Chapter 1

Introduction to Analog & Digital Communications
Outline

• Signals and Communication Systems
• Digital & Analog Sources & Systems
• Block Diagram of a Communication System
• Deterministic and Random Signals
• Frequency Allocations Frequency Allocations
• Review
  – Logarithmic Power Calculations
Communication Systems

• What is a signal?
  – a single-valued function of time that conveys information

• What is a communication system?
  – Enabling the process of transmitting meaningful signals from one location to another (e.g., Sender to Receiver over a communication channel)

• Key design issues of a communication system
  – Selection of the information-bearing waveform or signal
  – Bandwidth
  – Signal power and energy consumption
  – Probability of error
  – System noise and its impact
  – Data rate
  – As well as....
    • Cost of the system
Digital Vs. Analog Signal

- **Analog signal**: continuous function of time with continuous amplitude
- **Discrete-time signal**: only defined at discrete points in time, amplitude continuous
- **Digital signal**: discrete in both time and amplitude (e.g., PCM signals,)
## Analog Vs. Digital Systems

- A quick comparison

<table>
<thead>
<tr>
<th></th>
<th>Analog</th>
<th>Digital</th>
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<tbody>
<tr>
<td><strong>Information Source</strong></td>
<td>Produces messages that are defined on a continuum</td>
<td>Produces a finite set of possible messages</td>
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<td></td>
<td>E.g., Microphone, its output voltage describes information in sound</td>
<td>E.g., A telephone touchtone, its output is a finite set of characters</td>
</tr>
<tr>
<td><strong>Communication System</strong></td>
<td>Transfers information from an analog source to the receiver</td>
<td>Transfers information from a digital source to the receiver</td>
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<td></td>
<td>E.g., AM radio system</td>
<td>E.g., A computer Network</td>
</tr>
<tr>
<td><strong>Advantages</strong></td>
<td>Reverse disadvantages of digital communication</td>
<td>• Relatively inexpensive circuits can be used</td>
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<td></td>
<td></td>
<td>• Privacy is preserved by data encryption</td>
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<td></td>
<td></td>
<td>• Greater dynamic range is possible</td>
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<td></td>
<td></td>
<td>• Data from voice, video, data may be merged</td>
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<td></td>
<td></td>
<td>• Noise does not accumulate in long-distance</td>
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<td></td>
<td></td>
<td>• Storing more reliable &amp; cheaper</td>
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<td></td>
<td></td>
<td>• Error in detected data may be small</td>
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<tr>
<td></td>
<td></td>
<td>• Errors may be corrected by using codes</td>
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<tr>
<td><strong>Disadvantage</strong></td>
<td>Reverse advantages of digital communication</td>
<td>• Generally requires more bandwidth than analog</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Synchronization is required</td>
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**Deterministic Vs. Random Waveforms**

- **Deterministic waveform** can be modeled as a completely specified function of time, e.g., if
  \[ \omega(t) = A \cos(\omega_0 t + \varphi), \text{ where } A, \omega_0, \text{ and } \varphi, \text{ are known constant,} \]
  describes a waveform, this waveform is deterministic because
  - for any \( t \), the value of \( \omega(t) \) can be evaluated.

- **Random (or stochastic) waveform** cannot be completely specified as a function of time & must be modeled probabilistically, e.g., noise is described by a random waveform.

- In this course we use a deterministic approach in analyzing communication systems without going to statistical analysis.
Communication System Block Diagram

- Baseband Signals (fc=0)
  - LPF
  - ADC
  - Baseband Processor
  - Coding (parity for error detection)

- Baseband signal
  - Adds carrier signal
  - Also referred to as modulation

Freq. band or Bandpass Signals (fc>>0) e.g., AM has fc=850 KHz

\[ s(t) = R(t) \cos(\omega_c t + \theta(t)) \]

Note that if phase =0 \(\rightarrow\) pure sinusoid, with zero BW

Model for effect of noise can be additive Gaussian noise channel

\[ \text{Noise } n(t) \]

\[ \text{Channel} \]

\[ \text{Bandpass } s(t) \]

\[ r(t) = s(t) + n(t) \]
Bandwidth

- Extent of the significant spectral content of a signal for positive frequencies
Signal & Noise

Data transmitted: 1 0 1 0 0 1 1 0 0 1 1 0 1 0 1

Signal:

Noise:

Signal plus noise:

Sampling times:

Data received: 1 0 1 0 0 1 1 0 0 0 1 1 0 1 1 1

Original data: 1 0 1 0 0 0 1 1 0 0 1 1 0 1 0 1

Bits in error
Frequency Allocations

- Wireless communication uses the atmosphere for transmission channel.
- The interference & propagation conditions strongly depend on frequency.
- To provide some order & minimize the interference, ITU, an international standardization organization, has set frequency assignment & technical standards.
- The spectrum of EM frequencies are defined in terms of frequency bands for various communication applications, e.g., radio, TV, remote controls, cell phone, radar.

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<th>Classification</th>
<th>Typical Uses</th>
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<td>3 – 30 kHz</td>
<td>Very Low Frequencies (VLF)</td>
<td>Navigation &amp; Submarine communication</td>
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<td>3 – 30 GHz</td>
<td>Super High Frequencies (SHF)</td>
<td>Satellite communication &amp; microwave links</td>
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<td>Infrared, visible light, &amp; UV</td>
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FCC = Federal Communications Commission, ITU = International Telecommunications Union, RF = Radio Frequency, EM = Electromagnetic
Example 1: What is the antenna length for an AM transmitter at 1 MHz?

Solution: At 1 MHz, \( \lambda = \frac{c}{f_c} = \frac{3 \times 10^8 \text{ m/s}}{1 \times 10^6} = 300 \text{ m} \)

Note that for efficient radiation, the length of the antenna must be longer than 1/10 the wavelength \( \rightarrow \) Antenna length = 30 m

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Review
Power in Telecommunication Systems –
Power change can have large dynamic range

- **Remember:**

\[
10^x = y \rightarrow \log(10^x) = \log y \rightarrow x = \log y 
\]

- **Example 1:** if \( P2 = 2 \text{mW} \) and \( P1 = 1 \text{mW} \) →

\[
10 \log_{10}(P2/P1) = 3.01 \text{ dB}
\]

- **Example 2:** if \( P2 = 1 \text{KW} \) and \( P1 = 10 \text{W} \) → 20dB

- What if dB is given and you must find \( P2/P1 \)?
  - \( P2/P1 = \text{Antilog}(\text{dB}/10) = 10^{\text{dB}/10} \).

- **Example 3:** if dB is +10 what is \( P2/P1 \)?
  - \( P2/P1 = \text{Antilog}(+10/10) = 10^{+10/10} = 10 \)

**We tend to express power in dBW or dBm**
Decibel values refer to relative magnitudes or changes in magnitude, not to an absolute level. It is convenient to be able to refer to an absolute level of power or voltage in decibels so that gains and losses with reference to an initial signal level may be calculated easily. The dBW (decibel-Watt) is used extensively in microwave applications. The value of 1 W is selected as a reference and defined to be 0 dBW. The absolute decibel level of power in dBW is defined as

\[ \text{Power}_{\text{dBW}} = 10 \log \frac{\text{Power}_W}{1 \text{ W}} \]

**EXAMPLE 3.9** A power of 1000 W is 30 dBW, and a power of 1 mW is −30 dBW.

Another common unit is the dBm (decibel-milliWatt), which uses 1 mW as the reference. Thus 0 dBm = 1 mW. The formula is

\[ \text{Power}_{\text{dBm}} = 10 \log \frac{\text{Power}_{\text{mW}}}{1 \text{ mW}} \]

Note the following relationships:

+30 dBm = 0 dBW
0 dBm = −30 dBW

A unit in common use in cable television and broadband LAN applications is the dBmV (decibel-millivolt). This is an absolute unit with 0 dBmV equivalent to 1 mV. Thus

\[ \text{Voltage}_{\text{dBmV}} = 20 \log \frac{\text{Voltage}_{\text{mV}}}{1 \text{ mV}} \]
dBm
References

• Leon W. Couch II, Digital and Analog Communication Systems, 8\textsuperscript{th} edition, Pearson / Prentice, Chapter 1
• Stallings, William. \textit{Data and Computer Communications, 10/\textsuperscript{e}}. Pearson Education, Chapter 3