Example Systems, Signals

Analog and Digital Communications
Autumn 2005-2006

Example: PSTN

- Public Switched Telephone Network
- Components
  - Phone set (analog signal is generated)
  - Local exchange (A/D conversion)
  - Long-haul exchange
- Characteristics
  - Circuit-switched network
  - Designed for voice communications (analog???)
  - Faxes and modems use PSTN for transmission of digital data in analog form
Example: PSTN

Local exchange

Long distance line

International exchange

International line

Local exchange

Long distance line

Long distance line

Local exchange

Example: Cellular

Edamabad

MTSO

PSTN

MTSO

MTSO: Mobile Telephone Switching Office

MTSO

Lahore

Sep 08, 2005 CS477: Analog and Digital Communications
Example: Cellular

- Cellular Communication System
  - A cell is assigned some number of channels
  - Typically one channel is allocated to a user
  - Users communicate with a base station
  - Base station is connected to MTSO/PSTN
  - AMPS is an analog system
    - Uses FM and frequency-division multiple access
  - Digital systems use digital modulation

Example: Radio broadcast

- Two modes are used
  - AM
    - Amplitude modulation
    - 535-1605kHz
    - 10kHz channels
  - FM
    - Frequency modulation
    - 88-108MHz
    - Channels centered at 200kHz intervals starting at 88.1MHz
Example: Wireless LANs

- Various standards
- IEEE 802.11a/b/g popular
- IEEE 802.11b
  - 11Mb/s data rate
  - 2.4-2.4835GHz band
  - Modulation: Direct sequence spread spectrum (DSSS)
- IEEE 802.11a
  - 55Mb/s data rate
  - 5.725-5.825GHz band (in U.S.)
  - Uses orthogonal frequency division multiplexing (OFDM)

Example: LANs and WANs

- Local Area Networks (LANs)
  - Connect “closely” located computers
  - Data bits are transmitted in chunks (packets) for efficiency/feasibility reasons
  - Various LAN protocols are used in practice
- Wide Area Networks (WANs)
  - A wide area backbone network connects different LANs
  - A standard protocol is needed for such communication (TCP/IP)
Example: Ad Hoc Networks

- Various devices connected to each other without using an infrastructure
  - Sensor Networks
    - Similar to ad hoc Networks (may be considered a special case of ad hoc networks)
    - Have power constraints (Use non-rechargeable battery)
  - Mesh Networks
    - Another example of ad hoc networks
    - Used for provide communications to remote areas

A Generic Communication System

```
<table>
<thead>
<tr>
<th>Transmitter</th>
<th>Channel</th>
<th>Receiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>m(t)</td>
<td>s(t)</td>
<td>n(t)</td>
</tr>
<tr>
<td>(Modulator)</td>
<td>h(t)</td>
<td>Demodulator</td>
</tr>
<tr>
<td>Analog or Digital</td>
<td></td>
<td>m̂(t)</td>
</tr>
</tbody>
</table>
```

Sep 08, 2005 CS477: Analog and Digital Communications
### Elements of Communication Systems

- **Transmitter**
  - Modulation
  - Coding
- **Channel**
  - Attenuation
  - Noise
  - Distortion
  - Interference
- **Receiver**
  - Detection (Demodulation+Decoding)
  - Filtering (Equalization)

### Transmitter

- **What does modulation do?**
  - Encodes messages (analog) or bits (digital) into amplitude, frequency, or phase of a carrier signal
  - Also makes transmitted signal robust against channel impairments
- **Coding**
  - Source coding - remove redundancy
  - Channel coding - add redundancy
Channel

- Channel introduces impairments
  - Noise
    - Thermal noise is the most significant
    - Additive white Gaussian noise (AWGN)
  - Distortion
    - Inter-symbol interference
  - Attenuation and fading
    - Constant attenuation
    - Variable attenuation
  - Interference
    - Crosstalk

Receiver

- What does demodulator do?
  - Extracts messages or bits from the received signal
  - Mitigates channel impairments by making use of equalizers
  - Decodes the signal, especially if channel coding was performed at the transmitter
Performance Criterion

- How a “good” communication system can be differentiated from a “sloppy” one?

  - For analog communications
    - How close is $\hat{m}(t)$ to $m(t)$? Fidelity!
    - SNR is typically used as a performance metric

  - For digital communications
    - Data rate and probability of error
    - No channel impairments, no error
    - With noise, error probability depends upon data rate, signal and noise powers, modulation scheme

Review of Signals and Spectra

- A generic sinusoidal signal
  \[ v(t) = A \cos(w_0 t + \phi); \quad w_0 = 2\pi f_0 \]

- Phasor representation
  \[ v(t) = A \cos(w_0 t + \phi) = \Re[A e^{j(w_0 t + \phi)}] \]

- Frequency domain representation
  - Rotating phasors
  - Frequency plots
    - Amplitude
    - Phase