EEN 1043/EE452 Wireless and Mobile Communication

Week 1: Basics of Digital Communication System

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Data Communication Terms

Data: entities that convey meaning, or information

Signals: electric or electromagnetic representations of data

Transmission: communication of data by the propagation and processing of signals

Examples of Analog and Digital Data

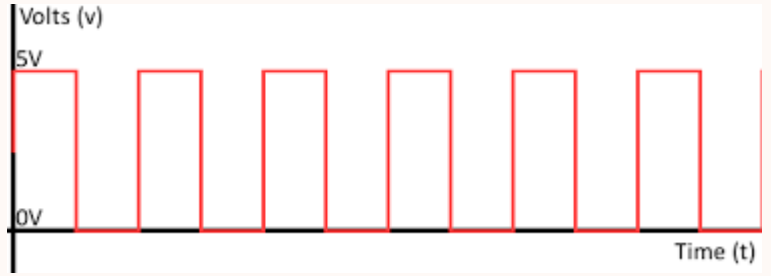
- Analog
  - Video
  - Audio
- Digital
  - Text
  - Integers

Analog Signals

- A continuously varying electromagnetic wave that may be propagated over a variety of media, depending on frequency
- Examples of media:
  - Copper wire media (twisted pair and coaxial cable)
  - Fiber optic cable
  - Atmosphere or space propagation
- Analog signals can propagate analog and digital data

Digital signals

- A sequence of voltage pulses that may be transmitted over a copper wire medium
- Generally cheaper than analog signalling
- Less susceptible to noise interference
- Suffer more from attenuation
- Digital signals can propagate analog and digital data



Data and Signal Combination

- Digital data, digital signal
  - Equipment for encoding is less expensive than digital-to-analog equipment
- Analog data, digital signal
  - Conversion permits use of modern digital transmission and switching equipment
- Digital data, analog signal
  - Some transmission media will only propagate analog signals
  - Examples include optical fiber and satellite
- Analog data, analog signal
  - Analog data easily converted to analog signal

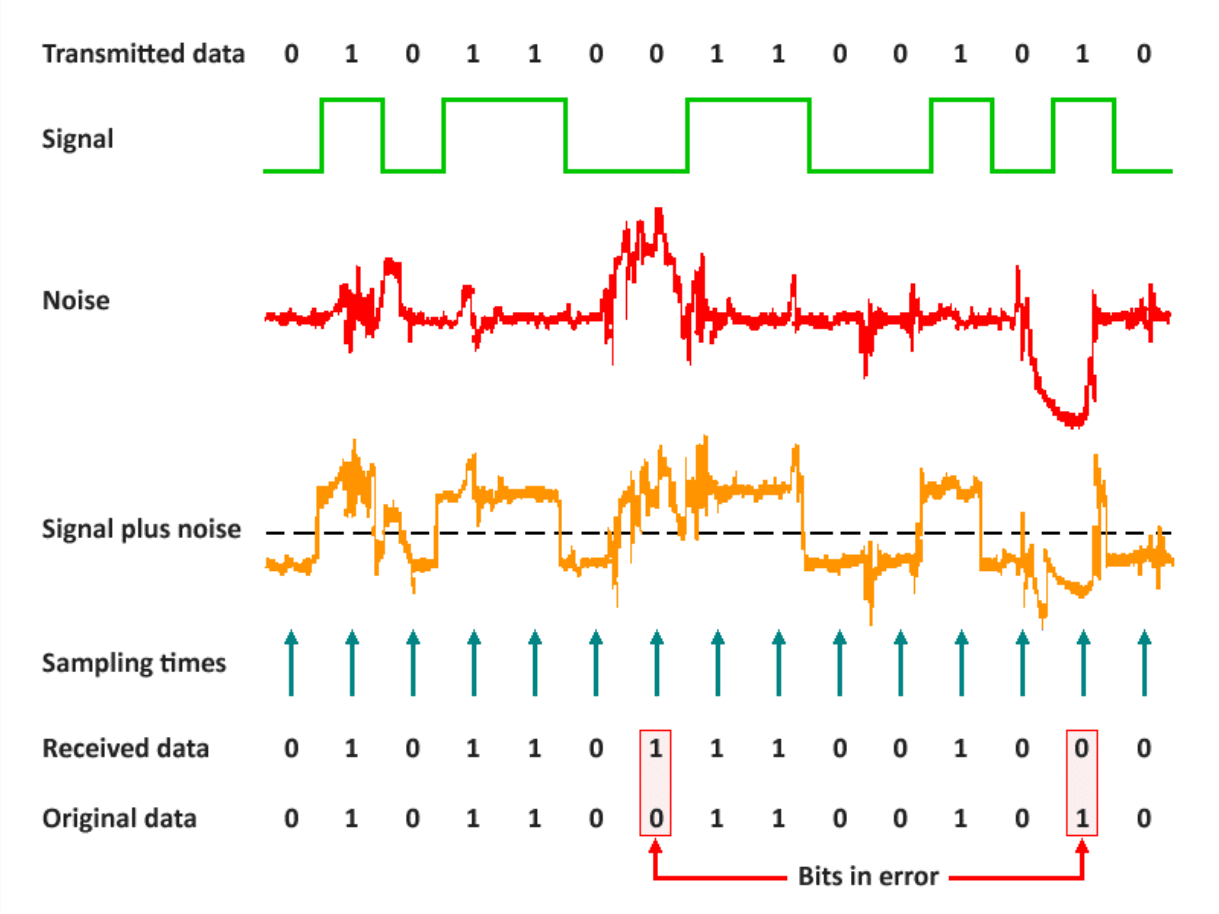
Analog Transmission

- Transmit analog signals without regard to content
- Attenuation limits length of transmission link
- Cascaded amplifiers boost signal's energy for longer distances but cause distortion
  - Analog data can tolerate distortion
  - Introduces errors in digital data

Digital Transmission

- Concerned with the content of the signal
- Attenuation endangers integrity of data
- Digital Signal
  - Repeaters achieve greater distance
  - Repeaters recover the signal and retransmit
- Analog signal carrying digital data
  - Retransmission device recovers the digital data from analog signal
  - Generates new, clean analog signal

Effect of Noise on Digital Signal



Electromagnetic Signal

- Function of Time
- Can also be expressed as a function of frequency
  - Signal consists of components of multiple frequencies

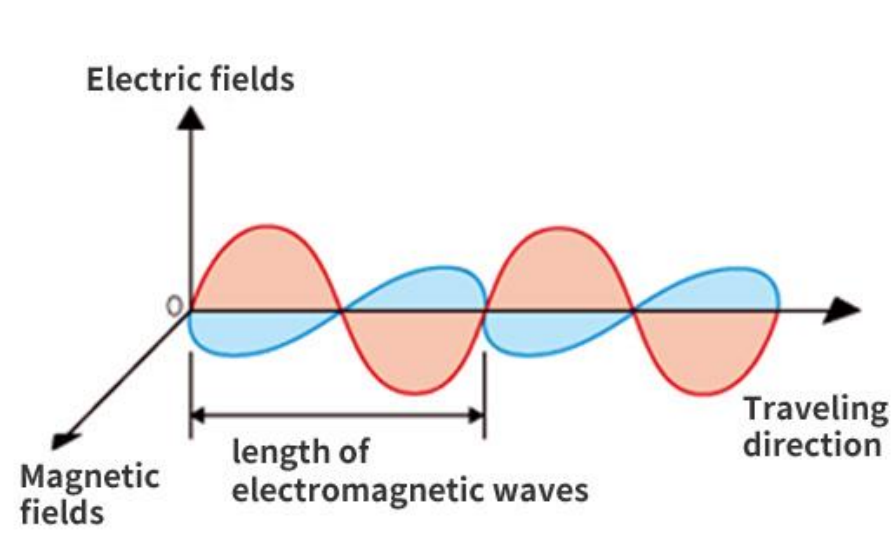


Image courtesy: https://www.artiencegroup.com/

Channel Capacity

- Impairments, such as noise, limit data rate that can be achieved
- For digital data, to what extent do impairments limit data rate?
- The maximum rate at which data can be transmitted over a given communication path, or channel, under given conditions

Channel Capacity Definitions

- Data rate - rate at which data can be communicated (bps)
- Bandwidth - the bandwidth of the transmitted signal as constrained by the transmitter and the nature of the transmission medium (Hertz)
- Noise - average level of noise over the communications path
- Error rate - rate at which errors occur −Error = transmit 1 and receive 0; transmit 0 and receive 1

Nyquist Bandwidth

- For binary signals (two voltage levels)

$$C = 2B$$

- With multilevel signaling

$$C = 2B \log 2\ M$$

- M = number of discrete signal or voltage levels

Signal-to-Noise Ratio

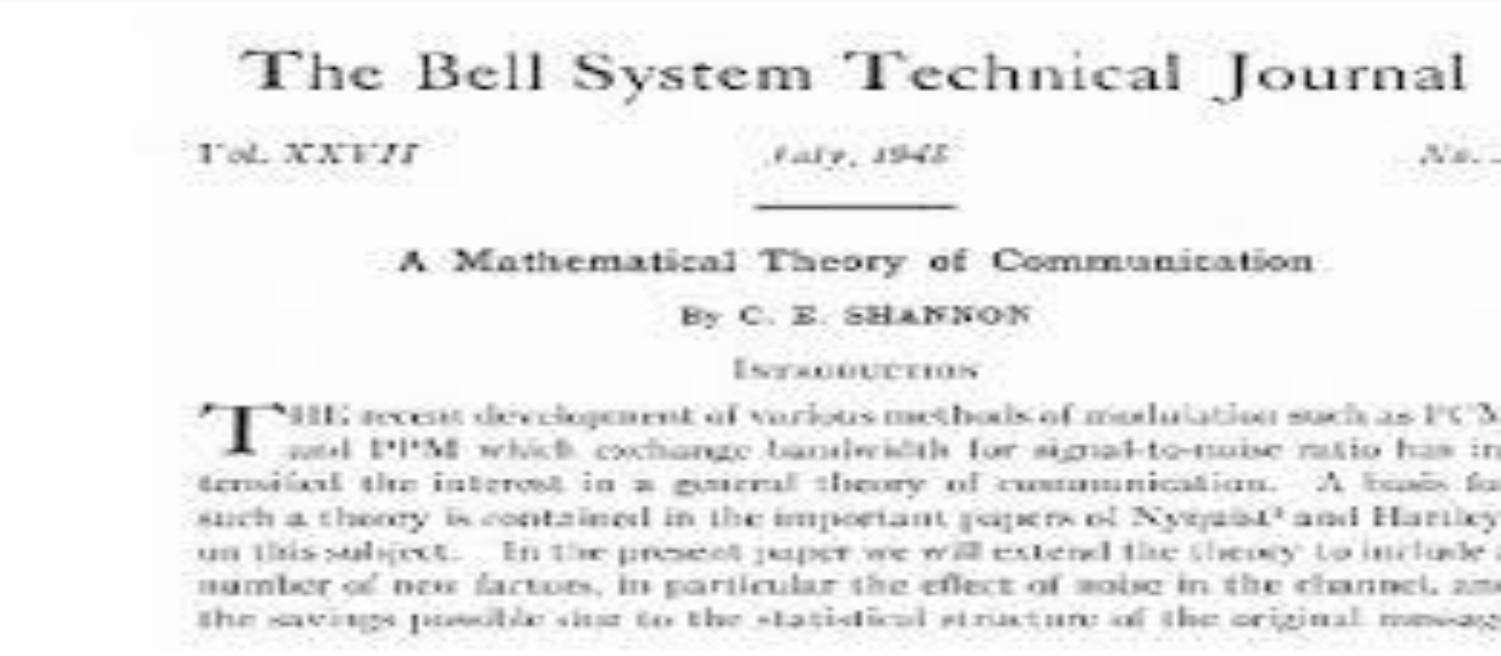
- Ratio of the power in a signal to the power contained in the noise that's present at a particular point in the transmission
- Signal-to-noise ratio (SNR, or S/N)

$$SNR = \frac{signal\ power}{noise\ power}$$

$$(SNR)_{dB} = 10 \log_{10} \frac{signal\ power}{noise\ power}$$

- A high SNR means a high-quality signal, low number of required intermediate repeaters
- SNR sets upper bound on achievable data rate. Typically measured at a receiver

Shannon Capacity



The Bell System Technical Journal

Vol. XXVII July, 1948 No.

A Mathematical Theory of Communication

By C. E. SHANNON

INTRODUCTION

THE recent development of various methods of modulation such as PCM and PPM which exchange bandwidth for signal-to-noise ratio has intensified the interest in a general theory of communication. A basis for such a theory is contained in the important papers of Nyquist[1] and Hartley[2] on this subject. In the present paper we will extend the theory to include a number of new factors, in particular the effect of noise in the channel, and the savings possible due to the statistical structure of the original message

- Represents theoretical maximum that can be achieved

$$C = Blog_2(1 + SNR)$$

- In practice, only much lower rates achieved
  - Formula assumes white noise (thermal noise)
  - Impulse noise is not accounted for
  - Attenuation distortion or delay distortion not accounted for

Example

- Suppose the spectrum of the channel is from 3 MHz to 4MHz and SNR(in dB)= 24dB Find the max channel Capacity

- $B = 4MHz - 3MHz = 1\ MHz$
- $SNR_{dB} = 24dB = 10\log_{10} SNR$,
- $SNR = 251$
- $C = Blog_2(1 + SNR) = 8Mbps$

Example

- How many signaling levels are required?

$$C = 2Blog_2M$$

M=16

Transmission Media

Transmission Medium: Physical path between transmitter and receiver

Guided Media:

- Waves are guided along a solid medium
- E.g., copper twisted pair, copper coaxial cable, optical fiber

Unguided Media:

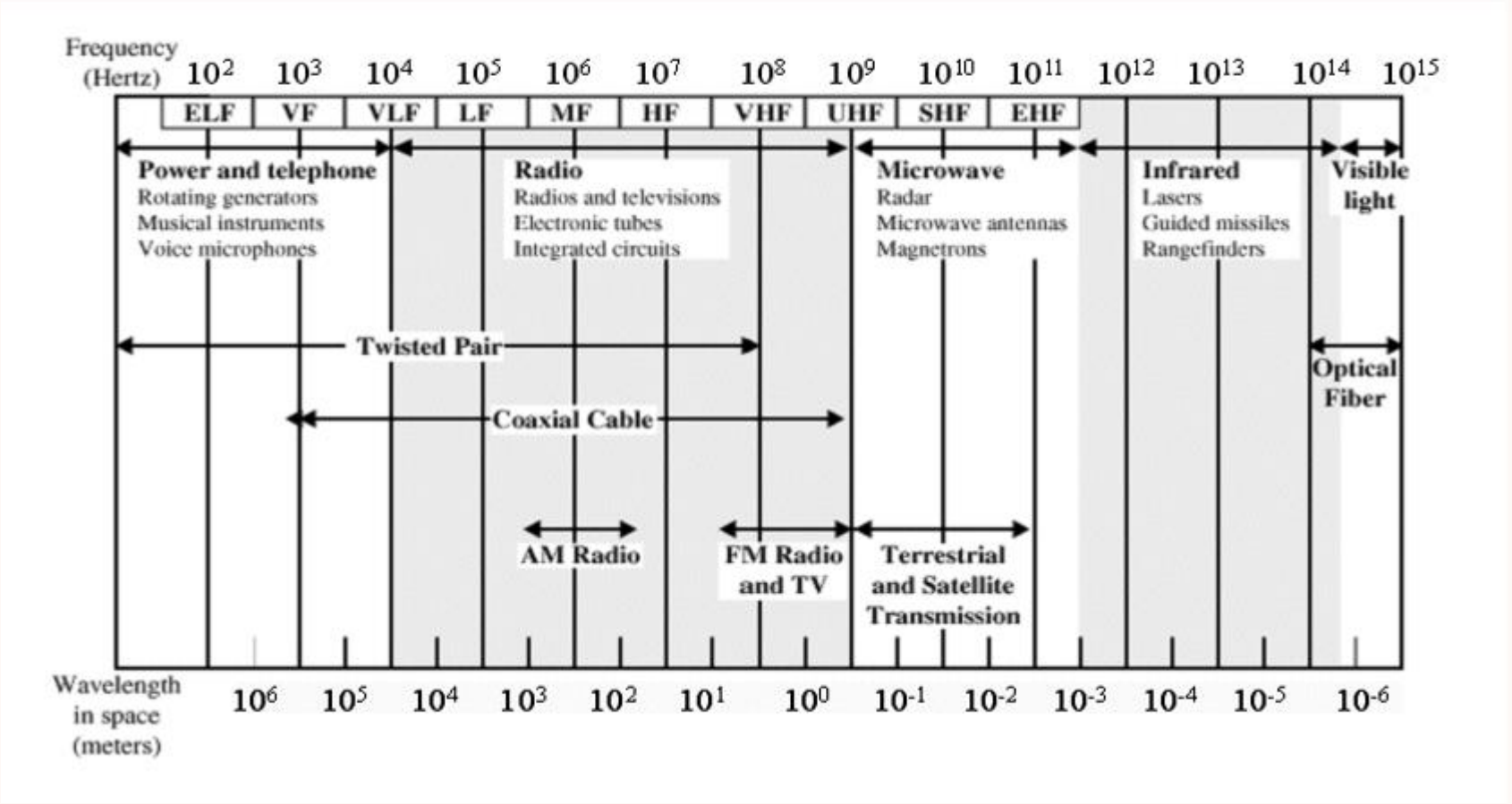
- Provides means of transmission but does not guide electromagnetic signals
- Usually referred to as wireless transmission
- E.g., atmosphere, outer space

Unguided Media

- Transmission and reception are achieved by means of an antenna
- Configurations for wireless transmission
  - Directional
  - Omnidirectional

Electromagnetic Spectrum of Telecommunications

For details on frequency band table 6.3 in the text book



General Frequency Ranges

- Microwave frequency range
  - 1 GHz to 40 GHz
  - Directional beams possible
  - Suitable for point-to-point transmission
  - Used for satellite communications
- Radio frequency range
  - 30 MHz to 1 GHz
  - Suitable for omnidirectional applications
- Infrared frequency range
  - Roughly, 3x10^11 to 2x10^14 Hz
  - Useful in local point-to-point multipoint applications within confined areas

Terrestrial Microwave

- Description of common microwave antenna
  - Parabolic "dish", 3 m in diameter
  - Fixed rigidly and focuses a narrow beam
  - Achieves line-of-sight transmission to receiving antenna
  - Located at substantial heights above ground level
- Applications
  - Long haul telecommunications service
  - Short point-to-point links between buildings

Satellite Microwave

- Description of communication satellite
  - Microwave relay station
  - Used to link two or more ground-based microwave transmitter/receivers
  - Receives transmissions on one frequency band (uplink), amplifies or repeats the signal, and transmits it on another frequency (downlink)
- Applications
  - Television distribution
  - Long-distance telephone transmission
  - Private business networks

Broadcast Radio

- Description of broadcast radio antennas
  - Omnidirectional
  - Antennas not required to be dish-shaped
  - Antennas need not be rigidly mounted to a precise alignment
- Applications
  - Broadcast radio
    - VHF and part of the UHF band; 30 MHZ to 1GHz
    - Covers FM radio and UHF and VHF television

Multiplexing

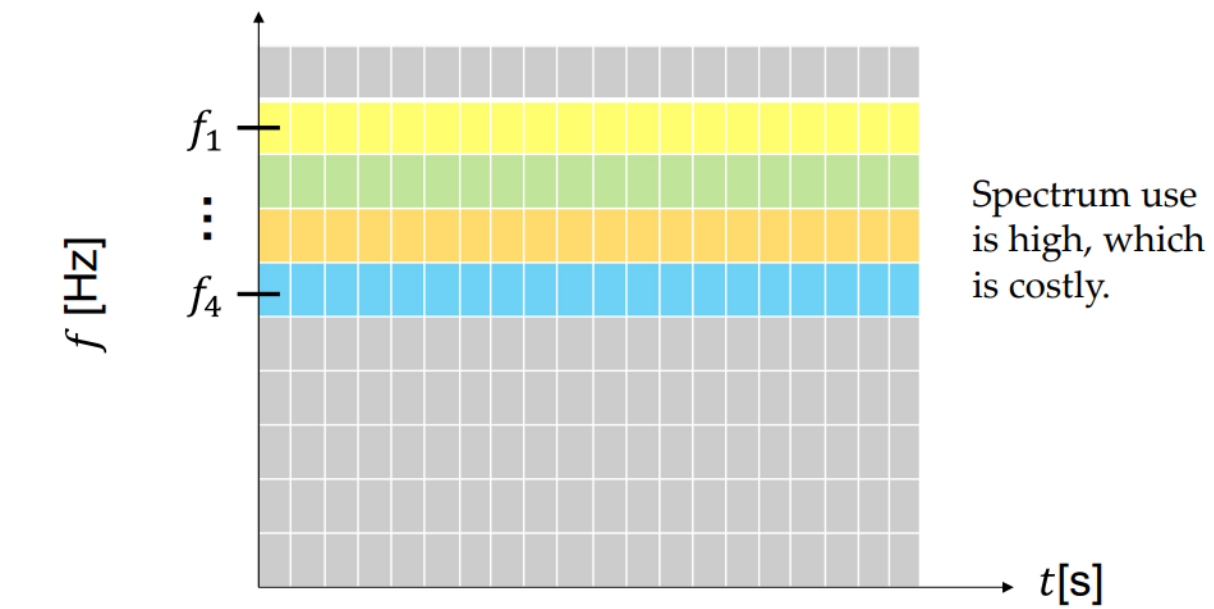
- Capacity of transmission medium is usually more than the capacity required for transmission of a single signal
- Multiplexing - carrying multiple signals on a single medium
  - More efficient use of transmission medium

Need for Multiplexing

- Cost per kbps of transmission facility declines with an increase in the data rate
- Cost of transmission and receiving equipment declines with increased data rate
- Most individual data communicating devices require relatively modest data rate support

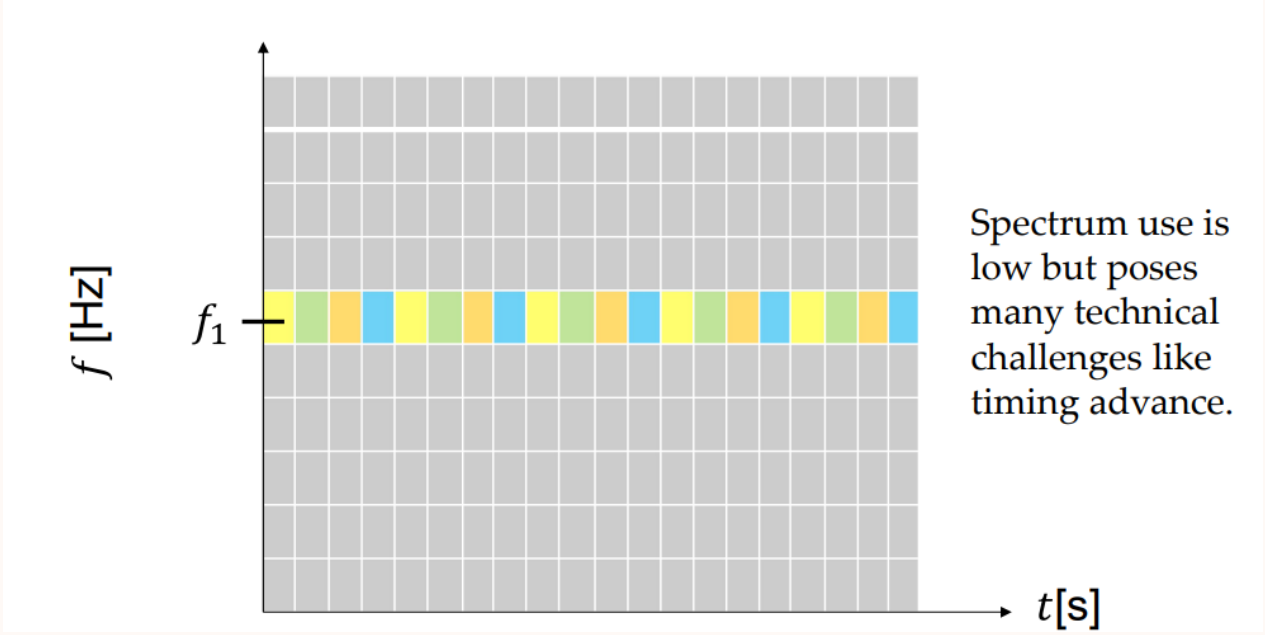
Multiplexing Techniques

- Frequency-division multiplexing (FDM)
  - Takes advantage of the fact that the useful bandwidth of the medium exceeds the required bandwidth of a given signal



Multiplexing Techniques

- Time-division multiplexing (TDM)
  - Takes advantage of the fact that the achievable bit rate of the medium exceeds the required data rate of a digital signal



Digital Communication System

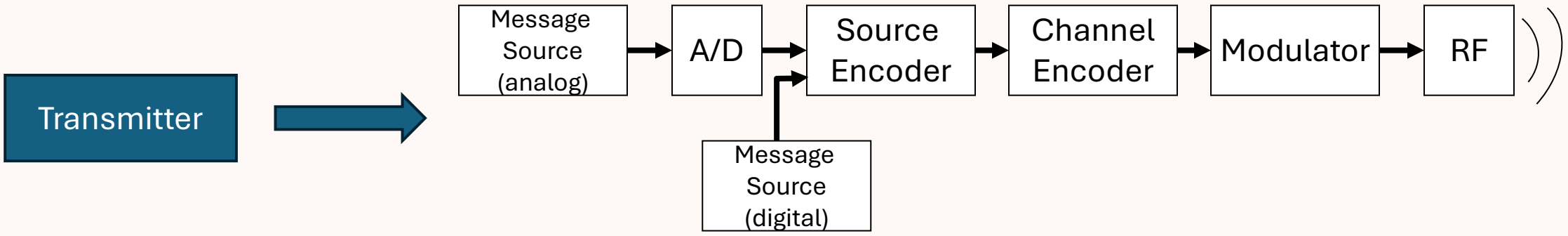
Digital Communication System

- The purpose of a digital communication system is to effectively convey information from sender (source) to receiver (sink).

- In our case, the *physical transmission* of the message occurs via a *radio link*.
  - "radio wave" = sinusoidal signal
- The information (message) may originally be in analogue or digital form
  - Analogue = voice
  - Digital
    - Coded video
    - Files
    - Control signals
    - etc.

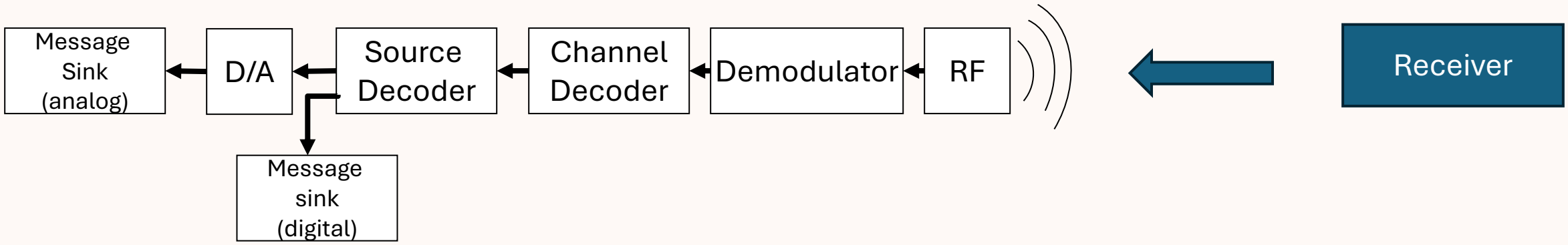
Transmitter

- Analogue to digital converter
  - Converts initial voice signal into a digital form
- Source encoder
  - efficiently represents the bits with little or no redundancy.
- Channel coder
  - Adds redundancy to combat effects of information loss introduced in transmission.
- Modulator
  - Converts the digital information sequence into a waveform representation which is consistent with the characteristics of the channel.

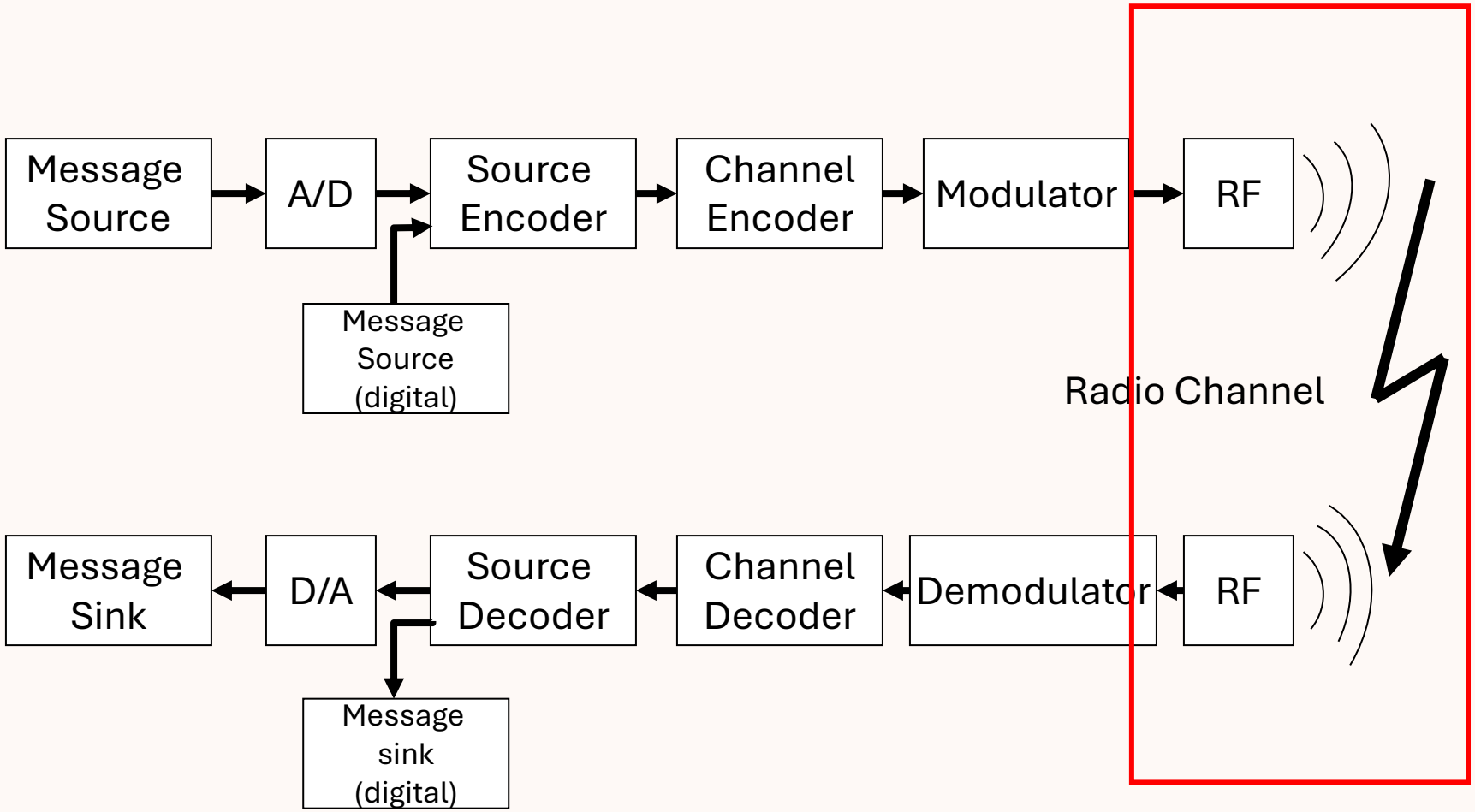


Receiver

- Demodulator
- Equalization
  - Counteract the multipath effects of the channel
- Channel Decoder
- Source Decoder
- D/A



Radio Link


Message Source
A/D
Source Encoder
Channel Encoder
Modulator
RF
Message Source (digital)
Radio Channel
Message Sink
D/A
Source Decoder
Channel Decoder
Demodulator
RF
Message sink (digital)

Summary

- Chapter 2 of the textbook.
- Shannon capacity

$$C = Blog_2(1 + SNR)$$