Professional Development Short Course On:

Fundamentals of Telecommunications

Instructor:

Dr. Charles Alexander

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TOPICS COVERED

• Introduction to Telecommunications
• Transmission Channel Characteristics
• Open Systems Interface (ISO) Model
• Signal Formatting & Data Communications
• Modulation & Multiplexing
• Digital Signal Processing Concepts
• Principles of Speech & Video Compression
APPLICATIONS & TRENDS

• Satellite Communications (Past & Present)
• Digital Telephony, PSTN & CPE
• LAN, WLAN, WiFi, Bluetooth
• SONET & Optical Communications
• Wireless Technologies (GSM, TDMA, 3G)
• Multimedia Data Compression Techniques
• Echo Cancellation (LMS Vs Adaptive)
CASE STUDIES/ TRADE-OFFS

- Wired Vs Wireless Communications
- Satellite Vs Microwave Vs Optical
- Circuit Vs Packet Switching
- Multiple Access (TDMA, FDMA, CDMA)
- ISDN Vs ATM Vs SS7
- Cellular (TDMA Vs CDMA Vs GSM)
- Echo Cancellation (LMS Vs Adaptive)
Basic Communications Model

Source Input → A/D → Format → Mod → {Transmitter} → Propagation Channel → Dem → D/A → Format → Destination Output

{Receiver}
Telecommunication Signal Types

– Signals Classifications (Analog or Digital)
  • Deterministic (Periodic or Aperiodic)
    – Follows some analytic or graphical form
    – Predictable (Amplitude, Frequency & Phase)
    – Time Averaging (Fourier Transforms)
  
  • Nondeterministic (Periodic or Aperiodic)
    – Stochastic or Random Processes
    – Random events or occurrences
    – Statistical Averaging (Auto-Correlation)
## Signal Classifications

<table>
<thead>
<tr>
<th>Name</th>
<th>Digital?</th>
<th>Type of Signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fourier Series</td>
<td>Analog signals</td>
<td>Periodic signals</td>
</tr>
<tr>
<td>Fourier Transform</td>
<td>Analog signals</td>
<td>Arbitrary functions including realizable transients</td>
</tr>
<tr>
<td>Discrete Time Fourier Transform</td>
<td>Continuous in $\omega$</td>
<td>Finite length or exponentially decaying infinite length</td>
</tr>
<tr>
<td>Discrete Fourier Transform</td>
<td>Digital</td>
<td>Finite duration and periodic signals</td>
</tr>
<tr>
<td>Z-Transform</td>
<td>Digital</td>
<td>Arbitrary functions including realizable transients</td>
</tr>
</tbody>
</table>
Noise & Interference

• In the real world (practical systems) there is not only signals but noise (both internal such as thermal and external such as man-made interference, multipath and galactic)

• Noise is a random or stochastic process (amplitude, phase and/or frequency not deterministic or known for all time)
Analog-To Digital (A/D)

• Three Steps In A/D Conversion
  – Continuous Time to Discrete Time Sampling (C/D)
    (Also Called Time Quantization – Nyquist Criteria)
  – Amplitude Quantization (Quantization Noise)
    (Uniform/Linear or Nonuniform/Nonlinear - Voice)
  – Encoding or Bit Stream Time Representation
    (PCM, DM, ADM, ADPCM)
Modulation and Demodulation

• Need some type of methodology for transmission over long distances (Modulation)
• Need to modulate the signal at one end- (transmitter) demodulate at other (receiver)
• Basic Modulation Types (Analog/Digital): Amplitude (AM/ASK), Frequency (FM/FSK), and Phase (PM/PSK)
Propagation Channel

- Wires, Satellite, Microwave, Optical
- Could be through sets of exchanges (PBXs)
- Channel Restricts Signal Characteristics
  - Matching
    - Electromagnetic transmission will support high frequencies
    - Speech is low frequency
      process of matching signal to medium:
      (modulation, multiplexing, multiple access)
Public Switched Telephone Network (PSTN)

• Telephones, facsimile machines, and computer systems are ubiquitous
  – More computers sold than TV sets
  – More telephones than people

• Basic communications model (PSTN)
  – Information flows from source to destination over a channel (wire/fiber/microwave/satellite)
PSTN Network Limitations

- Subscriber connected to network: local loop
  - Terminates in central office in line circuit
  - Signals between line circuits are trunks
- On demand links
- Two-wire: to CPE
- Four-wire: from line circuit (Echos)
- CPE is analog
- Switching likes digital signals
  - A/D, D/A, anti-aliasing, replicate, amplify
Echo Cancellation Problem

- A typical hybrid is depicted as

- Some of the Receive signal leaks into the Send path ⇒ echo
- If all Receive power coupled into subscriber loop, there would be no echo
  - Governed by Balance Impedance, $Z_B$
Hybrid Circuits

• If the impedance into the subscriber loop is $Z_{in}$ (depends on number of devices hung, current, and distances [hundreds of feet to a few miles]), the transfer function
  
  – US: less than 12 kft
  
  $$H(f) = \frac{1}{2} \frac{Z_{in}(f) - Z_B(f)}{Z_{in}(f) + Z_B(f)}$$

• Matching the impedance of the input and the subscriber loop
Solutions To PSTN Echo

• Time & Frequency Compression
• Round Trip Attenuation (small delays)
• Echo Suppressors (medium delays)
• Echo Cancelors (large delays-satellite)
• Adaptive Algorithms (Digital Filters)
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