Computer Networks(CS30006)

Spring Semester (2021-2022)

Analog Transmission

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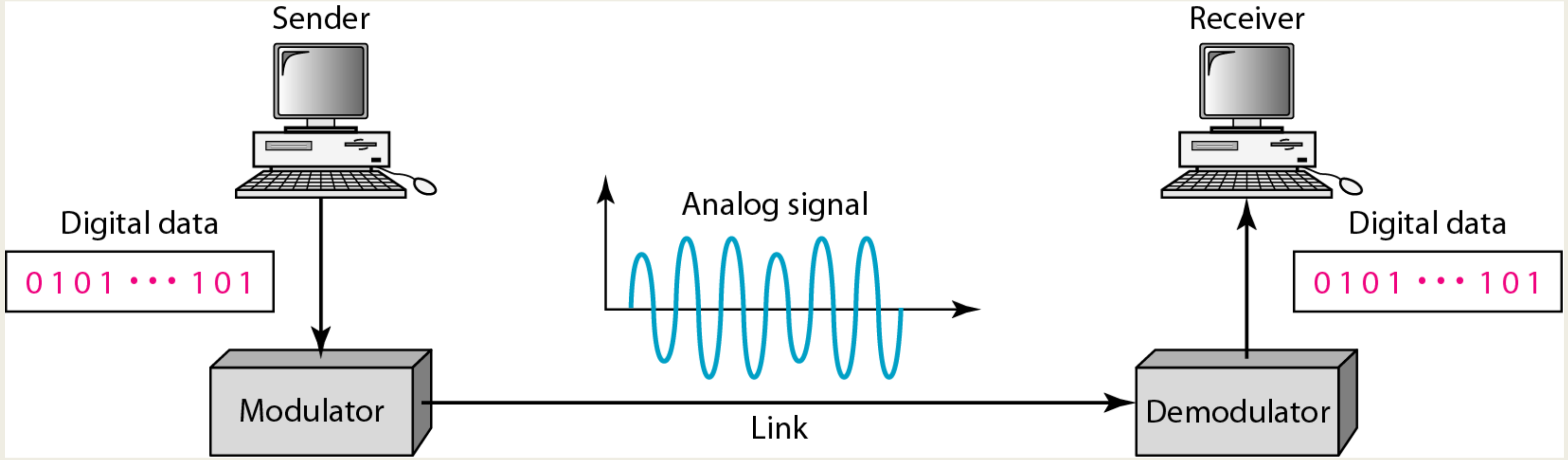
Digital to Analog Conversion

- Digital-to-analog conversion is the process of changing one of the characteristics of an analog signal based on the information in digital data.
- Digital data needs to be carried on an analog signal.
- A carrier signal (frequency f_c) performs the function of transporting the digital data in an analog waveform.
- The analog carrier signal is manipulated to uniquely identify the digital data being carried.



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- Bit rate, N, is the number of bits per second (bps).
- Baud rate is the number of signal elements per second (bauds).
- In the analog transmission of digital data, the signal or baud rate is less than or equal to the bit rate.

$$\mathbf{S=Nx1/r\ bauds}$$

Where r is the number of data bits per signal element and N is 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

$$S = N \times (1/r) \quad \text{or} \quad N = S \times r = 1000 \times 4 = 4000 \text{ bps}$$

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?

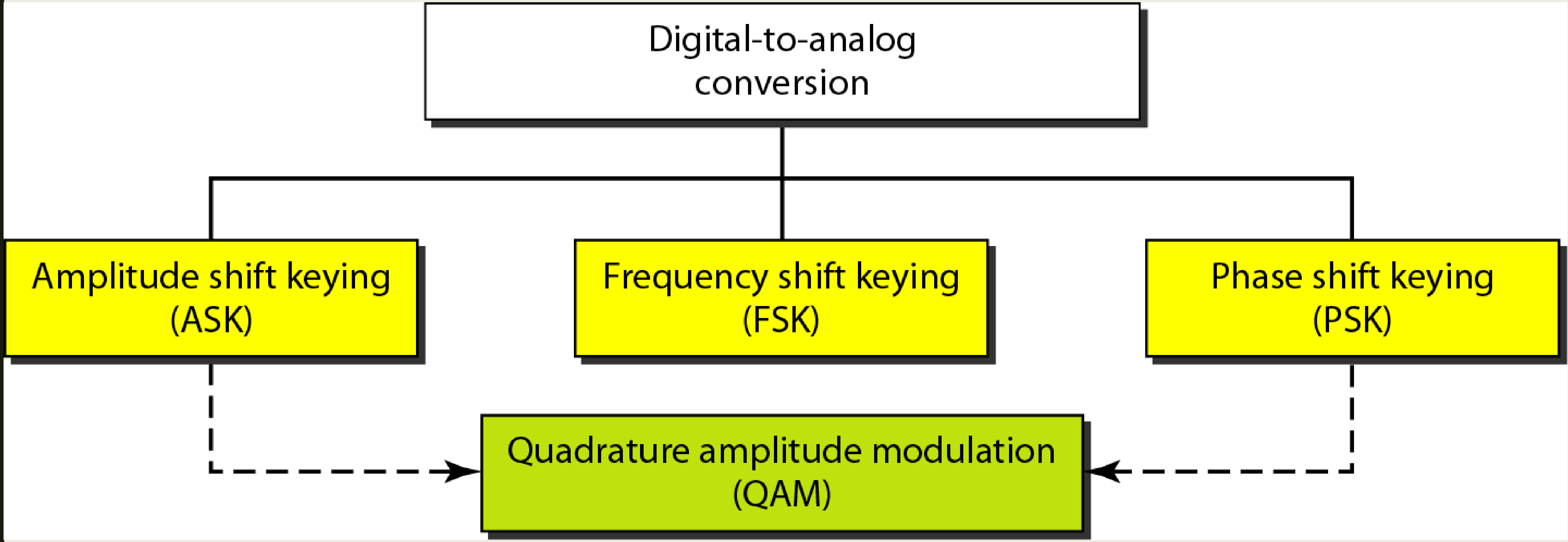
Solution

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

$$S = N \times 1/r \longrightarrow r = N / S = 8000 / 10{,}000 = 8 \text{ bits/baud}$$

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

Types



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Amplitude Shift Keying

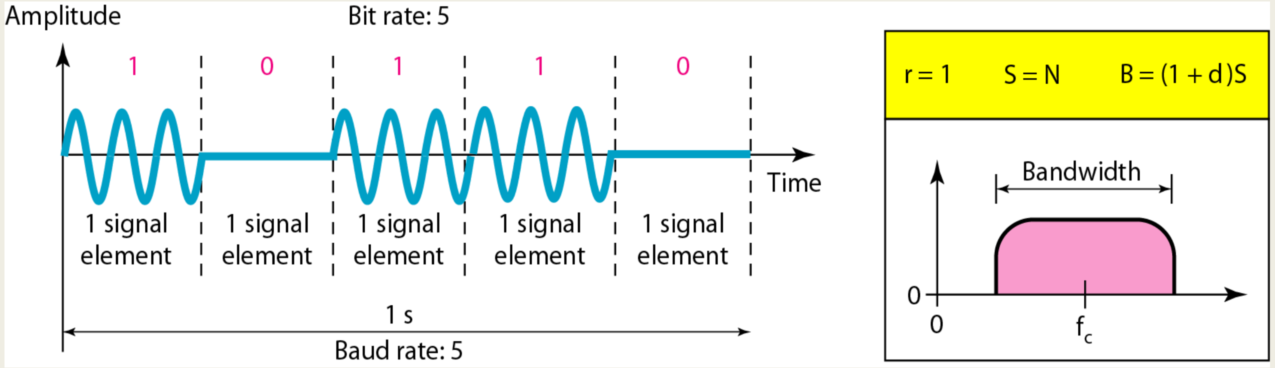
- ASK is implemented by changing the amplitude of a carrier signal to reflect amplitude levels in the digital signal.
- For example: a digital “1” could not affect the signal, whereas a digital “0” would, by making it zero.
- The line encoding will determine the values of the analog waveform to reflect the digital data being carried.
- The bandwidth B of ASK is proportional to the signal rate S.

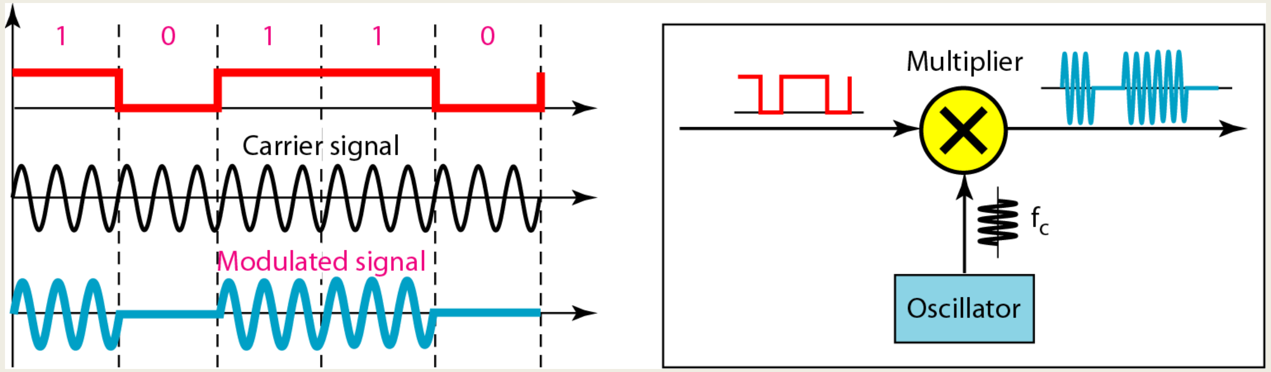
$$\mathbf{B = (1+d)S}$$

“d” is due to modulation and filtering, lies between 0 and 1.

Binary Amplitude Shift Keying

- Normally implemented using only two levels.
- Referred to as binary amplitude shift keying or *on-off keying* (OOK).
- The peak amplitude of one signal level is 0; the other is the same as the amplitude of the carrier frequency.





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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

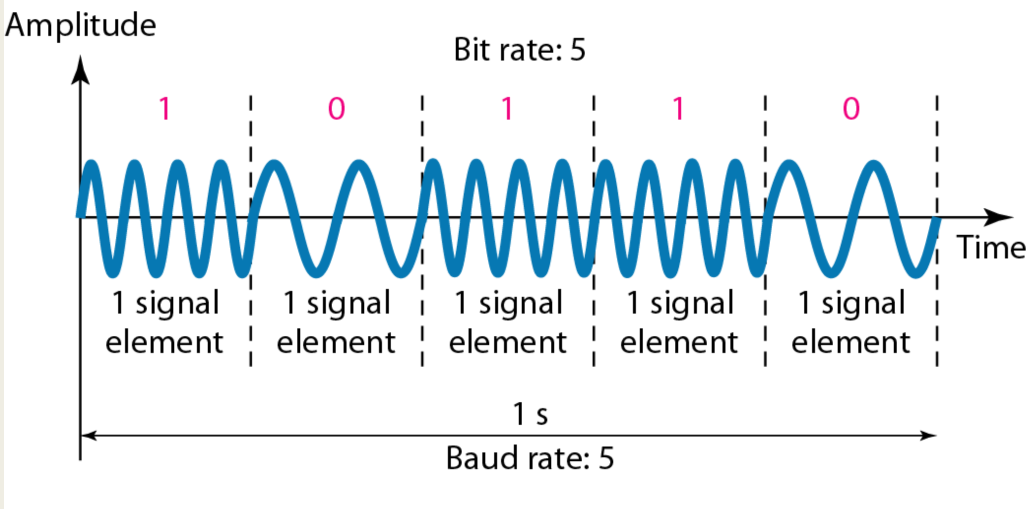
The middle of the bandwidth is located at 250 kHz. This means that our carrier frequency can be at fc = 250 kHz. We can use the formula for bandwidth to find the bit rate (with d = 1 and r = 1).

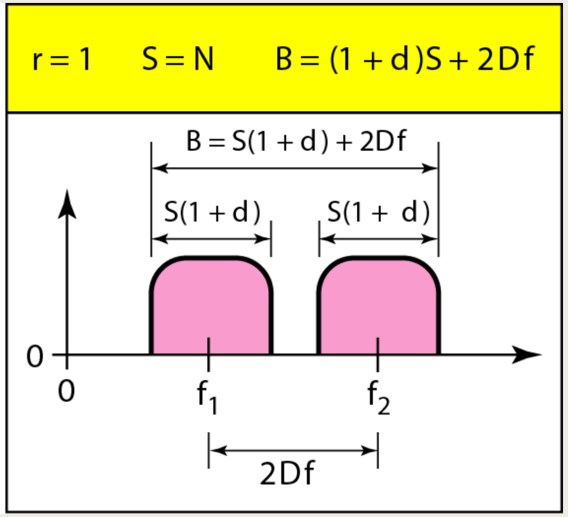
$$B = (1 + d) \times S = 2 \times N \times (1/r) = 2 \times N = 100 \text{ kHz} \longrightarrow N = 50 \text{ kbps}$$

Frequency Shift Keying (FSK)

- The digital data stream changes the frequency of the carrier signal, f_c.
- For example, a “1” could be represented by $f_1=f_c+\Delta f$, and a “0” could be represented by $f_2=f_c-\Delta f$.
- If the difference between the two frequencies (f_1 and f_2) is $2\Delta f$, then the required BW B will be:

$$\mathbf{B = (1+d)xS + 2\Delta f}$$





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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

The midpoint of the band is at 250 kHz. We choose 2Δf to be 50 kHz; this means

$$B = (1 + d) \times S + 2\Delta_f = 100 \longrightarrow 2S = 50\text{ kHz} \longrightarrow S = 25\text{ kbaud} \longrightarrow N = 25\text{ kbps}$$

Coherent and Non Coherent (FSK)

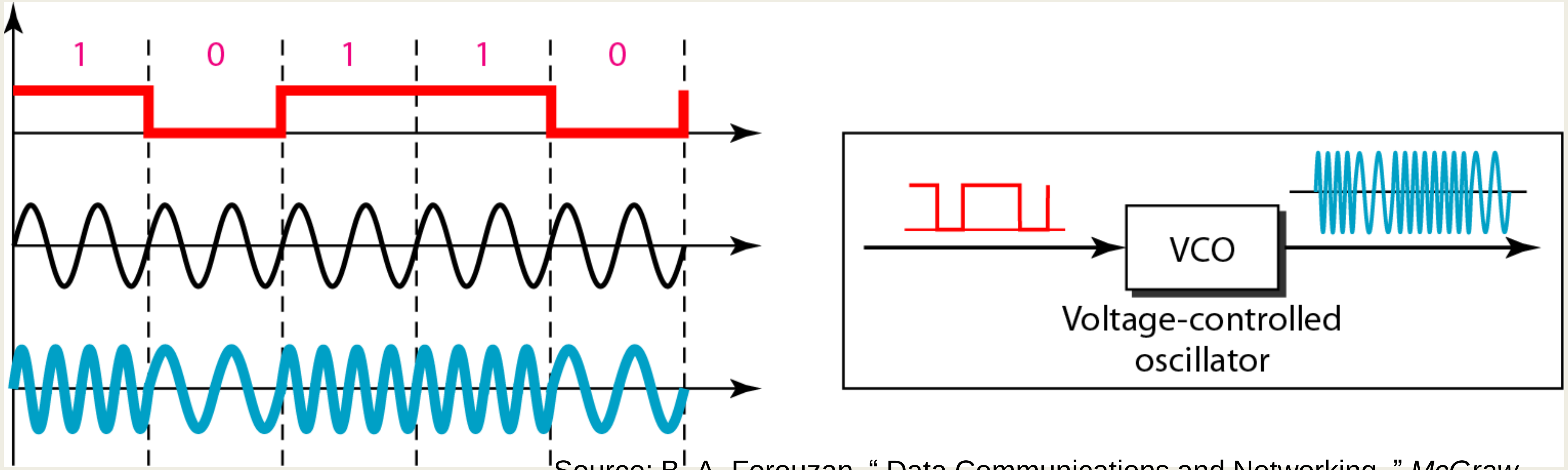
- In a non-coherent FSK scheme, when we change from one frequency to the other, we do not adhere to the current phase of the signal.

- In coherent FSK, the switch from one frequency signal to the other only occurs at the same phase in the signal.

Multi-level FSK

- Similar to ASK, FSK can use multiple bits per signal element.
- That means we need to provision for multiple frequencies, each one to represent a group of data bits.
- The bandwidth for FSK can be higher

$$B = (1+d)xS + (L-1)/2\Delta f = LxS$$



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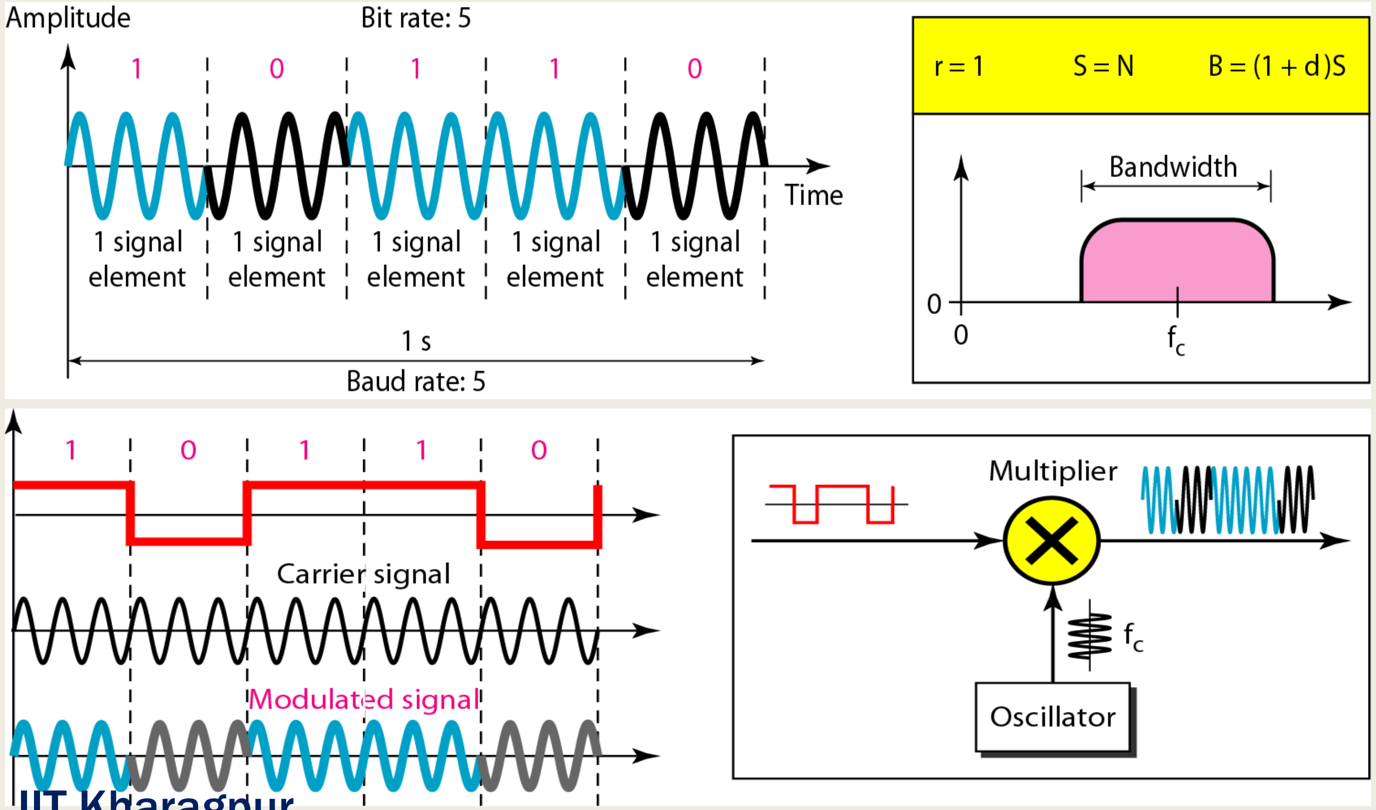
Phase Shift Keying

- We vary the phase shift of the carrier signal to represent digital data.
- The bandwidth requirement, B is:

$$\mathbf{B = (1+d)xS}$$

- PSK is much more robust than ASK as it is not that vulnerable to noise, which changes amplitude of the signal.



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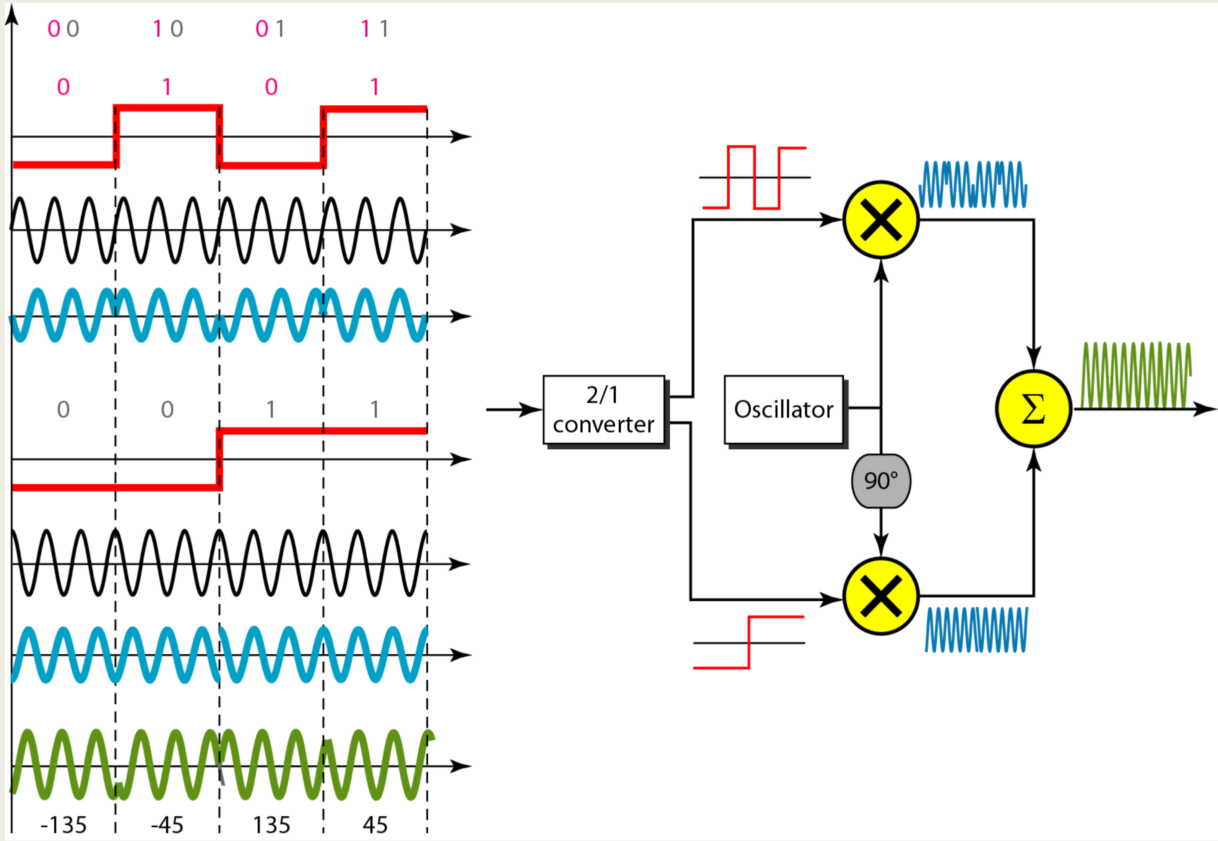
Binary Phase Shift Keying

- Binary Phase-shift keying (BPSK) is a digital modulation scheme that conveys data by changing, or modulating, two different phases of a reference signal (the carrier wave).
- This gives maximum phase-separation between adjacent points and thus the best immunity to corruption.
- Used in various wireless standards such as CDMA, WiMAX (16d, 16e), WLAN 11a, 11b, 11g, 11n, Satellite, DVB, Cable modem etc.

Quadrature Phase Shift Keying

- To increase the bit rate, we can code 2 or more bits onto one signal element.
- In QPSK, we parallelize the bit stream so that every two incoming bits are split up and PSK a carrier frequency. One carrier frequency is phase shifted 90º from the other - in quadrature.
- The two PSKed signals are then added to produce one of 4 signal elements. L = 4 here.



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Example

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

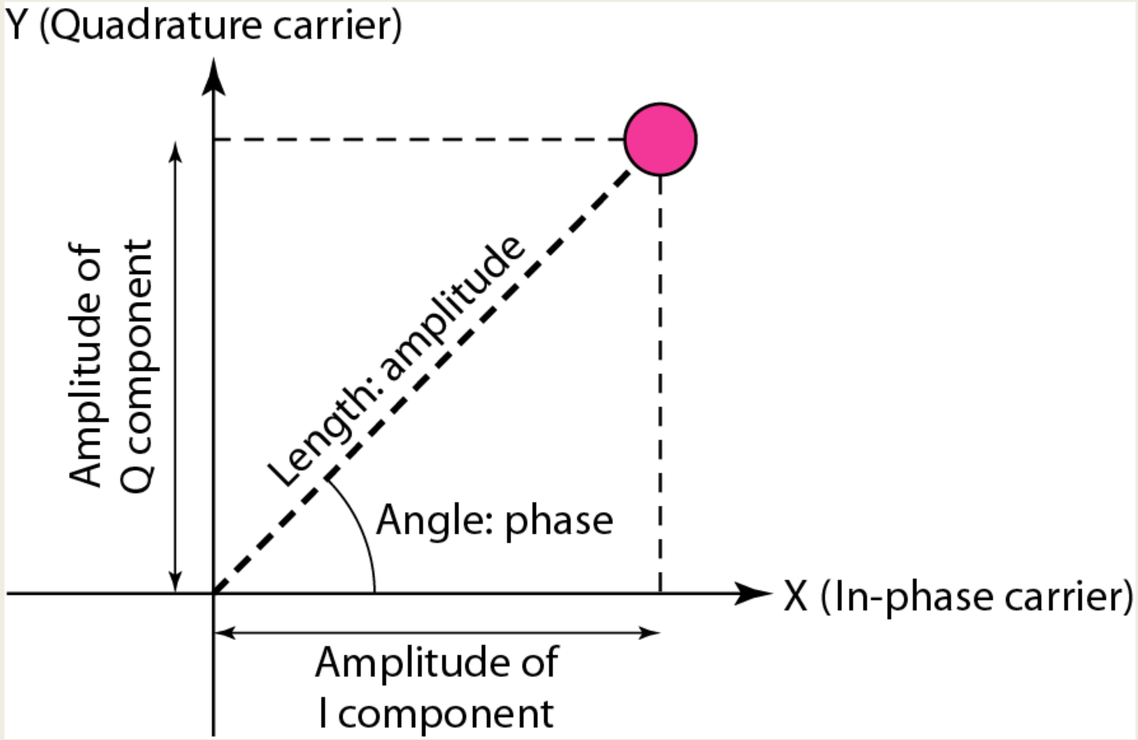
Solution

For QPSK, 2 bits are 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.

Constellation Diagrams

- A constellation diagram helps us to define the amplitude and phase of a signal when we are using two carriers, one in quadrature of the other.

- The X-axis represents the in-phase carrier and the Y-axis represents quadrature carrier.



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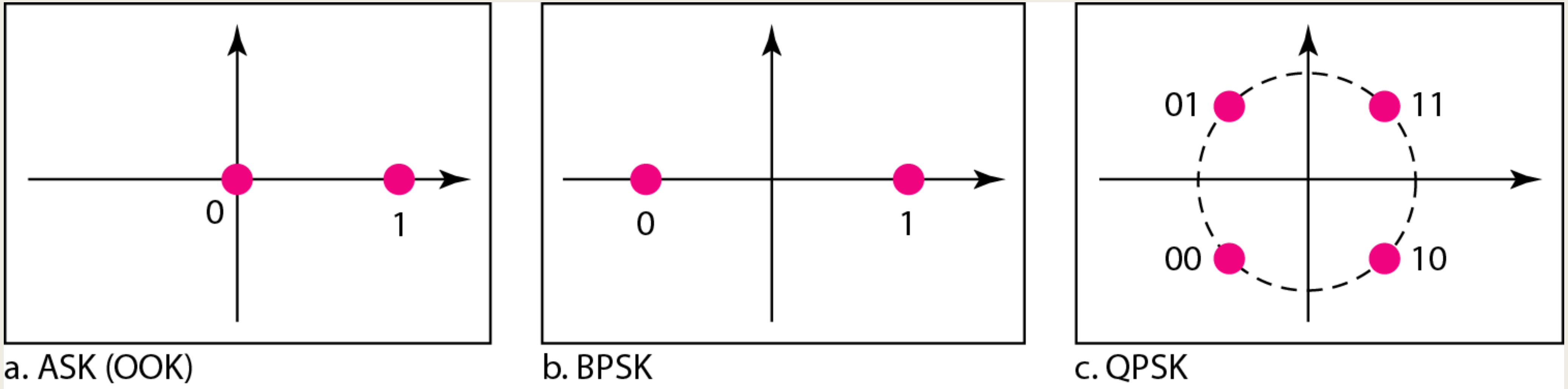

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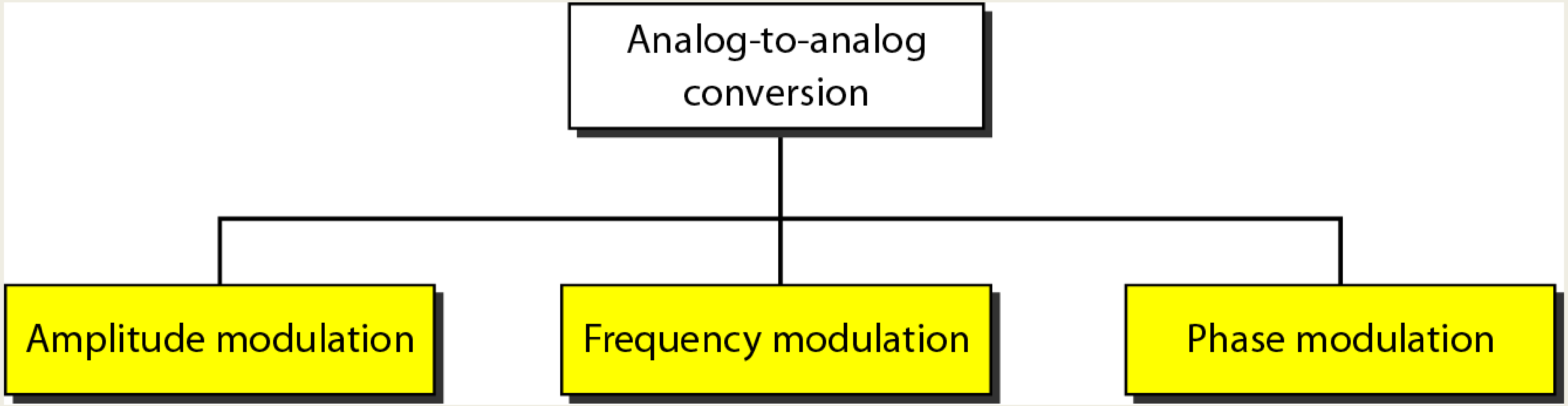
Thank You!!!

Appendix

Analog to Analog Conversion

- 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.



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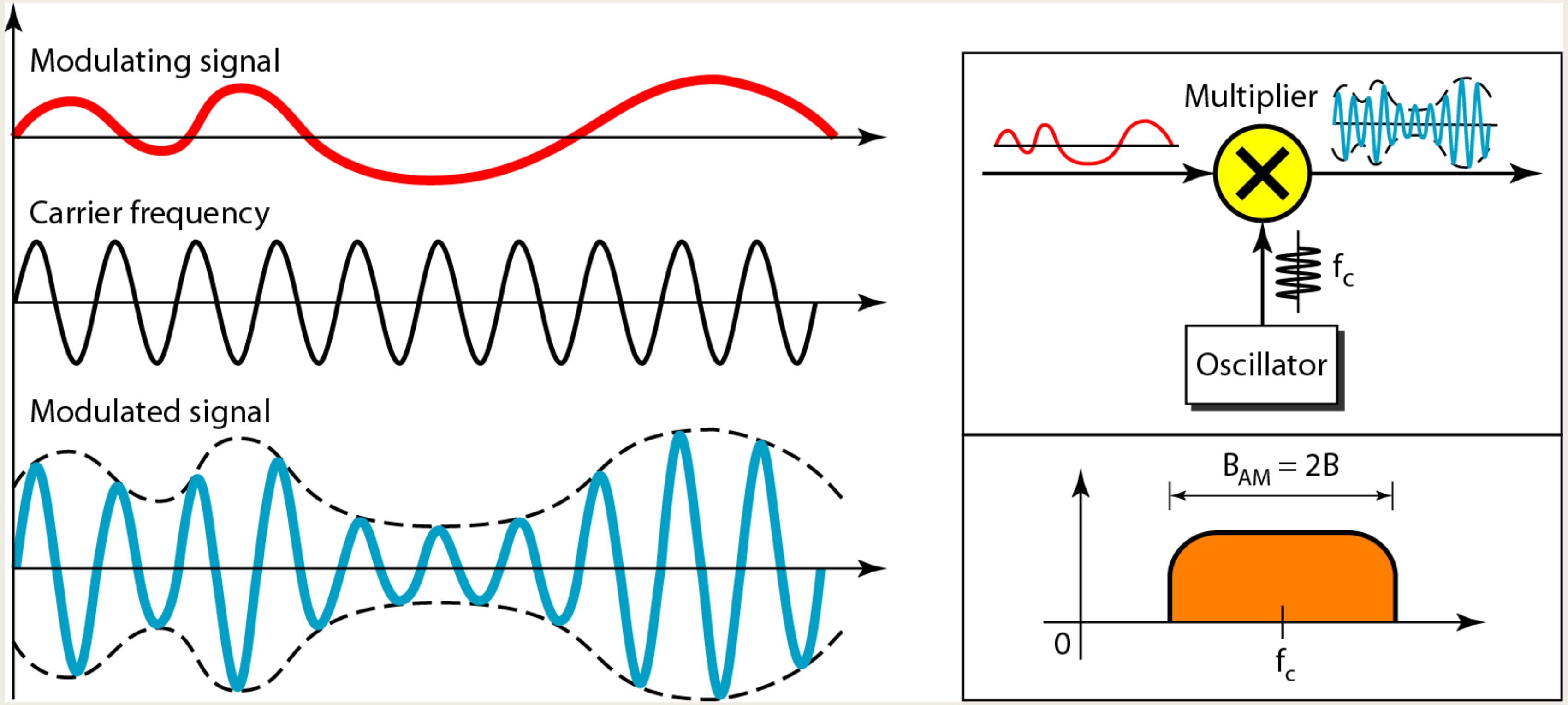
Amplitude Modulation

- A carrier signal is modulated only in amplitude value.
- The modulating signal is the envelope of the carrier.
- The required bandwidth is 2B, where B is the bandwidth of the modulating signal.



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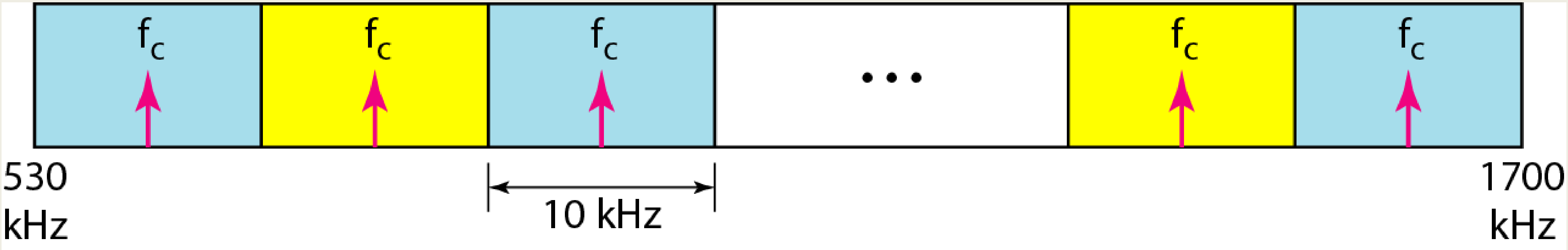
- Since on both sides of the carrier frequency f_c, the spectrum is identical, we can discard one half, thus requiring a smaller bandwidth for transmission.
- The total bandwidth required for AM can be determined from the bandwidth of the audio signal: $\mathbf{B_{AM} = 2B}$.
- The band allocation is as:



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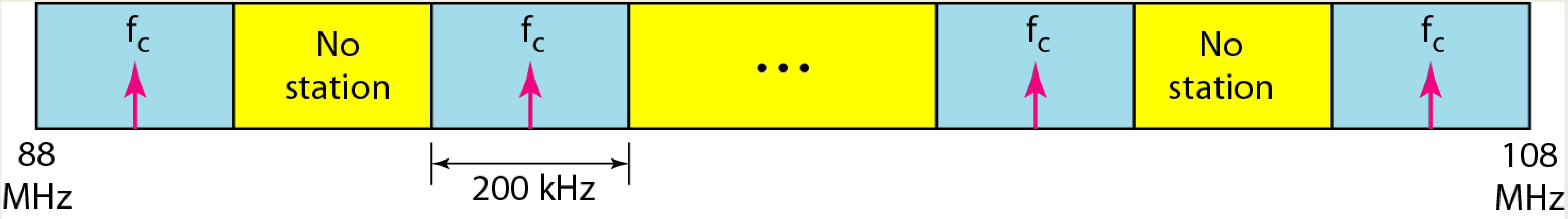
Frequency Modulation

- The modulating signal changes the freq. f_c of the carrier signal.
- The bandwidth for FM is high.
- It is approx. 10x the signal frequency.
- The total bandwidth required for FM can be determined from the bandwidth of the audio signal:

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

- Where β is usually 4.
- The FM band allocation is:



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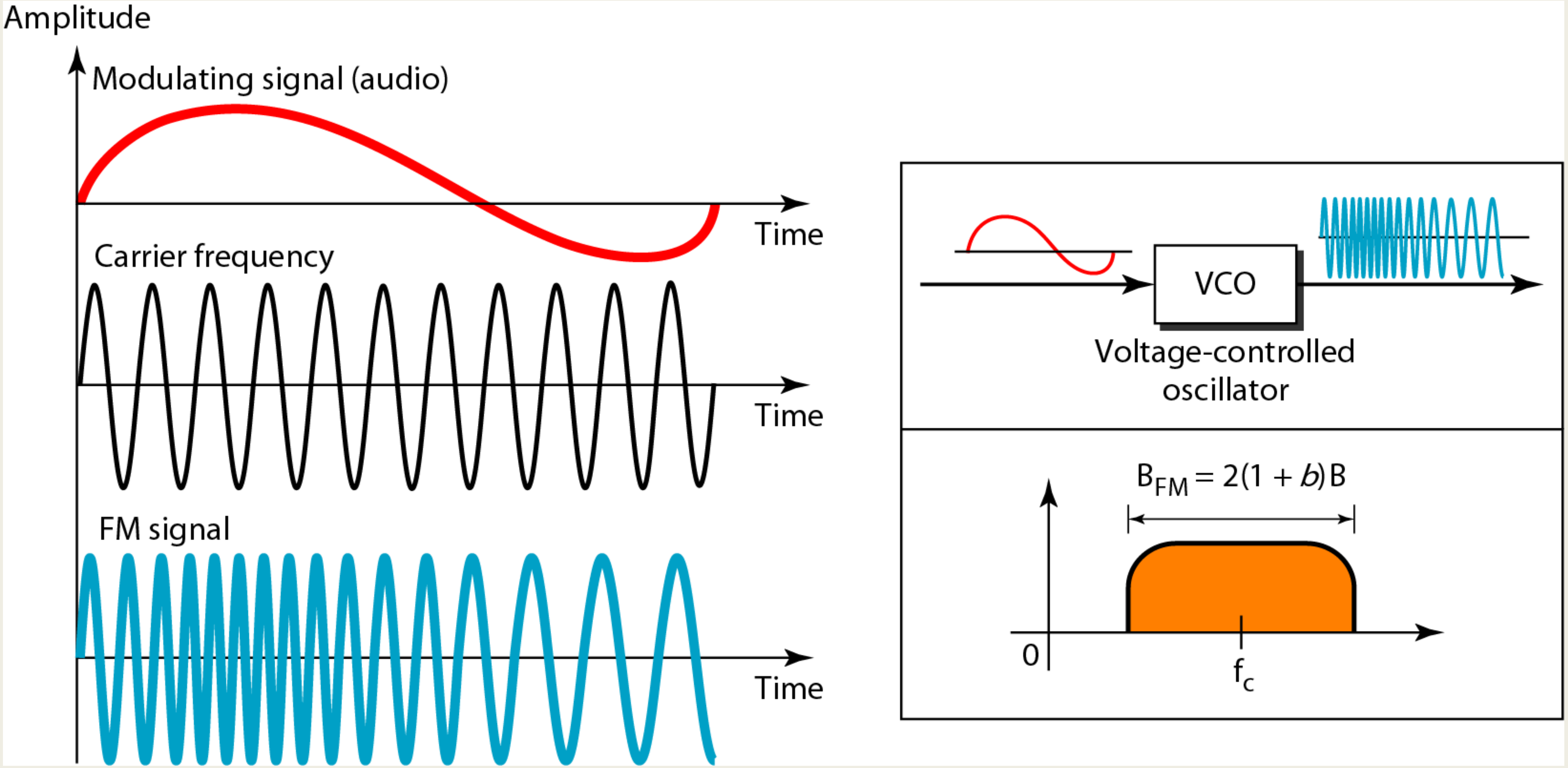

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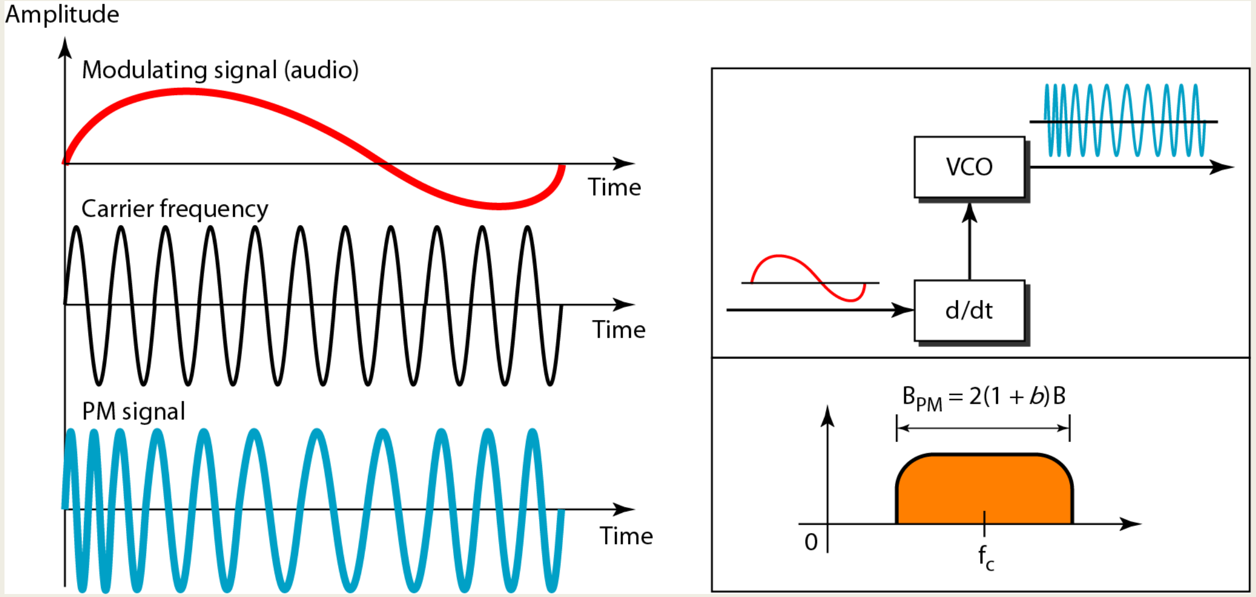
Phase Modulation

- The modulating signal only changes the phase of the carrier signal.
- The phase change manifests itself as a frequency change but the instantaneous frequency change is proportional to the derivative of the amplitude.
- The bandwidth is higher than for AM.
- The total bandwidth required for PM can be determined from the bandwidth and maximum amplitude of the modulating signal:

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

Where $\beta = 2$ most often.



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