

Announcements

- project #1 is due on Friday at 6:00 PM
 - submit a tar file with
 - source
 - typescript file
 - use submit program from ~jh01/bin/submit
- Extra office hours this week
 - Thursady (10:45 to noon)
 - Friday (by appointment)

Sending Information

- data is sent by varying a value over time
 - can model this as a single valued function $f(t)$
 - the physical property that is changed could be
 - current
 - voltage
- goal is to analyze the properties of this function
 - how much energy is required?
 - how does the physical media affect the signal

Fourier Analysis

- Any periodic function $g(t)$ can be represented by
 - a constant term
 - a series (possibly infinite) of sines and cosines
 - a signal has a fundamental frequency $f=1/T$
 - each term is called a harmonic

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

- finite functions can be repeated forever
 - effectively any signal is finite so it has a Fourier transform

Fourier Analysis (cont.)

- can solve for a_n, b_n , and c to get:

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

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

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

Bandwidth Limits

- Consider sending 01100010 (ascii b):

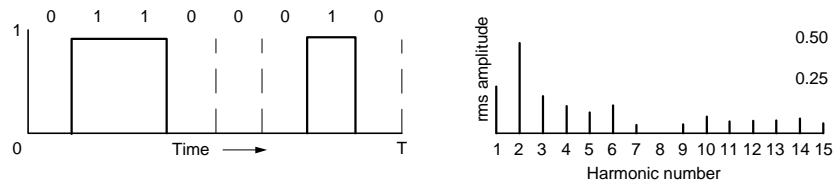
$$a_n = \frac{1}{\pi n} [\cos(\pi n / 4) - \cos(3\pi n / 4) + \cos(6\pi n / 4) - \cos(7\pi n / 4)]$$

$$b_n = \frac{1}{\pi n} [\sin(3\pi n / 4) - \sin(\pi n / 4) + \sin(7\pi n / 4) - \sin(6\pi n / 4)]$$

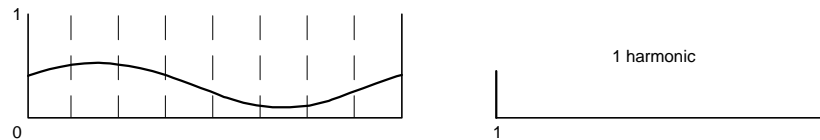
$$c = \frac{3}{8}$$

- how much power is required to send the signal ?
 - height of a_n and b_n dictate power requirements
 - (rms) $\sqrt{a^2 + b^2}$ indicates the power required

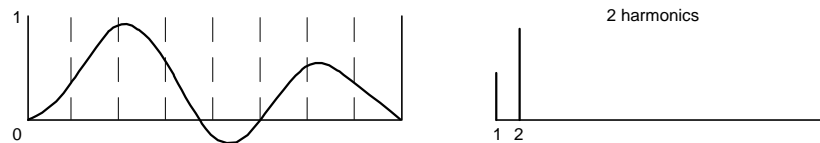
How many Harmonics do we need?



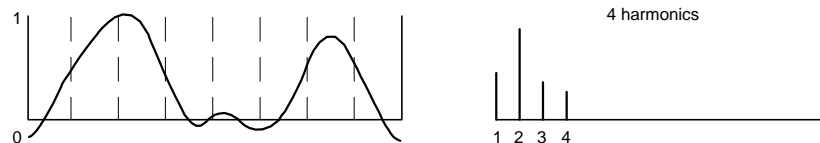
(a)



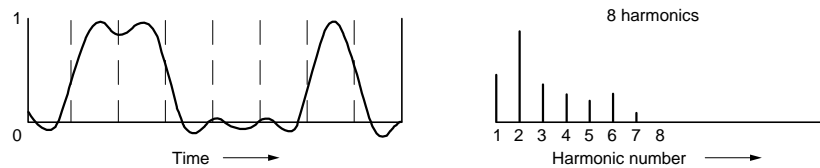
(b)



(c)



(d)



(e)

● Adding Harmonics

- reduce error in regenerated signal
- requires additional bandwidth

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Importance of Harmonics

- **Bandwidth limits**
 - physical circuits often only pass up to a cutoff frequency
 - sometimes limit bandwidth (it costs money)
- **Non-Uniform Attenuation**
 - not all frequencies pass equally well
 - 60 Hz is a bad frequency due to electrical circuits
 - try to ensure that the “important” parts get through
 - this is called distortion
 - exactly like bad sound when you turn up the stereo amp

Why baud may not equal bits/sec

- baud is number of changes per second
 - if the signal has 0/1 volts then bits/ baud ==1
 - but if 0,1,2,3,4,5,6, and 7 volts used then 3 bits/ baud
- limit on baud per second over a phone line
 - phone lines are limited to about 3khz
 - so only harmonics less than 3,000 will get sent
 - for 9600Bps the first harmonic is at 1,200
 - only two harmonics will be sent
 - not possible to send past 38.4kBps

Max Data Rates Over A Channel

- Shannon/Nyquist limit

- max data rate is $2H\log_2 V$ bits/sec
 - H - bandwidth of the channel
 - V - number of levels used to encode data
- for example, a noiseless 3khz channel can carry
 - 6,000 kbs for binary traffic but
 - 12,000 kpbs for quadary (4 level) traffic

- What about noise?

- noise is measured as the ratio of signal to noise power
- normally measured in db or $10 \log_{10}(S/N)$
- Shannon limit:
 - max bits/sec = $H \log_2(1+S/N)$
 - 3khz, 30dB channel limited to 30,0000 bps

Transmission Media

- **Magnetic Media**

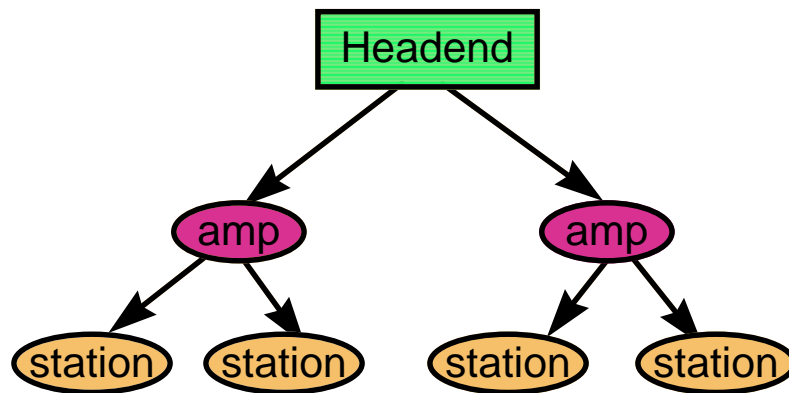
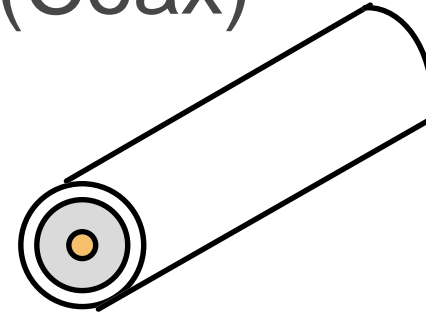
- tapes hold 40GB today
- a van can carry 2,000 tapes (or 80 TB)
- want to move data from DC to Baltimore
 - 80 TB/hour = 166 Gb/sec
- what about latency?
 - get all 80TB at once
 - need to read/write all of these tapes

- **Twisted Pair**

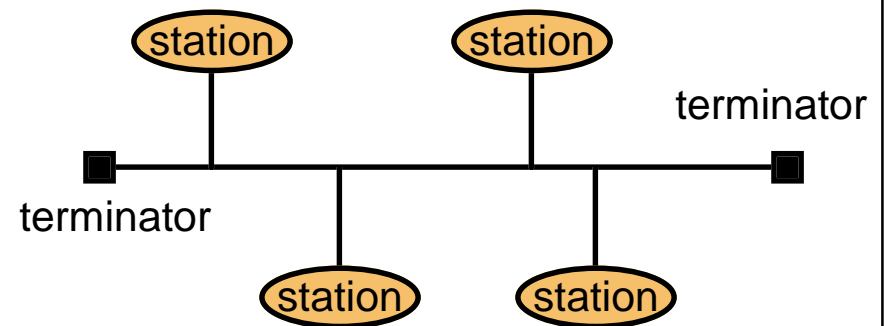
- copper wires (1.5 Mbps long haul)
- 100Mbps with two pairs for short distances

Transmission Media (Coax)

- copper with an insulator between it
 - 75 ohm - common for T.V.
 - 50 ohm - common for data transmission
- rates: 10's of Mbps baseband, 100's MPS broadband
 - supports multiple drops



Broadband Network



Baseband Network