Data Communication

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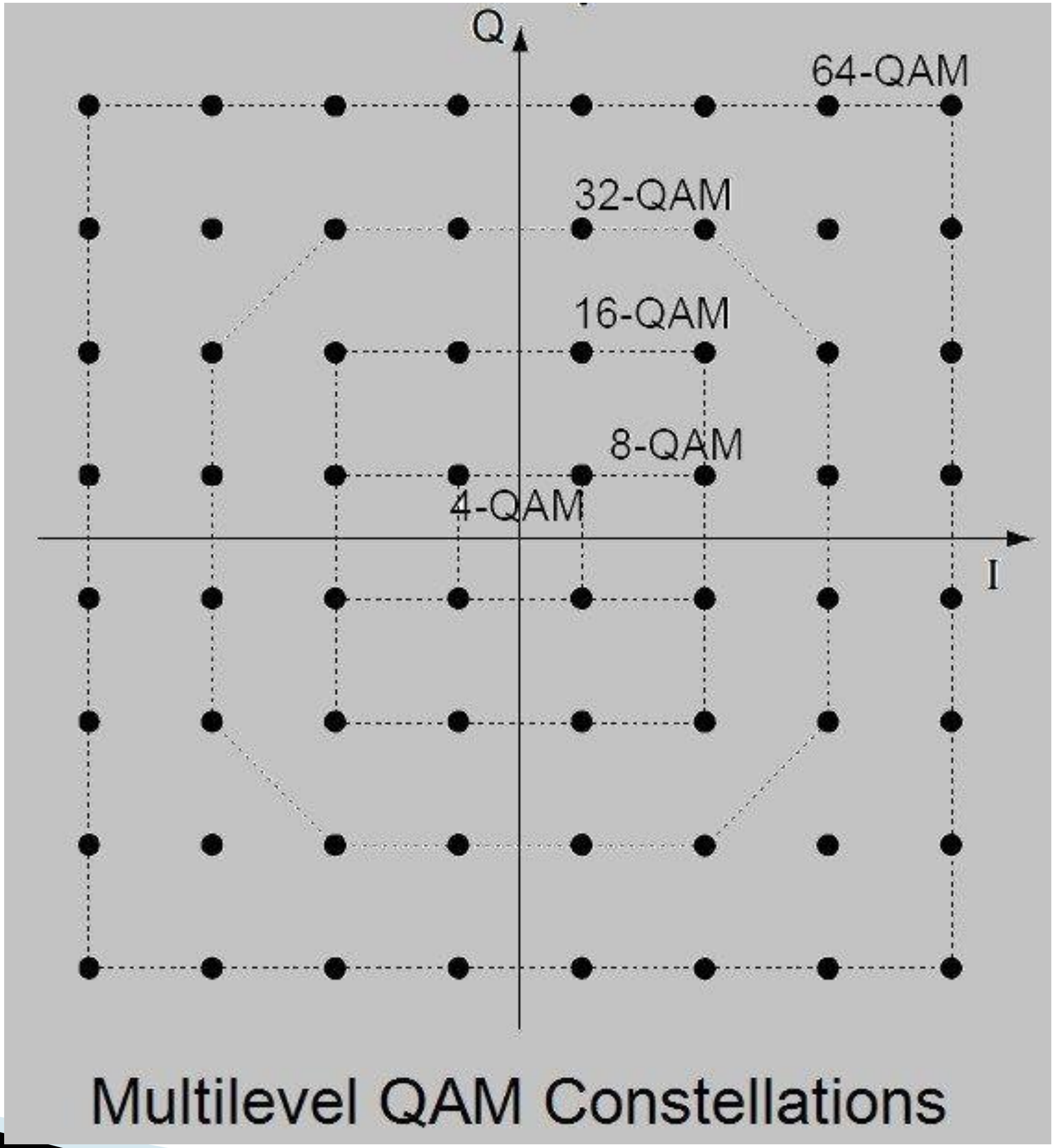
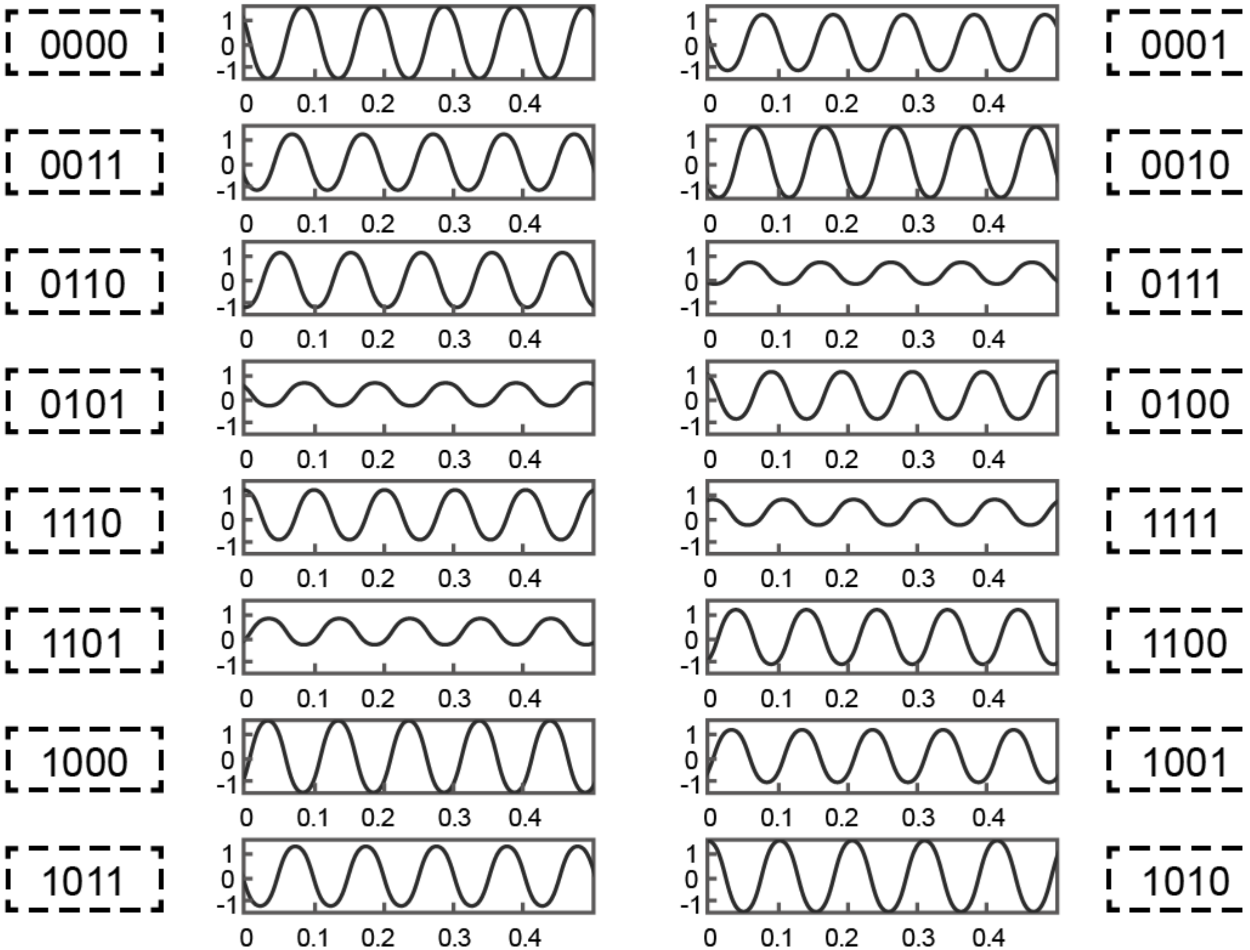
5.1.5 Quadrature Amplitude Modulation

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).**

Quadrature amplitude modulation is a combination of ASK and PSK.


Q
64-QAM
32-QAM
16-QAM
8-QAM
4-QAM
I
Multilevel QAM Constellations



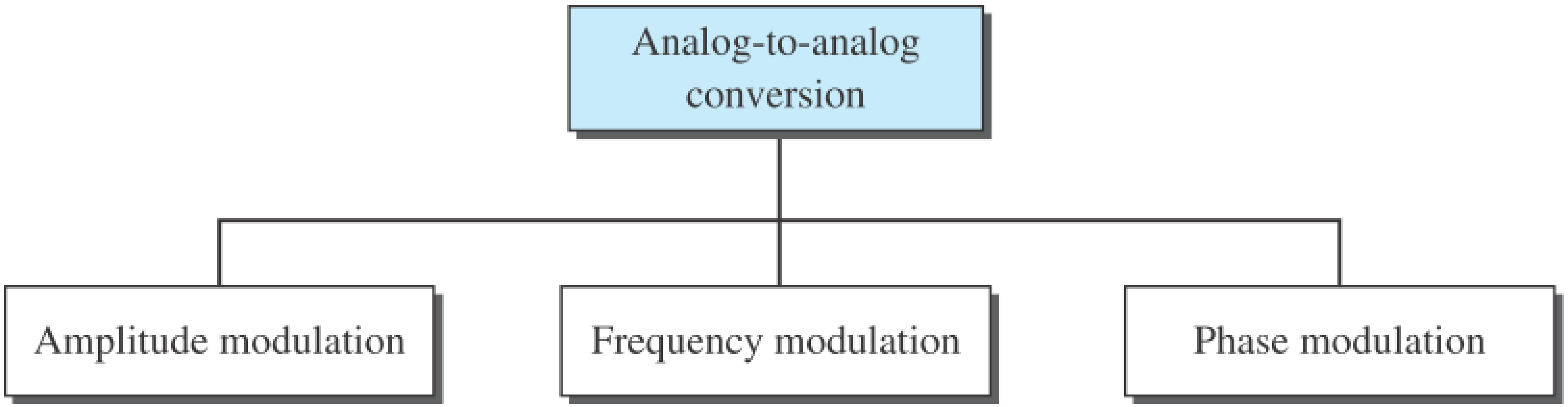
16-QAM diagram

Bandwidth for QAM

The minimum bandwidth required for QAM transmission is the same as that required for ASK and PSK transmission. QAM has the same advantages as PSK over ASK.

Analog-to-analog conversion can be accomplished in three ways: **amplitude modulation (AM), frequency modulation (FM),** and **phase modulation (PM).** FM and PM are usually categorized together. See Figure 5.15.

Figure 5.15 *Types of analog-to-analog modulation*



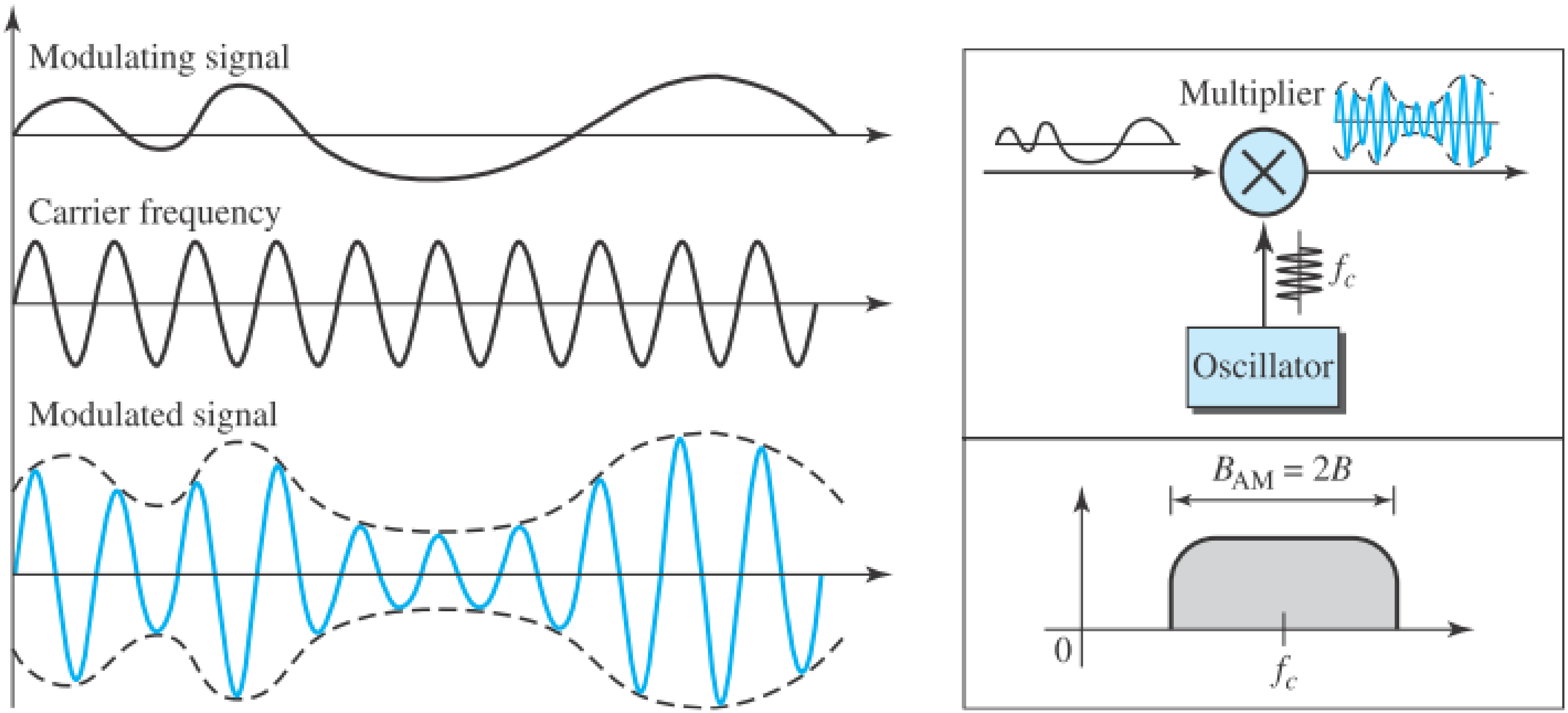
5.2.1 Amplitude Modulation (AM)

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 shows how this concept works. The modulating signal is the envelope of the carrier. As Figure 5.16 shows, AM is normally implemented by using a simple multiplier because the amplitude of the carrier signal needs to be changed according to the amplitude of the modulating signal.

AM Bandwidth

Figure 5.16 also shows the bandwidth of an AM signal. The modulation creates a bandwidth that is twice the bandwidth of the modulating signal and covers a range centered on the carrier frequency. However, the signal components above and below the carrier frequency carry exactly the same information. For this reason, some implementations discard one-half of the signals and cut the bandwidth in half.

Figure 5.16 *Amplitude modulation*



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

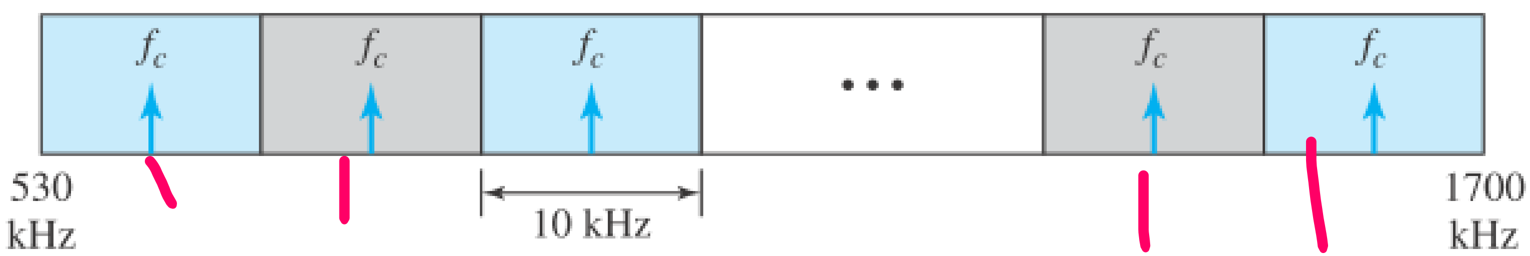
*

Standard Bandwidth Allocation for AM Radio

The bandwidth of an audio signal (speech and music) is usually 5 kHz. Therefore, an AM radio station needs a bandwidth of 10 kHz. In fact, the Federal Communications Commission (FCC) allows 10 kHz for each AM station.

AM stations are allowed carrier frequencies anywhere between 530 and 1700 kHz (1.7 MHz). However, each station's carrier frequency must be separated from those on either side of it by at least 10 kHz (one AM bandwidth) to avoid interference. If one station uses a carrier frequency of 1100 kHz, the next station's carrier frequency cannot be lower than 1110 kHz (see Figure 5.17).

Figure 5.17 *AM band allocation*



5.2.2 Frequency Modulation (FM)

In FM transmission, the frequency of the carrier signal is modulated to follow the changing voltage level (amplitude) of the modulating signal. The peak amplitude and phase of the carrier signal remain constant, but as the amplitude of the information signal changes, the frequency of the carrier changes correspondingly. Figure 5.18 shows the relationships of the modulating signal, the carrier signal, and the resultant FM signal.

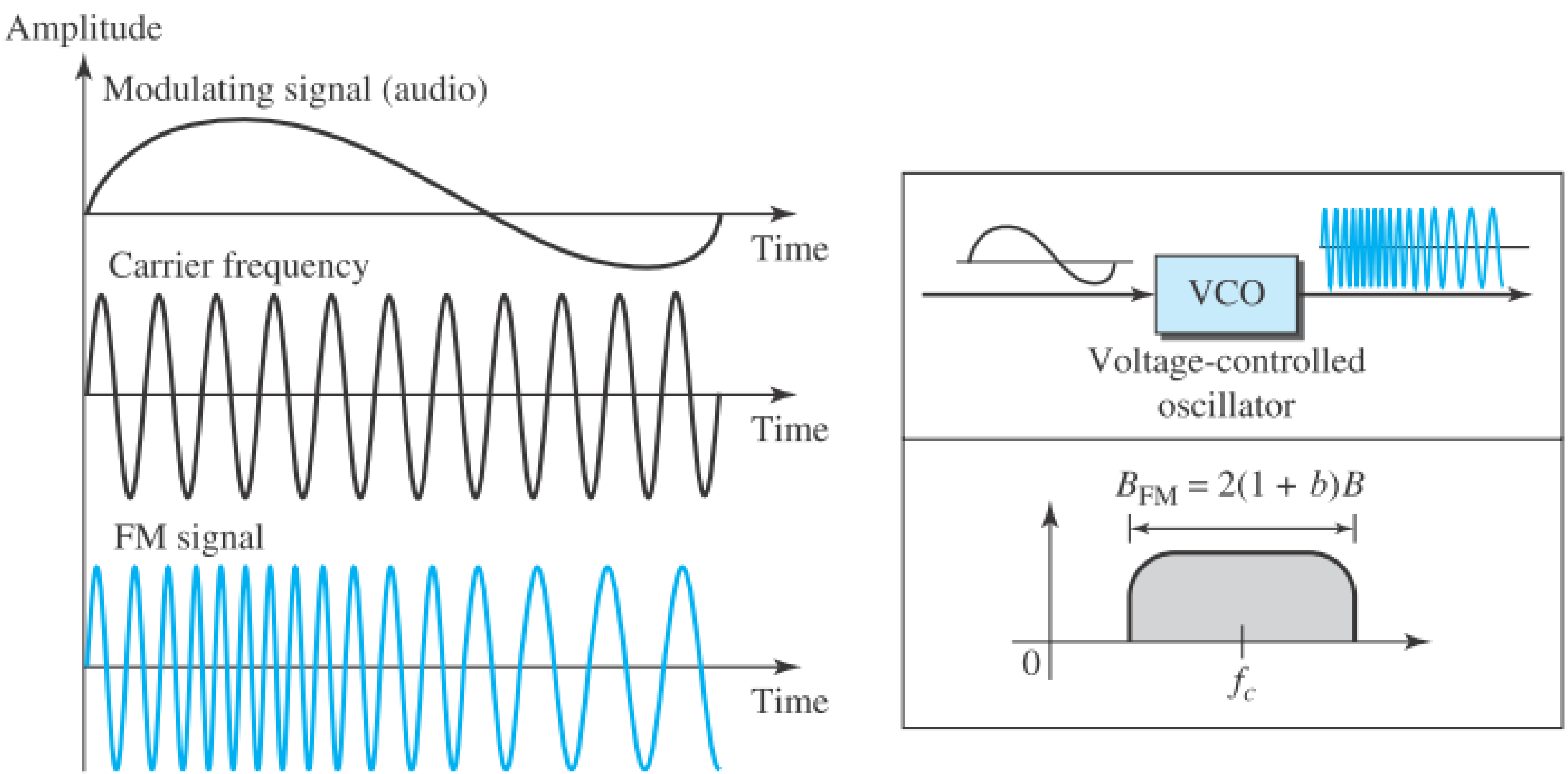
As Figure 5.18 shows, FM is normally implemented by using a voltage-controlled oscillator as with FSK. The frequency of the oscillator changes according to the input voltage which is the amplitude of the modulating signal.

FM Bandwidth

Figure 5.18 also shows the bandwidth of an FM signal. The actual bandwidth is difficult to determine exactly, but it can be shown empirically that it is several times that of the analog signal or $2(1 + \beta)B$ where β is a factor that depends on modulation technique with a common value of 4.

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

Figure 5.18 *Frequency modulation*



Standard Bandwidth Allocation for FM Radio

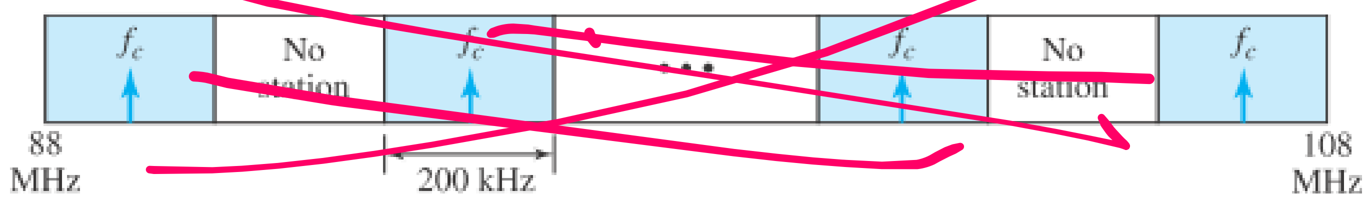
The bandwidth of an audio signal (speech and music) broadcast in stereo is almost 15 kHz. The FCC allows 200 kHz (0.2 MHz) for each station. This mean $\beta = 4$ with some extra guard band. FM stations are allowed carrier frequencies anywhere between 88 and 108 MHz. Stations must be separated by at least 200 kHz to keep their bandwidths from overlapping. To create even more privacy, the FCC requires that in a given area, only alternate bandwidth allocations may be used. The others remain unused to prevent any possibility of two stations interfering with each other. Given 88 to 108 MHz as a range, there are 100 potential FM bandwidths in an area, of which 50 can operate at any one time. Figure 5.19 illustrates this concept.

Figure 5.19 *FM band allocation*

5.2.3 Phase Modulation (PM)

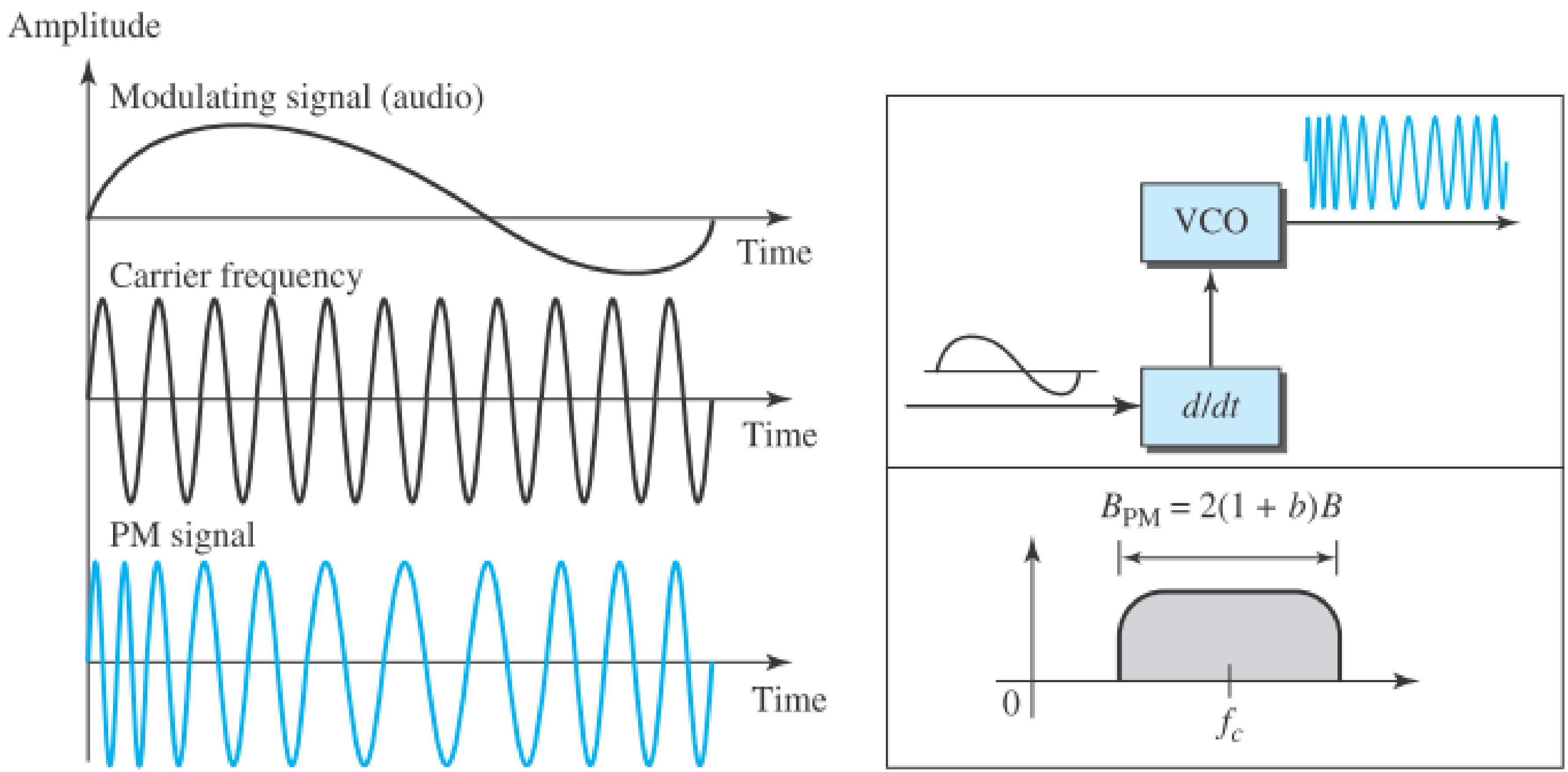
In PM transmission, the phase of the carrier signal is modulated to follow the changing voltage level (amplitude) of the modulating signal. The peak amplitude and frequency

Figure 5.19 *FM band allocation*



of the carrier signal remain constant, but as the amplitude of the information signal changes, the phase of the carrier changes correspondingly. It can be proved mathematically (see Appendix E) that PM is the same as FM with one difference. In FM, the instantaneous change in the carrier frequency is proportional to the amplitude of the modulating signal; in PM the instantaneous change in the carrier frequency is proportional to the derivative of the amplitude of the modulating signal. Figure 5.20 shows the relationships of the modulating signal, the carrier signal, and the resultant PM signal.

Figure 5.20 *Phase modulation*



As Figure 5.20 shows, PM is normally implemented by using a voltage-controlled oscillator along with a derivative. The frequency of the oscillator changes according to the derivative of the input voltage, which is the amplitude of the modulating signal.

PM Bandwidth

Figure 5.20 also shows the bandwidth of a PM signal. The actual bandwidth is difficult to determine exactly, but it can be shown empirically that it is several times that of the analog signal. Although the formula shows the same bandwidth for FM and PM, the value of β is lower in the case of PM (around 1 for narrowband and 3 for wideband).

Minimum shift keying

- It is found that binary data consisting of sharp transitions between "one" and "zero" states and vice versa potentially creates signals that have sidebands extending out a long way from the carrier, and this creates problems for many radio communications systems, as any sidebands outside the allowed bandwidth cause interference to adjacent channels and any radio communications links that may be using them.

- To overcome this problem GMSK is often used and this is based on Minimum Shift Keying, MSK modulation. The advantage of which is what is known as a continuous phase scheme. Here there are no phase discontinuities.
- In Minimum shift keying there are no phase discontinuities during modulation.

Gaussian minimum shift keying

- GMSK is similar to standard minimum-shift keying (MSK); however the digital data stream is first shaped with a Gaussian filter before being applied to a frequency modulator.
- This has the advantage of reducing sideband power, which in turn reduces out-of-band interference between signal carriers in adjacent frequency channels.

References

- The textbook–Forouzan
- https://www.youtube.com/watch?v=h_7d-m1ehoY
- Everythingrf.com.
- Huawei.com

Data Rate Versus Signal Rate

↓ bitrate

↓ (baud rate)

→ In analog transmission of digital data (baud rate ≤ bitrate)

$$\boxed{S = \frac{N}{r}}$$

where N is the data rate (bps)

S is the signal Rate

r is the number of data element carried in one signal element

$$\boxed{r = \log_2 L}$$

L is the type of signal element

$$\boxed{L = 2^r}$$

Describe FDM with proper example.

⇒ A very common application of FDM is AM and FM radio broadcasting. Radio uses the air as the transmission medium. A special band from 530 to 1700 KHz is assigned to AM radio. All radio stations need to share this band. Each AM station needs 10 KHz of bandwidth. Each station uses a different carrier frequency, which means it is shifting its signal and multiplexing. The signal that to the air is a combination of signals. A receiver receives all these signals, but filters only the one which is desired. Without multiplexing, only one AM station could broadcast to the common link, the air.

* Explain Amplitude Modulation (AM) with figure. why are guard bands required between AM radio

Ans

Amplitude Modulation (AM) is a method used in data communication to transmit information by varying the amplitude of a carrier wave

Carrier Wave: Imagine the carrier wave as steady, continous signal. It's like consistent vibration, like a sin wave, that serves as the medium for carry

Modulation Process: To create the modulated Signal, you combine the carrier wave with data signal. If the data signal is hight at a particular point it increase the carrier, If signal is low, the amplitude decrease

Demodulation at Reciver

At the receiving end, the modulated signal is demodulated to extract the orginal data

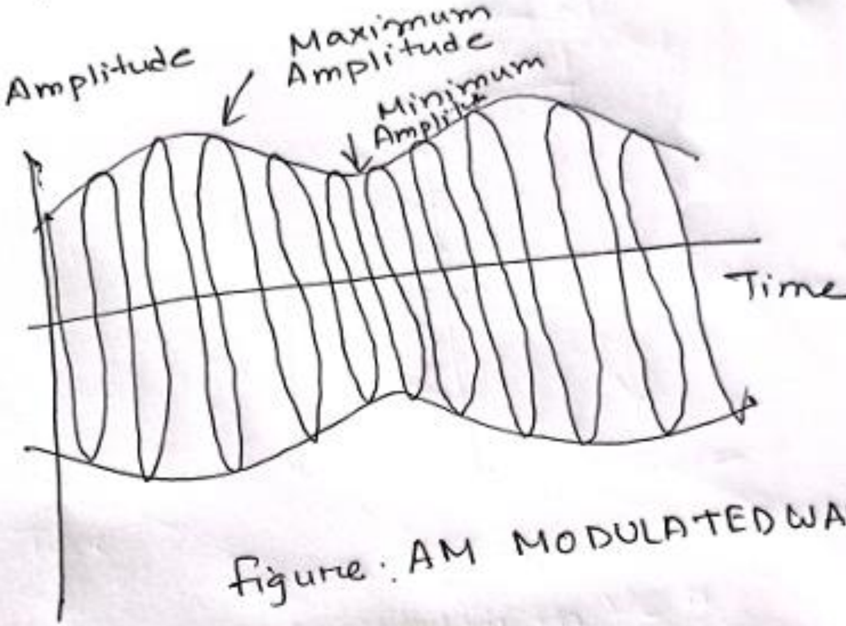


figure: AM MODULATED WAVE

Guard bands are used between ~~betwee~~ AM ratio station to prevent interface. They help ensure that adjacent radio frequencies don't overlap, which can lead to signal distortion and reduce the qulity of the received broadcast

What do you mean by 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. A sine wave is defined by three characteristics: amplitude, frequency and phase. When we vary anyone of these characteristics, we create a different version of the wave. So, by changing one characteristic of a simple electric signal, we can use it to represent digital data.

Draw the constellation diagram for 8 QAM with 2 different peak amplitude values 3 and 4 ~~about~~ and four different phases