Introduction to Communication Systems: An Overview

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What is a Communications System?

- A communications system transfers an information bearing signal from a source to one or more destinations.

Examples:
- Radio
- TV
- Telephone (landline or wireless)
- Computer Network (terminal-computer or computer-computer)
- Radar
- Wireless Microphone
Communications System Diagram

Information Source: Audio, image, text, data

Input Transducer: Converts source to electric signal
- Microphone
- Camera
- Keyboard
Communications System Diagram

Output Transducer: Converts electric signal to useable form
- Speaker
- Monitor

Transmitter:
- Converts electrical signal into form suitable for channel
- Modulator
- Amplifier
Communications System Diagram

Channel: Medium used to transfer signal from transmitter to receiver. Point to point or Broadcast

- Wire lines
- Fiber optic cable
- Atmosphere
- Often adds noise / weakens & distorts signal

Communications System Diagram

Receiver

- Extracts an estimate of the original transducer output
- Demodulator
- Amplifier
Why do we need Modulation/Demodulation?

- Example: Radio transmission

Voice 🔄 Microphone 🔄 Transmitter

Electric signal, 20 Hz – 20 KHz

Antenna: Size requirement > 1/10 wavelength

At 3 KHz: $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^3} = 10^5 = 100 km$

$\Rightarrow 0.1 \lambda = 10 km$

Antenna too large! Use modulation to transfer information to a higher frequency

Why do we need Modulation/Demodulation? (cont’d)

- Frequency Assignment
- Reduction of noise/interference
- Multiplexing
- Bandwidth limitations of equipment
- Frequency characteristics of antennas
- Atmospheric/cable properties
Types of Modulation

- **Analog Modulation**: A higher frequency signal is generated by varying some characteristic of a high frequency signal (carrier) on a continuous basis
  - AM, FM, DSB, SSB
- **Digital Modulation**: Signals are converted to binary data, encoded, and translated to higher frequency
  - FSK, PSK, QPSK, QAM
  - More complex, but reduces the effect of noise

Communications Channels

- **Wireline**
  - Twisted Pair
  - Cable
  - Waveguide
  - Fiber Optics
  - Increasing bandwidth
- **Wireless (radio)**: Transmission of electromagnetic waves from antenna to antenna
  - KHz to ultraviolet
  - Propagation characteristics vary with frequency
Propagation Characteristics of Radio Channels

- **Ground Wave**
  - Low MHz
  - Waves guided between earth and ionosphere
  - Distance of communication varies based on wavelength
  - AM Radio (1 MHz) – propagates < 100 miles in day but longer at night
  - Predictable propagation

- **Sky Wave**
  - Low MHz → 30 MHz
  - Signals reflect from various layers of ionosphere
  - Changes based on time, frequency, sun spots
  - Signals travel around the world
  - Less predictable propagation

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Propagation Characteristics of Radio Channels (cont’d)

- **Line of Sight**
  - Above 30 MHz
  - Need little or no obstruction – limited by horizon
  - Noise issues
  - In GHz range – rain issues
  - Used for Satellite and local communications
  - Very predictable / stable propagation

- **Other Channels**
  - Acoustic channels
Table of Frequencies

- **ELF**: 0 – 3 kHz. Submarine communications.
- **VLF**: 3 – 30 kHz. Submarine communications, Time Signals, Navigation

Chart of Frequencies (cont’d)

System Performance

- The performance of a communications link depends on the Signal to Noise ratio (S/N) at the receiver.
- Signal: The power received, $P_r$, is given by:

$$P_r = \frac{P_t g_i g_r \lambda^2}{(4\pi)^2 d^2}$$

- Noise
  - Receiver/Antenna noise
  - Atmospheric noise
  - Galactic Noise
  - Sun Noise
  - Thermal noise

Traditional Transmitter/Receiver Hardware
Disadvantages of the Traditional Receiver

- Simple modulation / demodulation only
- Limited implementation of filters
- Alignment
- Aging
- Complexity
- Fixed design: frequency/mode
- Non linearity – unwanted signals

What is Software Defined Radio (SDR)?

- A new technology for implementing radio communications systems
- Art and science of building radios using software
- Eliminating hardware and moving software as close to the antenna as possible
Software Defined Radio

Radio is modified by changing the software. The hardware remains the same.

Current SDR Applications

- Military
- Radio Astronomy
- Amateur Radio
Future SDR Applications

- Personal Communications
  - Cell phones
  - Wi Fi
  - Entertainment distribution
- Public Safety
- Broadcasting
  - Digital Radio
  - Digital Television

Components of a SDR System

[Diagram showing the components of a SDR system, including ADC, FPGA (Decimator, MUX, etc.), USB Controller, and PC, with labels indicating their functions such as shifts frequency, samples analog signal, performs initial signal processing, and software for transmitter/receiver.]
GNU Radio Software

- Community-based project started in 1998
- GNU Radio application consists of sources (inputs), sinks (outputs) and transform blocks
- Transform blocks: math, filtering, modulation/demodulation, coding, etc.
- Sources: USRP, audio, file input, signal generator, …
- Sinks: USRP, audio, file output, FFT, oscilloscope, …
- Blocks written in C++
- Python scripts used to connect blocks and form application
Questions?