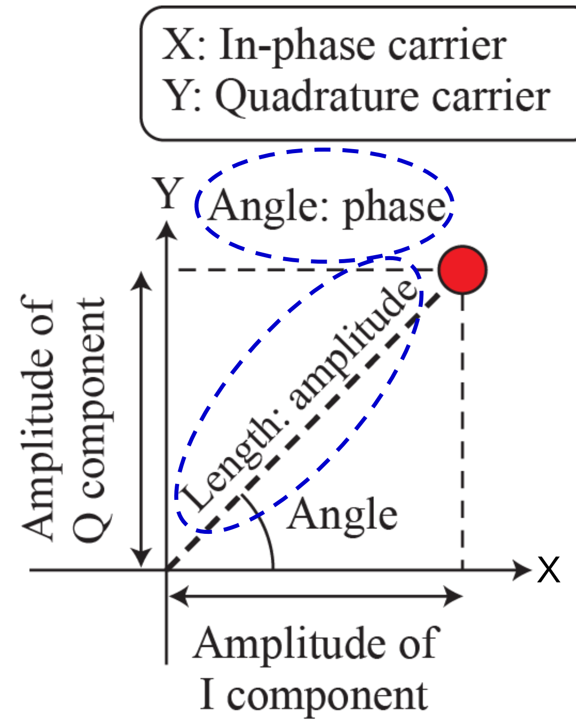
1) **PSK requires more <u>sophisticated hardware</u> to be able to distinguish between phases.**

5.1.5 Quadrature Amplitude Modulation (QAM)

So far, we have been altering only one of the three characteristics of a sine wave at a time; but what if we <u>alter two</u> and combine ASK (<u>amplitude</u>) and PSK (<u>phase</u>)?

The idea of using <u>two carriers</u> (same frequency, 90° out-of-phase with each other), one <u>in-phase</u> and the other <u>quadrature</u>, with <u>different amplitude levels</u> for each carrier is the concept behind <u>quadrature amplitude modulation</u> (QAM).

Constellation Diagram



Constellation Diagrams

Constellation diagrams define the <u>amplitude</u> and <u>phase</u> of a signal element, particularly when two carriers (in-phase and quadrature) are used. The diagrams are useful when dealing with <u>multi-level</u> ASK, PSK and QAM.

The diagram has <u>two axes</u>:

1. **<u>X-axis</u> relates to the <u>in-phase carrier</u>**
2. **<u>Y-axis</u> relates to the <u>quadrature carrier</u>**

For <u>each point</u> (symbol) on the diagram, <u>four pieces of information</u> can be deduced:

i. ***Peak amplitude of in-phase (I) component***
ii. ***Peak amplitude of quadrature (Q) component***
iii. ***<u>Peak signal amplitude of the signal element</u>***
iv. ***<u>Phase of the signal element</u>***

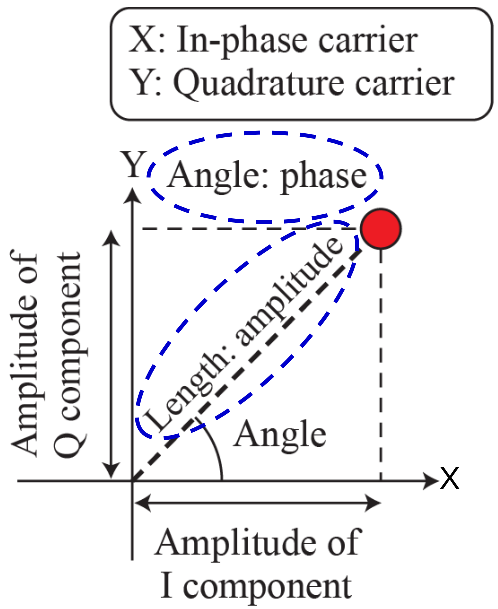
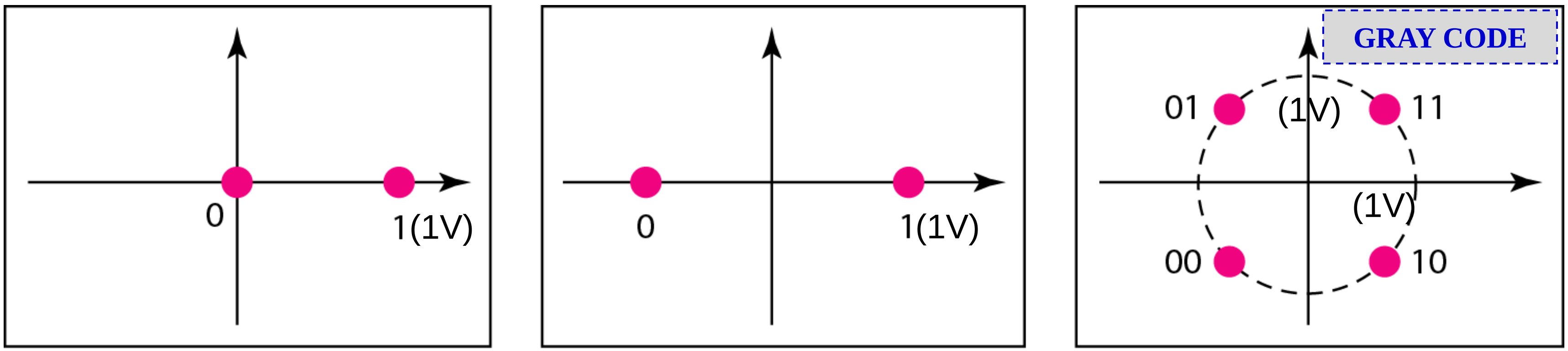


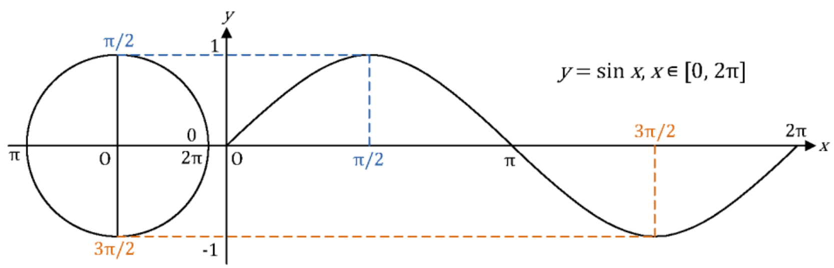
Figure 5.13: *Constellation diagrams for BASK, BPSK and QPSK*



a. BASK	b. BPSK	c. QPSK

Legend: **B**: Binary (2 points – 1 bit) **Q**: Quadrature (4 points – 2 bits)

Unit Circle – Sine Wave Relationship



<u>B</u>ASK: **uses only an <u>in-phase</u> carrier ➔ two points are on the X-axis.**

Binary 0 has an amplitude of <u>0 V</u>;
Binary 1 has an amplitude of <u>1 V</u>.

<u>B</u>PSK: **uses only an <u>in-phase</u> carrier ➔ two points are on the X-axis.**

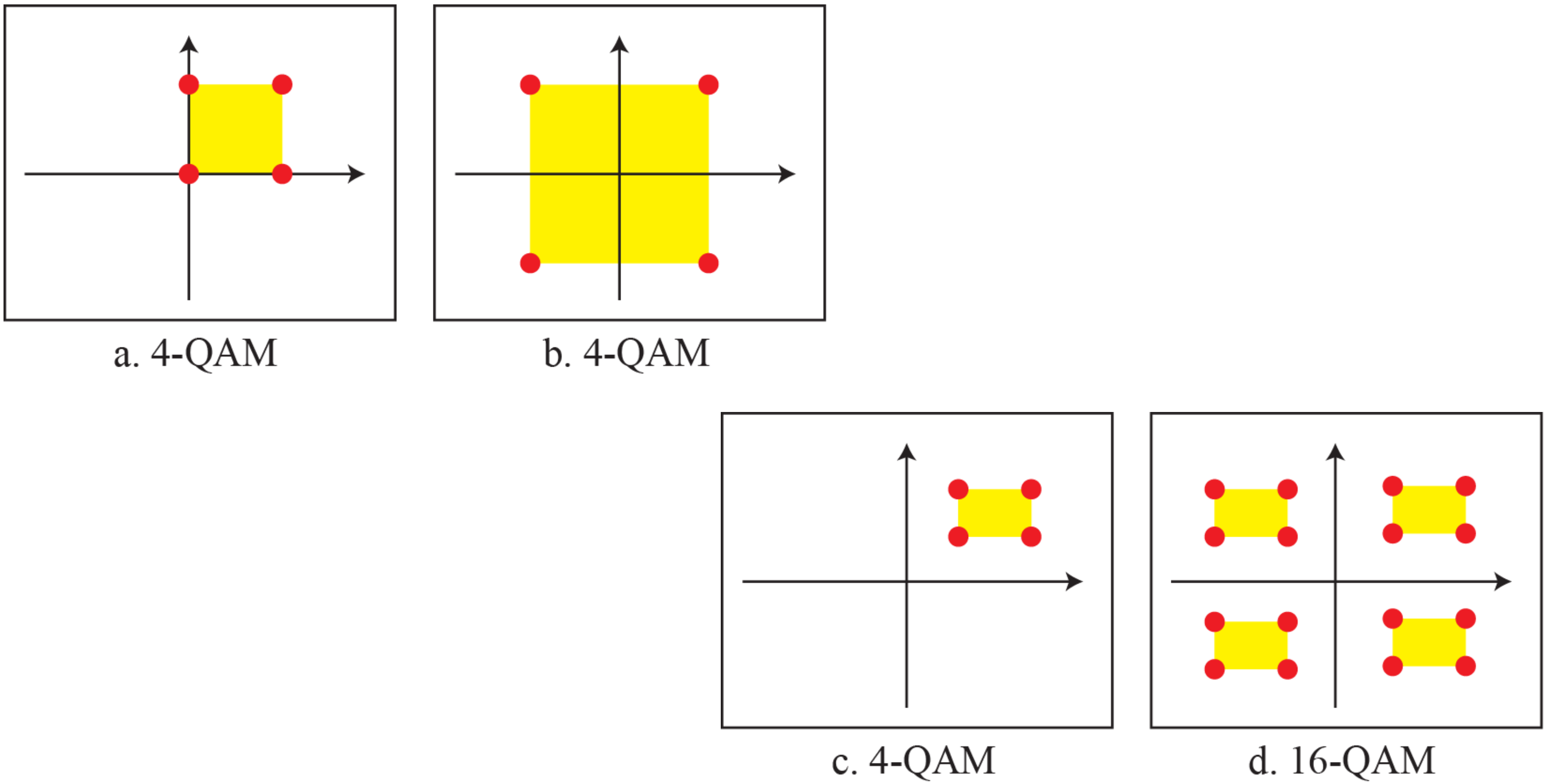
Binary 0 has an amplitude <u>1 V</u> (<u>180°</u> out of phase);
Binary 1 has an amplitude of <u>1 V</u> (<u>0°</u>).

<u>Q</u>PSK: **uses both <u>in-phase</u> and <u>quadrature</u> carriers ➔ the point representing '11' is made of 2 combined signal elements (in-phase and quadrature), each with an amplitude of 1 V.**

The amplitude of '11' is <u>√2 V</u> (Pythagoras' Theorem) at <u>45°</u>. The other signal elements also have amplitudes of <u>√2 V</u> but at <u>135°</u>, <u>-135°</u> and <u>-45°</u>.

Figure 5.14: Constellation diagrams for QAM

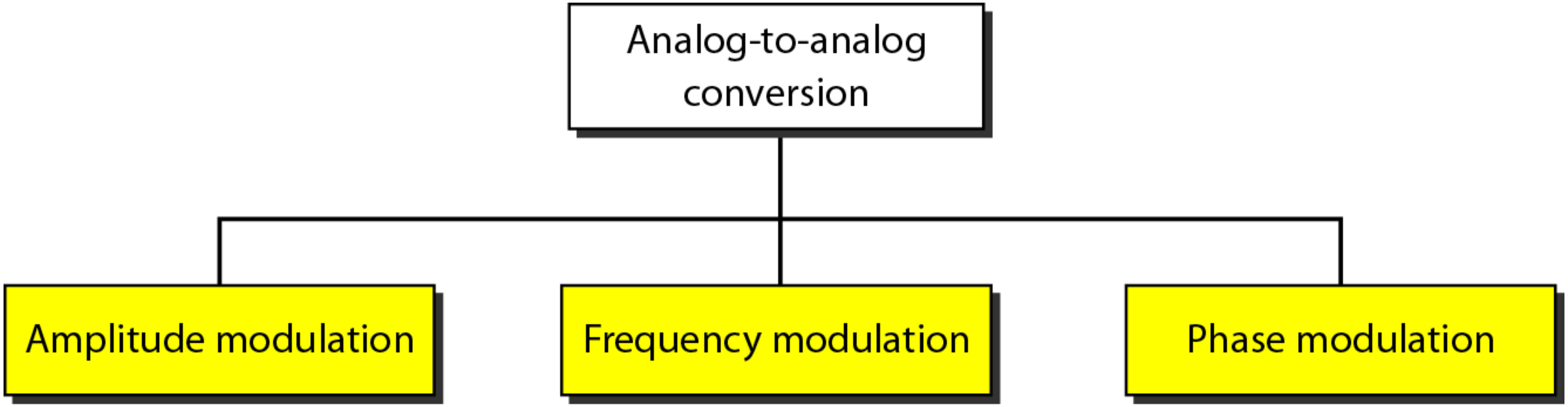
There are numerous possible variations of QAM:



5-2 ANALOG-TO-ANALOG CONVERSION

Analog-to-analog ***conversion, or analog modulation, is the*** ***representation*** ***of*** ***analog data*** ***by an*** ***analog signal*****.**

Modulation is needed if the medium is ***bandpass*** ***in nature or if only a bandpass channel is available.***

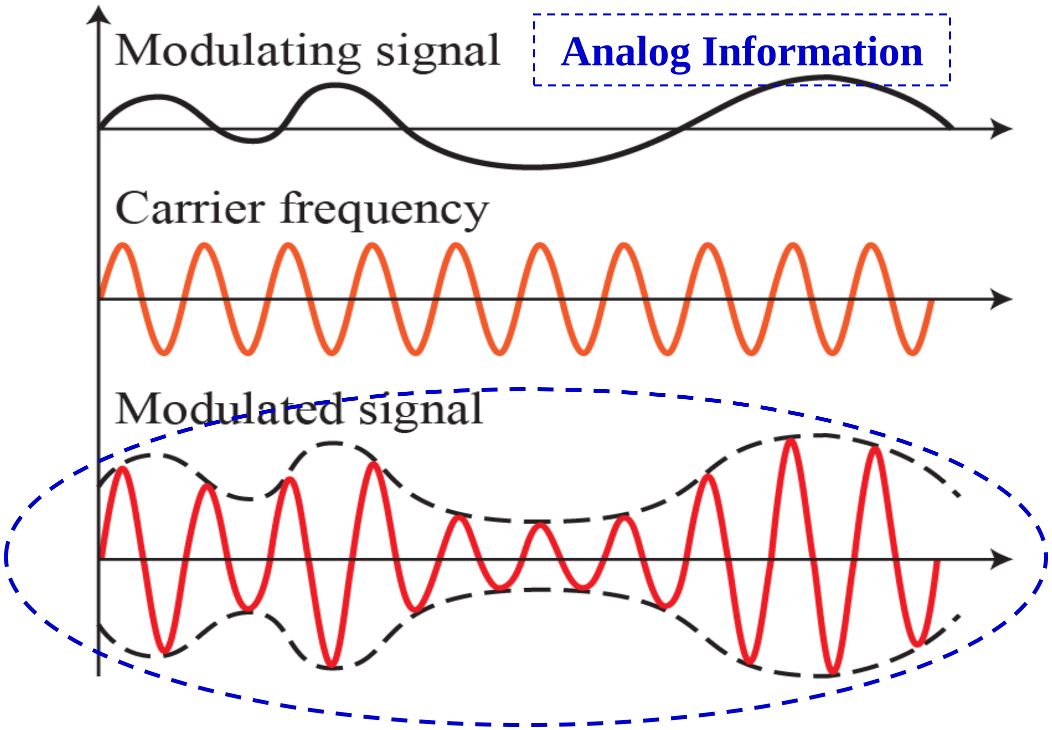


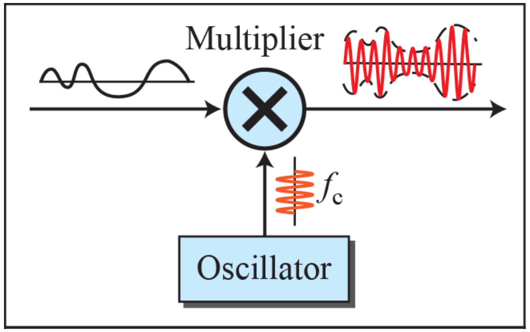
5.2.1 Amplitude Modulation (AM)

In AM transmission, the carrier signal is modulated so that its amplitude varies with the changing amplitudes of the modulating signal.

The frequency and phase of the carrier remain the same; only the amplitude changes to follow variations in the information.

Figure 5.16: *Amplitude modulation*





The <u>amplitude of the carrier signal</u> needs to be <u>changed</u> according to the <u>amplitude of the modulating signal</u>. The <u>modulating signal</u> is the <u>envelope</u> of the <u>carrier</u>.

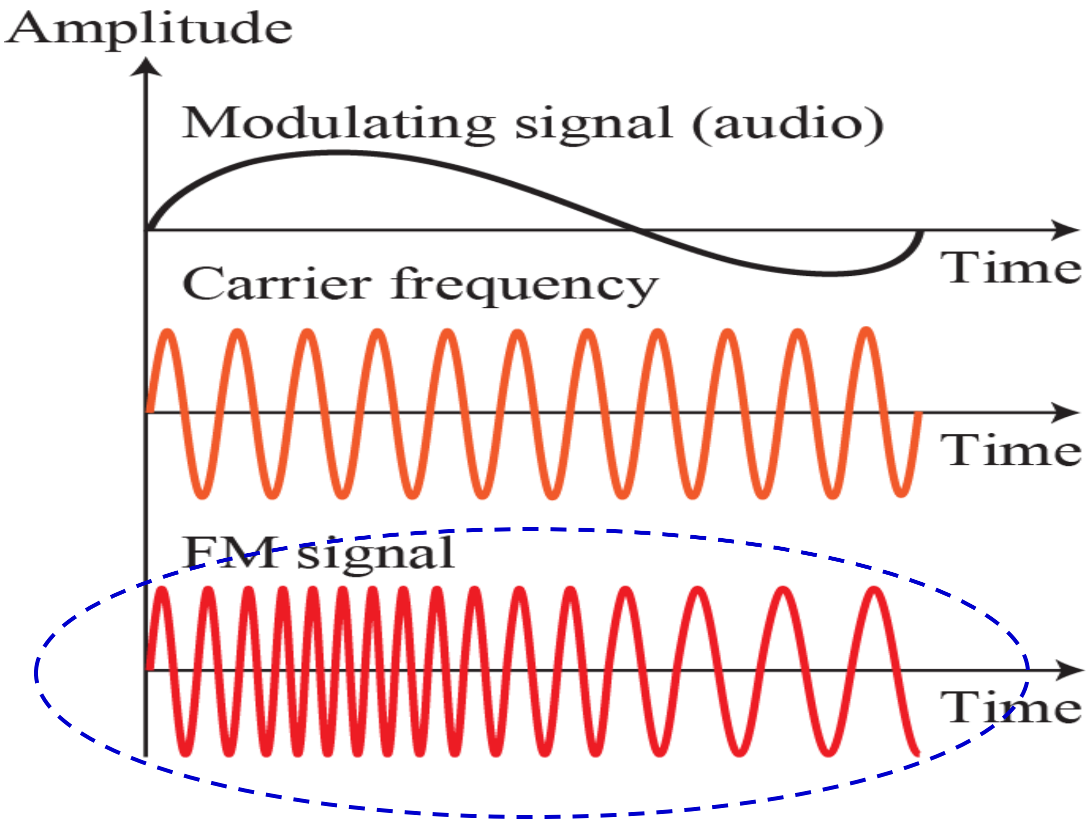
AM is normally implemented using a simple multiplier.

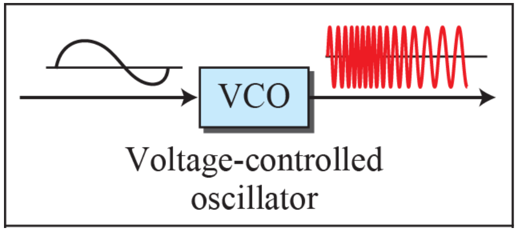
5.2.2 Frequency Modulation (FM)

In FM transmission, the frequency of the carrier signal is modulated to follow the changing amplitude of the modulating signal.

The peak amplitude and phase of the carrier signal remain constant.

Figure 5.18: ***Frequency modulation***





As the <u>amplitude</u> of the information signal changes, the <u>frequency</u> of the carrier changes correspondingly.

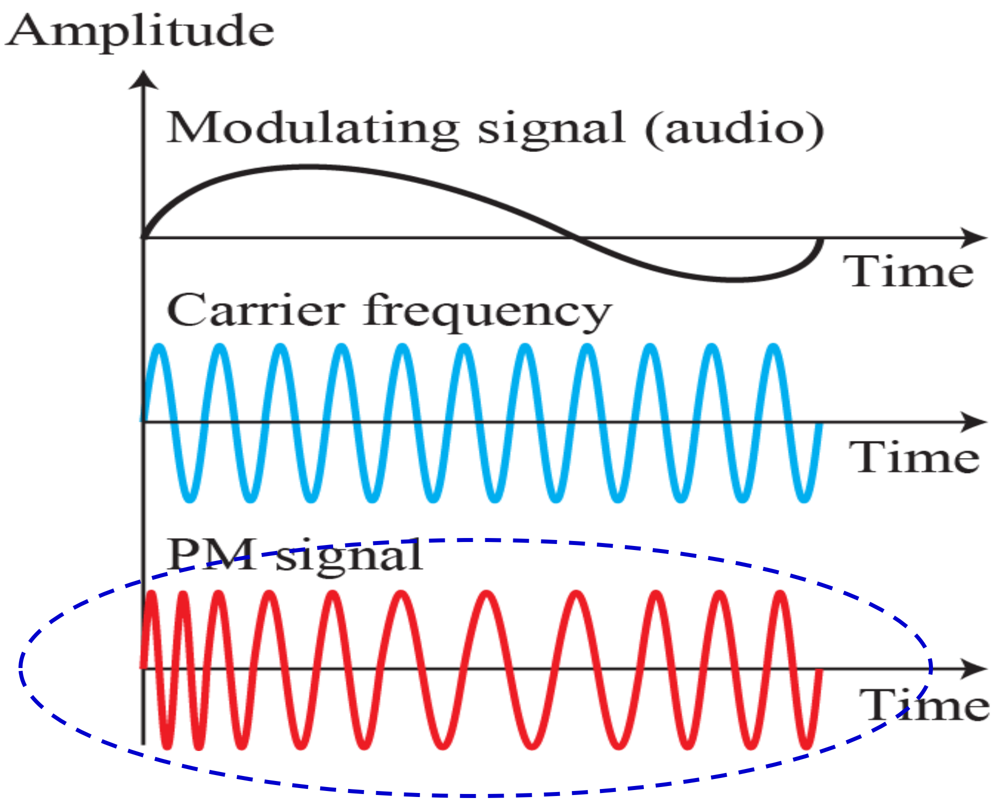
FM is normally implemented by using a voltage-controlled oscillator as with FSK.

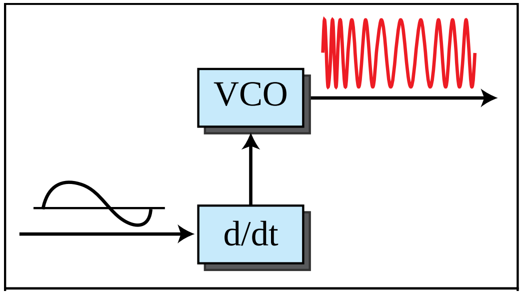
5.2.3 Phase Modulation (PM)

In PM transmission, the phase of the carrier signal is modulated to follow the changing amplitude of the modulating signal. The peak amplitude and frequency of the carrier signal remain constant.

PM can be mathematically shown (Appendix E) to be the same as FM with a difference: in PM, the instantaneous change in the carrier frequency is proportional to the derivative of the amplitude of the modulating signal (as opposed to the amplitude of the modulating signal in FM).

Figure 5.20: Phase modulation





As the <u>amplitude</u> of the information signal changes, the <u>phase</u> of the carrier changes correspondingly.

PM is normally implemented by using a voltage-controlled oscillator along with a derivative.