ITM 1010
Computer and Communication Technologies

Lecture #20
Review: Communication Technologies

Review of Communication Technologies

- Information Measure
- Analog Communication Technologies
  - Waveform, frequency spectrum and bandwidth
  - Modulation: AM and FM
- Digital Communication Technologies
  - Sampling, aliasing, Nyquist criterion and reconstruction
  - Shannon's channel capacity theorem
  - PCM system: quantization, bit rate, line coding, ISI
  - Keying
  - Multiplexing
  - Multiple Access Control
- Three communication systems
  - Cellular, optical and satellite

Information Measure

- Measurement of information content of a message

$$I_j = \log_2 \frac{1}{P_j} \quad \text{bits}$$

  - *Pj* is the probability of transmitting the *j*-th message

- Entropy: average information content

$$H = -\sum_{j=1}^{N} p_j \log_2 p_j \quad \text{bits per message}$$

Analog Communication Technologies: Time and Frequency Domain signals

- Signals: time domain and frequency domain representations
  - Fourier series: any repetitive signal may be represented by a sum of sinusoids.
  - Fourier transform is an extension of Fourier series technique for calculating the frequency domain contents of non-periodic signals.

	Time Domain Signal	Frequency Spectrum
Fourier Series	Periodic	Discrete
Fourier Transform	Non-periodic	Continuous

Analog Communication Technologies: Bandwidth

- Bandwidth: refers to the range of frequencies involved – that is, the difference between the lowest and the highest frequencies supported.
  - 3dB bandwidth
  - Absolute bandwidth
  - Equivalent noise bandwidth

Analog Communication Technologies: Amplitude Modulation

- AM

source message

$$s(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t)$$

modulation sensitivity

Over modulation $(1+k_a m(t)) < 0$

- AM bandwidth = 2 x baseband signal bandwidth
- AM variations: DSB-SC, SSB

Analog Communication Technologies: Frequency Modulation

- FM

$$f_i = f_c + k_f\, m(t)$$

source message

Instantaneous frequency

Carrier frequency

Modulation sensitivity

Modulated signal: $s(t) = A_c \cos\left(\omega_c t + 2\pi k_f \int_0^t m(t)\,dt \right)$

If $m(t) = V_m \cos \omega_m t$

$$s(t) = A_c \cos\left(\omega_c t + \frac{k_f V_m}{f_m} \sin(\omega_m t) \right)$$

$\beta = \dfrac{k_f V_m}{f_m} \Rightarrow$ modulation index $\qquad k_f V_m$ maximum freq deviation

Analog Communication Technologies: Frequency Modulation

- FM bandwidth ≠ Max(f_i) - Min(f_i)
- Carson's rule for FM bandwidth:

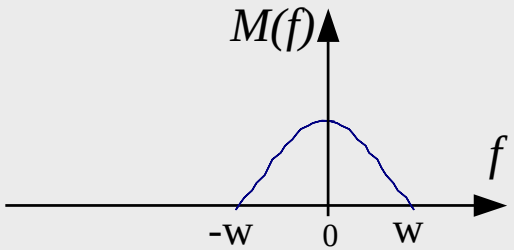
$$B = 2(1+\beta) f_m$$

Source signal bandwidth

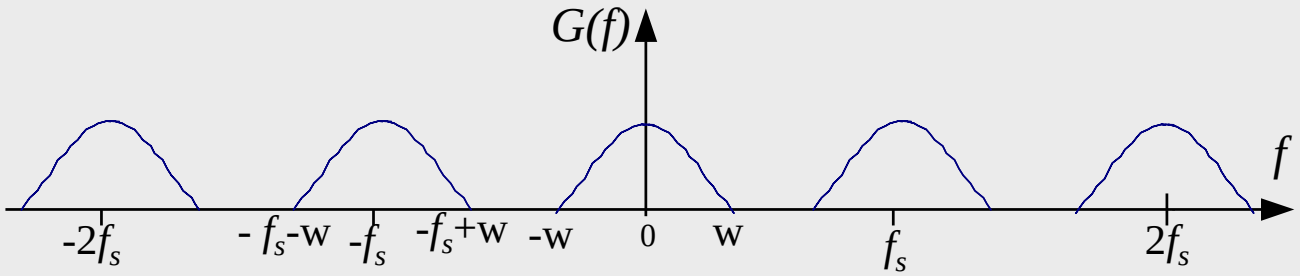
$$\beta = \frac{\text{Maximum Frequency Deviation}}{\text{Source Signal Bandwidth}}$$

Digital Communication Technologies: Sampling

- Sampling:



Spectrum of continuous signal $m(t)$

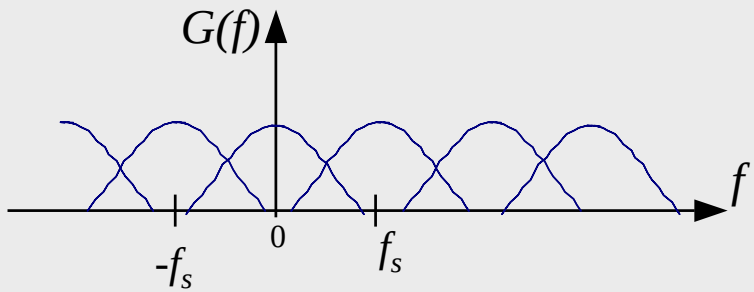


Spectrum of sampled signal $g(t)$

- Nyquist's criterion: the minimum sampling rate needed to avoid loss of information in a signal which is band-limited to a bandwidth of w is $2w$.

$$f_s \geq 2w$$

- Aliasing will occur if $f_s < 2w$



- Reconstruction

Digital Communication Technologies: Sampling

	Time Domain Signal	Frequency Spectrum
Before sampling	Continuous	Non-periodic
After sampling	Discrete	Periodic

	Time Domain Signal	Frequency Spectrum
Fourier Series	Periodic	Discrete
Fourier Transform	Non-periodic	Continuous

Digital Communication Technologies: Channel Capacity

- Communication channel capacity
  - Shannon's theorem: the capacity C (defined as the maximum rate at which information can be sent without error) is

$$C = B\log_2(1+P/N) \quad \text{bits per second}$$

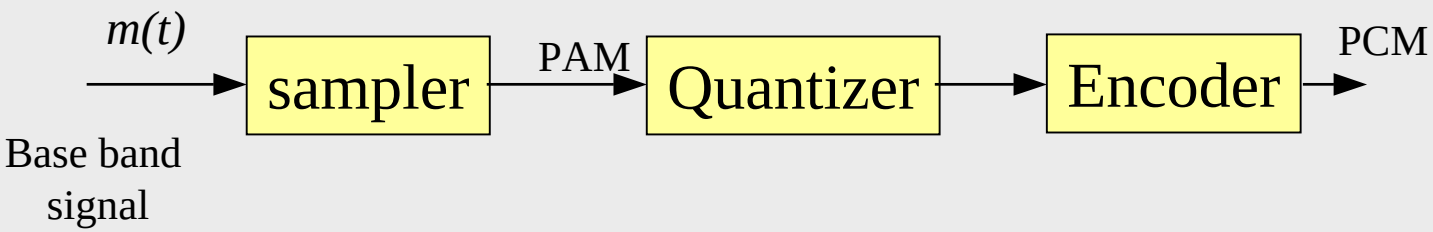
Channel bandwidth

Signal-to-noise ratio in received signal

  - The signal to noise power ratio is usually expressed in decibels:

$$\text{signal to noise ratio (in dB)} = 10\log_{10}\left(\frac{P}{N}\right)$$

Digital Communication Technologies: PCM



- PCM
  - Quantization noise:

$$S/N \ [\text{dB}] = 6.02n \quad [\text{dB}]$$

n is the number of bits used in the quantizer.

  - Bit rates needed in PCM = 2 n w (bits per second)

Baseband signal bandwidth

  - Advantages of PCM: Regeneration, Multiplexing, Compression

Digital Communication Technologies: PCM

- Example: A telephone line has a bandwidth of 20kHz to transmit digitized voice signal. The bandwidth of the voice source is 4kHz, and the number of quantization levels used to represent each sample is 256. What is the minimum bit rate required to send this signal? What is the minimum signal-to-noise ratio (in dB) required to support this bit-rate?

Digital Communication Technologies: PCM

- The frequency spectrum and bandwidth of the PCM signal depends on the form of coding used to represent the digital data (line coding)
- Line codes: NRZ, RZ, Manchester code
- ISI: Received pulse may be broadened in transmission because of the presence of low pass filters and dispersion in the transmission channel. Pulse broadening increases the probability of wrong detection.
- Keying: basic modulation techniques for sending digital data on a carrier wave
  - ASK
  - FSK
  - PSK

Digital Communication Technologies: Channel Sharing

- Channel sharing: multiplexing and multiple access
- Multiplexing: TDM, FDM (WDM)
- Multiple Access: TDMA, FDMA, CDMA
- TDM hierarchy in telephone system
  - Interleaving of different channels may be on a bit, byte or frame level
- Multiple access control
  - Aloha network: pure and slotted aloha network
  - Carrier sense multiple access (CSMA)
    - 1-persistent CSMA
    - P-persistent CSMA
    - Non-persistent CSMA
  - CSMA/CD (carrier detection)
    - Propagation delay and maximum channel length post a limit on the minimum packet size for a network with given bit rate (minimum packet transmission time > 2τ)

Digital Communication Technologies: Data Compression

- Data compression: lossless and lossy
- Lossless compression:
  - Run-length code
  - Huffman code (an Entropy coding method)
  - LZW code (an Entropy coding method)
- Image compression
  - JPEG
    - Uses Discrete Cosine Transform (DCT) to reduce information content of image
    - Huffman coding is used to compress data further
    - Trade-off between quality and compression ratio
- Audio-visual data compression
  - MPEG-1 (VCDs)
  - MPEG-2 (DVDs and digital video broadcasting)

Digital Communication Technologies: Data Compression

- mp3
  - Psychoacoustic redundancy
    - Sounds lower than the minimum threshold are not audible and thus not coded.
    - Sounds masked by a strong sound in the same frequency band may not audible and not coded
  - Entropic encoding redundancy
- MP1 Video coding
  - Interframe redundancy
  - Interpixel redundancy within a frame
  - Psychovisual redundancy
  - Entropic encoding redundancy

Digital Communication Technologies: Cellular, Optical and Satellite Comm. Sys.

- Communications systems: mobile (cellular), optical and satellite
- Cellular network
  - The concept of frequency reuse
  - TDMA can be used in digital network to increase capacity
  - 3G systems
- Optical network
  - Dispersion and ISI
    - Modal dispersion, Material dispersion and waveguide dispersion
  - Bit rate limited by dispersion
- Satellite communications
  - Geostationary satellite versus Low orbit satellite
  - Bit rate limited by carrier frequency due to loss