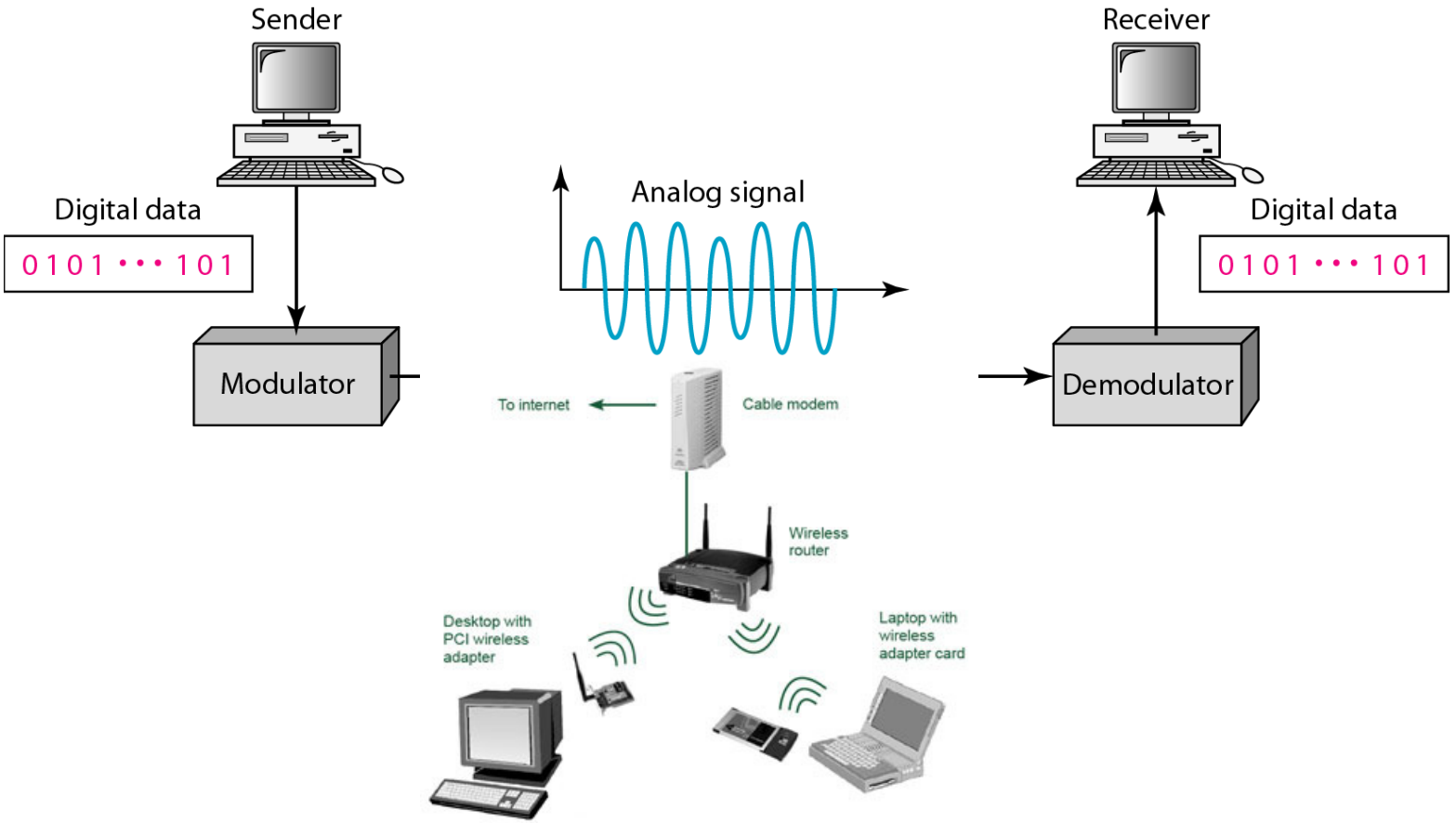
Analog Transmission of Digital Data:

ASK, FSK, PSK, QAM

Required reading:
Forouzan 5.1
Garcia 3.7

CSE 3213, Fall 2015
Instructor: N. Vlajic

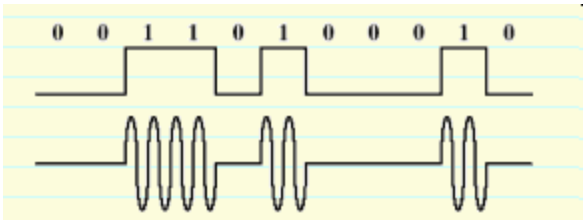
Why Do We Need Digital-to-Analog Conversion?!



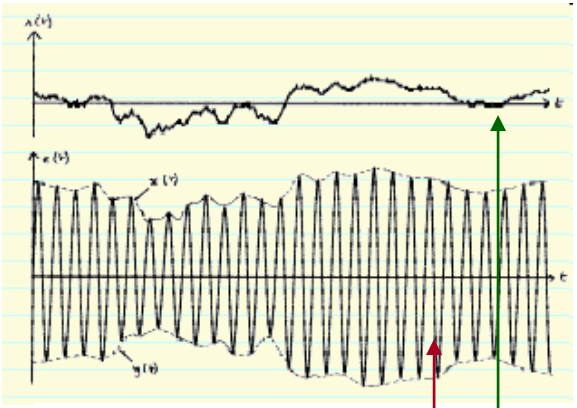
1) The transmission medium is bandpass, and/or
2) Multiple users need to share the medium.

Modulation of Digital Data

Modulation – process of converting digital data or a low-pass analog signal to band-pass (higher-frequency) analog signal



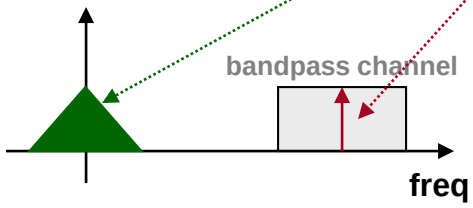
Digital-to-analog modulation.



Analog-to-analog modulation.

Carrier Signal – aka carrier frequency or modulated signal - high frequency signal that acts as a basis for the information signal

- information signal is called modulating signal

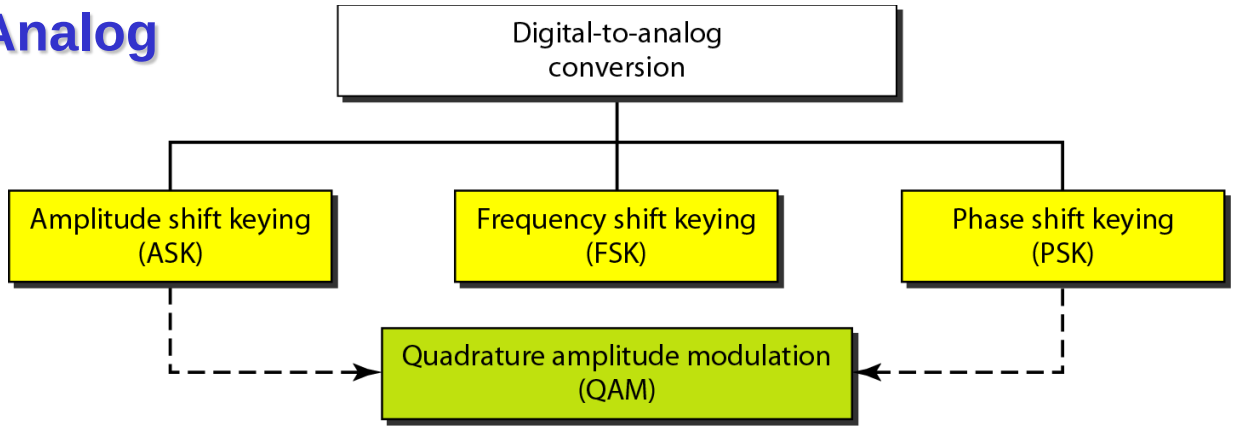


Modulation of Digital Data (cont.)

Digital-to-Analog Modulation – **process of changing one of the characteristics of an analog signal (typically a sinewave) based on the information in a digital signal**

- **sinewave is defined by three characteristics (amplitude, frequency, and phase) ⇒ digital data (binary 0 and 1) can be represented by varying any of the three**
- **application: transmission of digital data over telephone wire (modem)**

Types of Digital-to-Analog Modulation



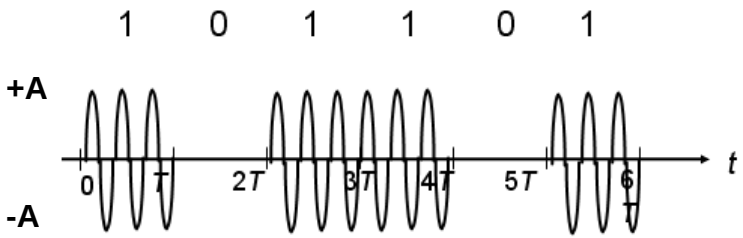
Modulation of Digital Data: ASK

ASK – **strength of the carrier signal is varied to represent binary 1 or 0**

- **both frequency and phase remain constant while the amplitude changes**
- **commonly, one of the amplitudes is zero**

$$s(t) = \begin{cases} A_0 \cos(2\pi f_c t), & \text{binary } 0 \\ A_1 \cos(2\pi f_c t), & \text{binary } 1 \end{cases} = \begin{cases} 0, & \text{binary } 0 \\ A\cos(2\pi f_c t), & \text{binary } 1 \end{cases}$$

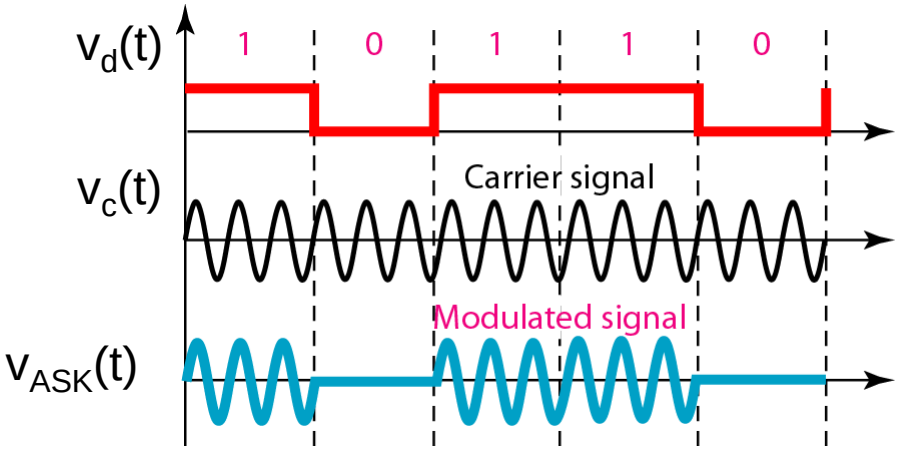
Is this picture, from the textbook, entirely correct?!

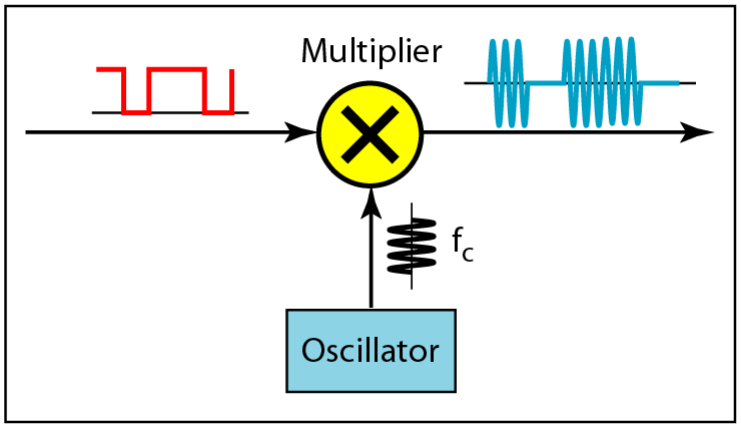


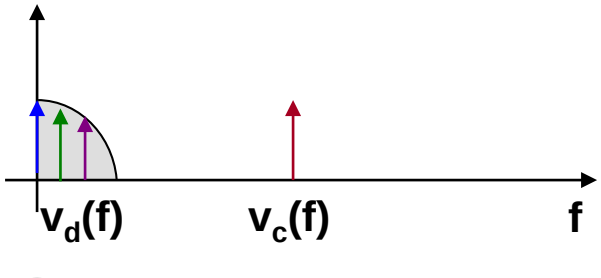
- **demodulation**: **only the presence or absence of a sinusoid in a given time interval needs to be determined**
- **advantage**: **simplicity**
- **disadvantage**: **ASK is very susceptible to noise interference – noise usually (only) affects the amplitude, therefore ASK is the modulation technique most affected by noise**
- **application**: **ASK is used to transmit digital data over optical fiber**

Modulation of Digital Data: ASK (cont.)

Example [ASK]







How does the frequency spectrum of $v_{ASK}(t)$ look like!?

ASK-Modulated Signal: Frequency Spectrum

$$\cos A \cdot \cos B = \frac{1}{2}\left(\cos(A-B)+\cos(A+B)\right)$$

Carrier signal: $v_c(t) = \cos(2\pi f_c t) = \cos(\omega_c t)$, **where** $2\pi f_c = \omega_c$

Digital signal: **(unipolar!!!)**

$$v_d(t) = A \cdot \left[\frac{1}{2} + \frac{2}{\pi}\cos\omega_0 t - \frac{2}{3\pi}\cos 3\omega_0 t + \frac{2}{5\pi}\cos 5\omega_0 t - \ldots\right]$$

Modulated signal:

$$v_{ASK}(t) = v_c(t)\cdot v_d(t) =$$

$$= \cos\omega_c t \cdot \left[\frac{1}{2} + \frac{2}{\pi}\cos\omega_0 t - \frac{2}{3\pi}\cos 3\omega_0 t + \frac{2}{5\pi}\cos 5\omega_0 t - \ldots\right] =$$

$$= \frac{1}{2}\cos\omega_c t + \frac{2}{\pi}\cos\omega_c t \cdot \cos\omega_0 t - \frac{2}{3\pi}\cos\omega_c t \cdot \cos 3\omega_0 t + \ldots =$$

$$= \frac{1}{2}\cos\omega_c t + \frac{1}{\pi}\left[\cos(\omega_c - \omega_0)t + \cos(\omega_c + \omega_0)t\right] -$$

$$- \frac{1}{3\pi}\left[\cos(\omega_c - 3\omega_0)t + \cos(\omega_c + 3\omega_0)t\right] + \ldots$$