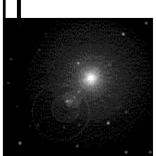
CS 4/54201
Computer

Communication
Network

Kent State University

Dept. of Computer Science

www.mcs.kent.edu/~javed/class-NET06F/



A Course on Networking and

Computer Communication

THEORETICAL BASIS FOR DATA COMMUNICATION

Fourier Decomposition

- Any reasonably behaved periodic function g(t), with period T can be constructed by summing a number of sins and cosines.

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

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$$f = \frac{1}{T}$$

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Fourier Transform

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

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- The coefficients can be computed by multiplying both sides with sins and cosines and performing integrals, because:

$$\int_0^T \sin(2nkft).\sin(2\pi kft)dt$$

$$= 0 \; when \; k \neq n$$

$$= \frac{T}{2} \; for \quad k = n$$

Fourier Transform

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

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$$f = \frac{1}{T}$$

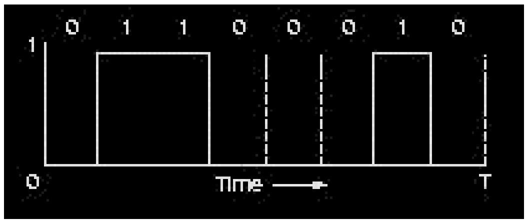
$$c_n = \frac{2}{T}\int_0^T g(t)dt$$

$$a_n = \frac{2}{T}\int_0^T g(t)\sin(2\pi nft)dt$$

$$b_n = \frac{2}{T}\int_0^T g(t)\cos(2\pi nft)dt$$

Example

ASCII character b='01100010'



$$a_n = \frac{2}{\pi n}[\cos(\frac{\pi n}{4}) - \cos(\frac{3\pi n}{4}) + \cos(\frac{6\pi n}{4}) - \cos(\frac{7\pi n}{4})]$$

$$b_n = \frac{2}{\pi n}[\sin(\frac{3\pi n}{4}) - \sin(\frac{\pi n}{4}) + \sin(\frac{7\pi n}{4}) - \sin(\frac{6\pi n}{4})]$$

$$c_n = \frac{3}{4}$$

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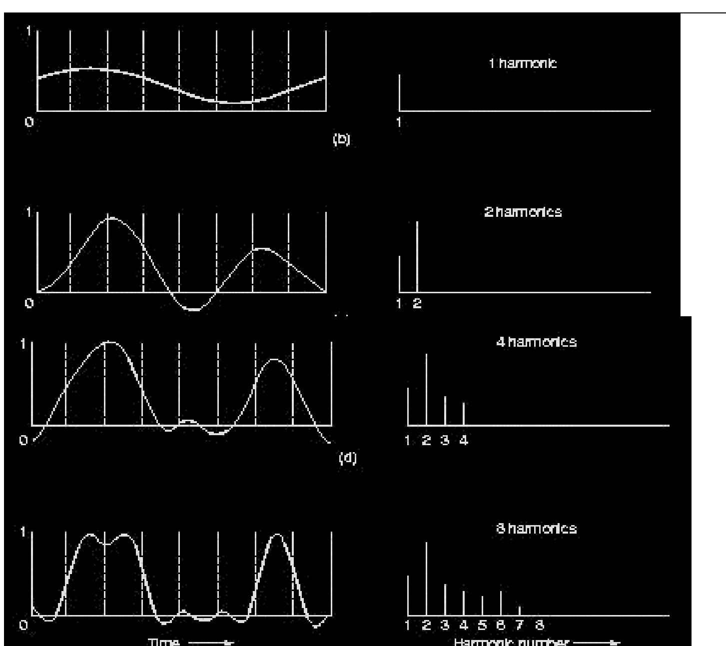

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Signal Power

$$\sqrt{a_n^2 + b_n^2}$$

Reconstruction

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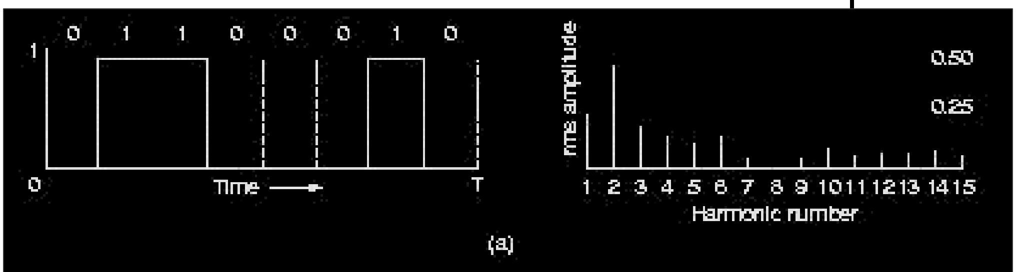

Data rate and Harmonics

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T=8*1/bps

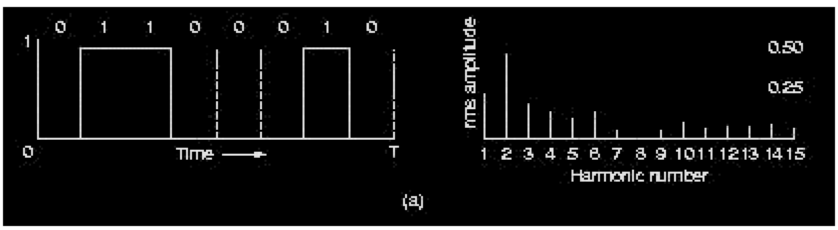
Hz=1/T

Via 3000 Hz channel

Bps	T (msec)	First harmonic (Hz)	# Harmonics sent
300	26.67	37.5	80
600	13.33	75	40
1200	6.67	150	20
2400	3.33	300	10
4800	1.67	600	5
9600	0.83	1200	2
19200	0.42	2400	1
38400	0.21	4800	0

Maximum Data rate of a Channel

- Nyquist Criteria
  - if an arbitrary signal has been run through a low-pass filter of bandwidth H, the filtered signal can be completely reconstructed by making only 2H (exact) samples per second.
  - Sampling more than H times per second is pointless because the higher frequency components such sampling could recover have already been filtered out.



Nyquist Theorem

- For a H Hz channel (a low pass channel with cutoff at H hz), if a signal consists of V discrete levels, then the maximum data rate is:

$$D = 2H \log_2 V \text{ bits/sec}$$

Example: a noiseless 3-kHz channel cannot transmit binary (two level) signals at a rate exceeding 6000 bps

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Shannon's Theorem

- Maximum data rate for a noisy channel whose bandwidth is H hz, and whose signal to noise ratio is S/N, is given by:

$$M = H \log_2 (1+S/N) \text{ bits/s}$$

S/N is expressed as decibels (DB).S/N=10 is 10 db, a ratio of 100 is 20 db, a ratio of 1000 is 30 db

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Example Problem

Problem: a noiseless 3-kHz channel has 30db signal to noise ratio. What will be the maximum data rate via this channel according to Shannon's result?

<u>Answer:</u>

– H=3000

– 30 db means S/N = 1,000

– M = 3000 x log 1001 = 30,000 bps

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