Digital Data, Analog Signals (5.2)

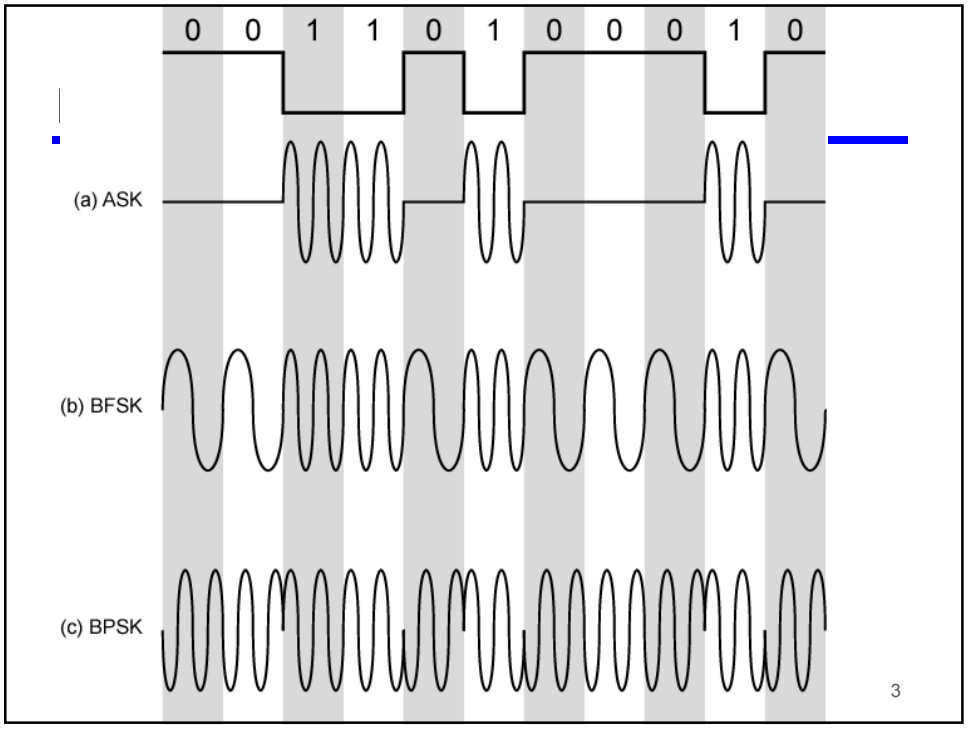
CSE 3213
Fall 2011

Digital Data, Analog Signal

Encoding Techniques

Amplitude shift keying (ASK)	Frequency shift keying (FSK)	Phase shift keying (PK)
• used to transmit digital data over optical fiber	• most common form is binary FSK (BFSK)	• phase of carrier signal is shifted to represent data

- main use is public telephone system
  - has frequency range of 300Hz to 3400Hz
  - uses modem (modulator-demodulator)



Amplitude Shift Keying

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

- Values represented by different amplitudes of carrier
- Usually, one amplitude is zero
  - i.e. presence and absence of carrier is used
- Susceptible to sudden gain changes
- Inefficient
- Used for voice grade lines (up to 1,200 bps)
- Used over optical fiber (e.g., 1 = light pulse; 0 = no light)

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Binary Frequency Shift Keying

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

- Most common form is binary FSK (BFSK)
- Two binary values represented by two different frequencies (near carrier)
- Less susceptible to error than ASK
- Used for
  - Up to 1,200 bps on voice grade lines
  - High frequency radio (3-30 MHz)
  - Even higher frequency on LANs using coaxial cable

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Multiple FSK

- each signalling element represents more than one bit
- more than two frequencies used
- more bandwidth efficient
- more prone to error

FSK on Voice-Grade Line

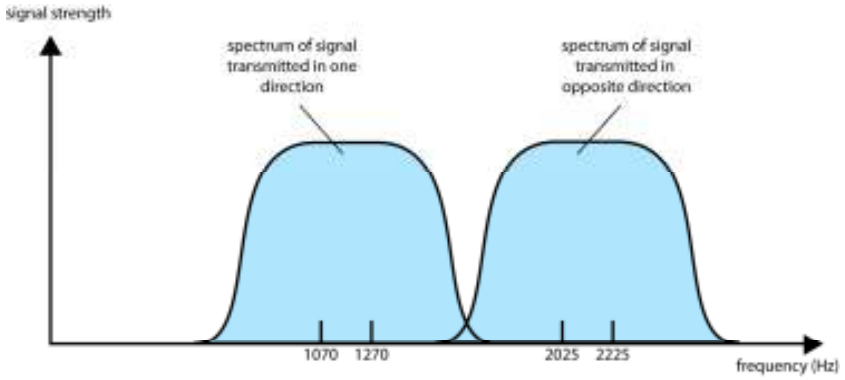

Figure 5.8 Full-Duplex FSK Transmission on a Voice-Grade Line

Phase Shift Keying

$$s(t) = \begin{cases} A\sin(2\pi f_c t + \pi) & \text{binary 1} \\ A\sin(2\pi f_c t) & \text{binary 0} \end{cases}$$

- Phase of carrier signal is shifted to represent data
- Binary PSK
  - Two phases represent two binary digits
- Differential PSK
  - Phase shifted relative to previous transmission rather than some reference signal

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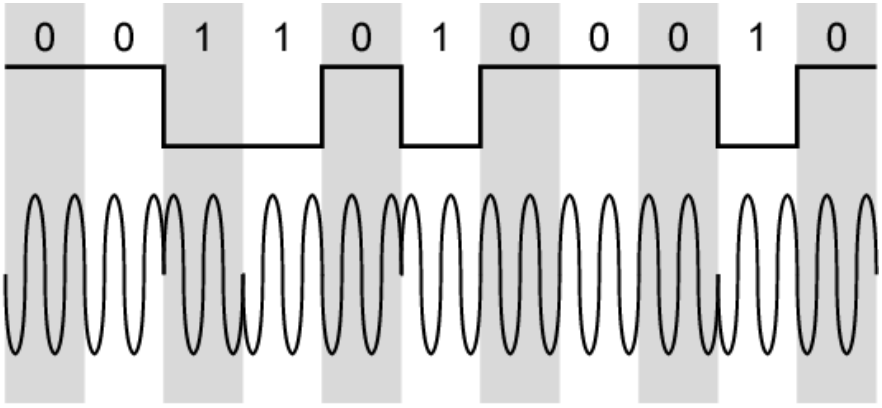
Differential PSK



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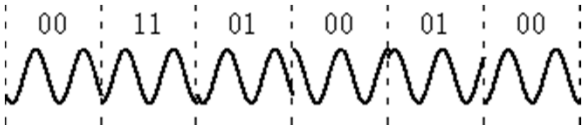
Bandwidth Efficiency for Digital-to-Analog Encoding Schemes

	$r = 0$	$r = 0.5$	$r = 1$
ASK	1.0	0.67	0.5
Multilevel FSK			
$M = 4, L = 2$	0.5	0.33	0.25
$M = 8, L = 3$	0.375	0.25	0.1875
$M = 16, L = 4$	0.25	0.167	0.125
$M = 32, L = 5$	0.156	0.104	0.078
PSK	1.0	0.67	0.5
Multilevel PSK			
$M = 4, L = 2$	2.00	1.33	1.00
$M = 8, L = 3$	3.00	2.00	1.50
$M = 16, L = 4$	4.00	2.67	2.00
$M = 32, L = 5$	5.00	3.33	2.50

Quadrature PSK

$$s(t) = \begin{cases} A\sin(2\pi f_c t + \pi/4) & \text{binary 11} \\ A\sin(2\pi f_c t + 3\pi/4) & \text{binary 10} \\ A\sin(2\pi f_c t + 5\pi/4) & \text{binary 01} \\ A\sin(2\pi f_c t + 7\pi/4) & \text{binary 00} \end{cases}$$



- More efficient: each signal element representing more than one bit
  - QPSK: each element represents two bits

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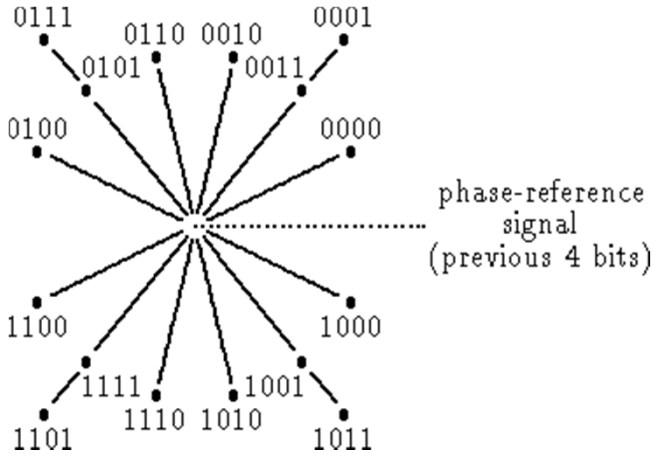
PSK Combined with ASK

- 9600 bps modem use 12 angles, four of which have two amplitudes



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Performance of Digital to Analog Modulation Schemes

bandwidth

ASK/PSK bandwidth directly relates to bit rate

multilevel PSK gives significant improvements

in presence of noise:

bit error rate of PSK and QPSK are about 3dB superior to ASK and FSK

for MFSK and MPSK have tradeoff between bandwidth efficiency and error performance

Performance of Digital to Analog Modulation Schemes

- Transmission bandwidth:
  - ASK and PSK bandwidth directly related to bit rate
  - FSK bandwidth related to data rate for lower frequencies, but to offset of modulated frequency from carrier at high frequencies

$$\text{ASK}: \quad B_T = (1+r)R; \qquad r \Rightarrow \text{rolloff factor}; 0 \le r \le 1$$

$$\text{FSK}: \quad B_T = 2\Delta f + (1+r)R; \qquad \Delta f = f_2 - f_c = f_c - f_1$$

$$\text{PSK}: \quad B_T = (1+r)R;$$

$$\text{Multilevel PSK}: \quad B_T = \frac{(1+r)}{\log_2 L} R; \qquad L \Rightarrow \text{no. of levels}$$

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Analog Data, Analog Signals (5.4)

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Analog Data, Analog Signals

- Why modulate analog signals?
  - Higher frequency can give more efficient transmission
  - Permits frequency division multiplexing (Chapter 8)
- Combining an input signal $m(t)$ and a carrier of frequency f_c to produce a signal $s(t)$ whose bandwidth is centered at f_c
  - $m(t)$: modulating signal
  - $s(t)$: modulated signal
- Types of modulation:

$$\text{Amplitude Modulation}: \quad s(t) = [1 + n_a x(t)]\cos 2\pi f_c t \quad n_a \Rightarrow \text{modulation index}$$
$$\text{Phase Modulation}: \quad s(t) = A_c \cos\left(2\pi f_c t + \phi(t)\right) \quad \phi(t) = n_p m(t); \quad n_p \Rightarrow \text{modulation index}$$
$$\text{Frequency Modulation}: \quad s(t) = A_c \cos\left(2\pi f_c t + \phi(t)\right) \quad \phi'(t) = n_f m(t); \quad n_f \Rightarrow \text{modulation index}$$

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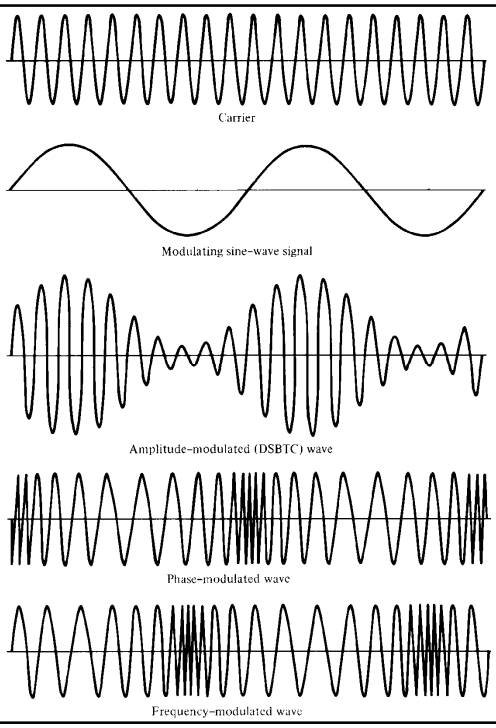
Analog Modulation



Transmission Bandwidth of Analog Modulation Schemes

- FM and PM require greater bandwidth than AM

AM: $B_T = 2B$

PM / FM: $B_T = 2(\beta + 1)B$

where $\beta = \begin{cases} A_m n_p & \text{for PM} \\ A_m n_f / 2\pi B & \text{for FM} \end{cases}$

and A_m is the maximum value of $m(t)$

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Summary

- Signal encoding techniques
  - digital data, digital signal
    - NRZ, multilevel binary, biphase
    - modulation rate, scrambling techniques
  - analog data, digital signal
    - PCM, DM
  - digital data, analog signal
    - ASK, FSK, BFSK, PSK
  - analog data, analog signal
    - AM, FM, PM

Reading

- Chapter 5, Stallings' book
- Next time: Digital Data Communications Techniques (chapter 6)

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