Communications & Electronics Engineering Dept.

Part1

Communication Networks

(650536)

Prerequisite: **Digital Communications** **(650533)**

Instructor: *Dr. Abdel-Rahman Al-Qawasmi*

Text Book :*Wireless Communications & Networking. William Stallings Published by: Pearson Education, 2002*

Transmission Fundamentals

Part 1
Transmission Fundamentals

1- <u>Introduction:</u> Read from text book (Pages 2-5)

2- <u>Transmission Fundamentals:</u>

Basic Information

-The signal can be represented in time and frequency domains

-Signals can be Analog, digital, periodic, or aperiodic.

-The general sine wave can be written as: $s(t) = A\cos(2\pi ft + \varphi)$

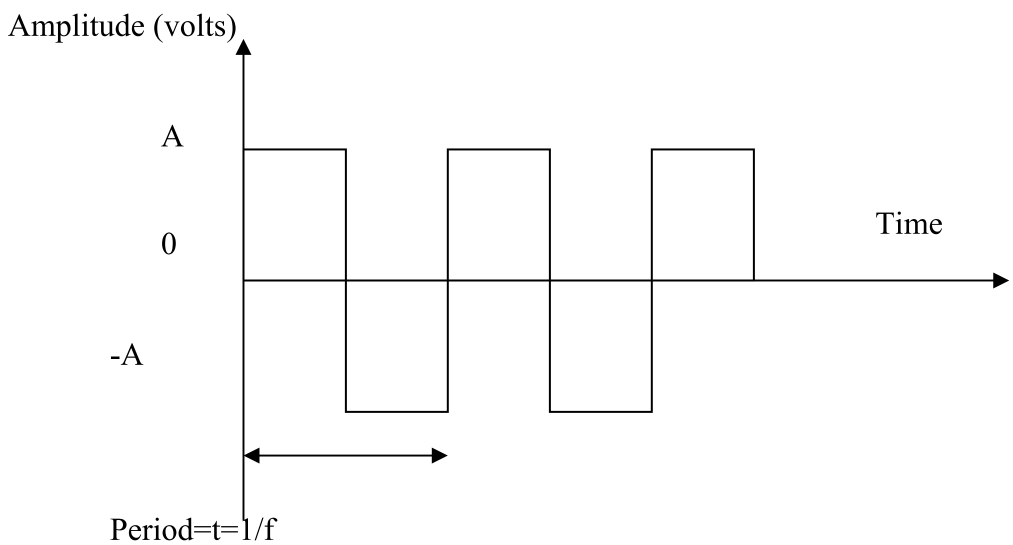
-The ***spectrum*** of a signal is the range of frequencies that it contains

- ***Bandwidth*** of a signal is the width of the spectrum

-The greater the ***bandwidth***, the higher the ***data rate***.

-Any digital wave form will have infinite bandwidth.

- Figure 1.1 Square Wave



Data rate

the information – carrying capacity of a signal [bits per second (bps)]

Analog & digital data transmission

	Analog Transmission	Digital Transmission
Data	Analog data take on continuous values in some interval [Voice, Video]	Digital Data take on discrete values [text, integers]
Signaling	Analog Signal is continually varying electromagnetic wave that may be propagated over a variety of media, depending on frequency [*copper wire* media: twisted pair and coaxial cable, *fiber optic, cable, wireless*]	A digital signal is a sequence of voltage pulse that may be transmitted over a copper wire medium [constant positive voltage levels]
Advantages	Less attenuation	Cheaper and less susceptible to noise interference
Representation	Analog signal can be represented by digital signal [A/D conversion]	Digital data can be represented by analog signal [D/A conversion]
Transmission	1-Analog transmission is a means of transmitting analog signals without regards to their constants. 2-The analog transmission system includes amplifiers that boost the energy in the signal	1-Digital transmission is concerned with the content of the signal. 2-To achieve greater distances, repeaters are used.

Channel Capacity

The maximum rate at which data can be transmitted over a given communication path or channel, under given conditions.

Noise

It is the average level of noise over the communication path

Error rate

It is the rate at which errors occur, where an error is the reception of a ***1*** when a ***0*** was transmitted or vice versa.

Nyquist Bandwidth

[Free noise channel]: If the rate of a signal transmission is 2B, then a signal with frequencies no greater then B is sufficient to carry the signal rate.

For Binary Signals (two voltage levels) the data rate that can be supported by B Hz is 2B bps.

The Nyquist Formulation:

$$C = 2B\log_2 M \qquad (1)$$

Where **C**- Channel Capacity, **M**- Number of discrete signal or voltage levels (for binary M=2) **B**-Bandwidth

Example 1: For M=8 and B=3100 Hz a Capacity C=18,600 bps.

By Nyquist formula. The higher the *data rate*, the *shorter* the bits so that more bits are affected by a given pattern of noise, then the higher the *error rate*.

Shannon Capacity Formula

(Channel with noise)

$$C = B \log_2 (1 + SNR)$$

Because formula assumes thermal noise only, the wider B, the more noise is admitted to the system

$$SNR_{dB} = 10 \log_{10} \frac{SignalPower}{NoisePower}$$

2

This ratio is measured at a receiver output. A high SNR will mean a high quality signal and a low number of required intermediate repeaters

Example: Suppose that the Spectrum of a channel is between 3MHz and 4MHz and SNR=24dB.

1. Find the channel capacity C by Shannon's Formula.
2. Based on Nyquist formula, how many signaling levels are required.

Solution:

1- B=4-3=1MHz $SNR_{dB} = 24 = 10\log_{10}(SNR)$

SNR=251. Using Shannon's Formula: C=8Mbps (Theoretical Limit)

2- Using Nyquist formula $C = 2B\log_2 M$ and we get M=16

Transmission Medium

Guided Medium

The waves are guided a long a solid medium, such as **Copper** or **Optical fiber**

Unguided Medium

Provide a means of transmitting electromagnetic signals but do not guide them **(Wireless Transmission)**

❖ Signals at lower frequencies are omnidirectional

❖ Signals at higher frequencies are directional

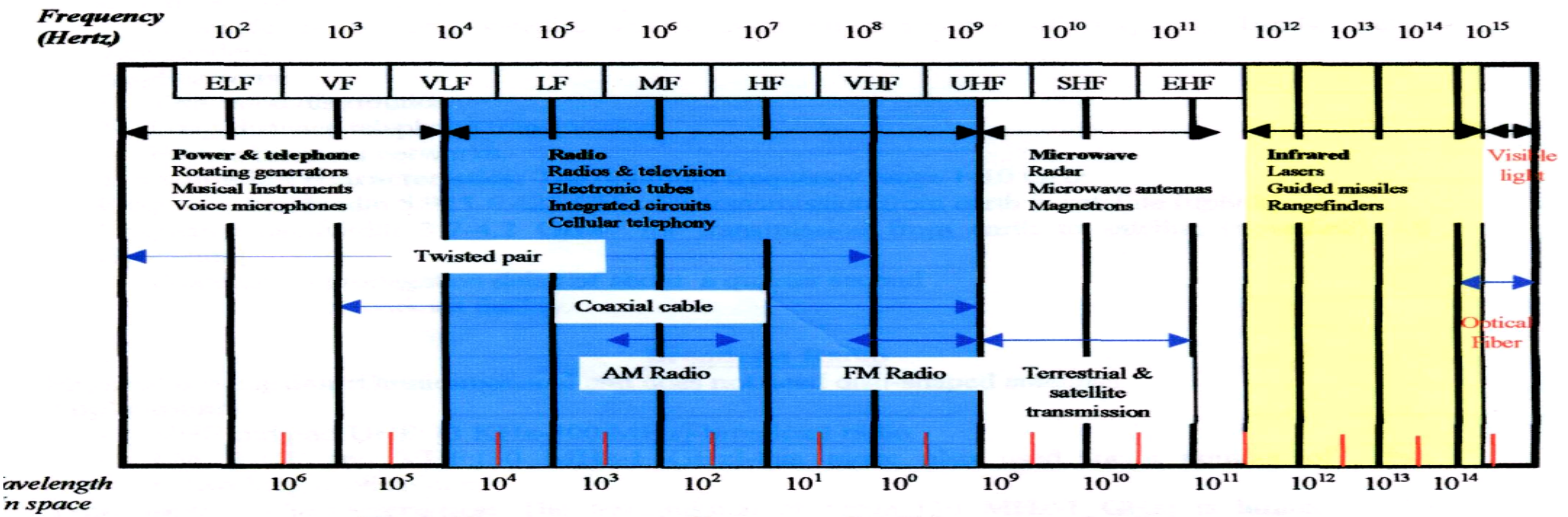


Fig.2 Electromagnetic Spectrum for Telecommunication

ELF =Extremely low frequency
VF =Voice frequency
VLF =Very low frequency
LF =Low frequency.
MF = Medium frequency
HF = High frequency
VHF=Very high frequency
UHF=Ultrahigh frequency
SHF=Superhigh frequency
EHF=Extremely high frequency

$$f = c / \lambda$$

Terrestrial Microwave

- **Physical Description : Microwave Antenna is the parabolic (3m Diameter) [Line-of-site Transmission].**
- **Applications:**

1. **Long-haul telecommunications service [Voice and television transmission]**
2. **Shirt point-to-point lines between buildings [TV or Wireless LAN]**
3. **Cellular systems and fixed wireless access.**

- **Transmission characteristic: Rang (2-40) GHz. The higher the frequency used, the higher the potential bandwidth and therefore the potential data rate.**
- **Attenuation for microwave**

$$l = 10\log\left(\frac{4\pi d}{\lambda}\right)^2 dB \quad (4)$$

- **Where d-is the distance and λ- is the wave length in the same units.**

The higher microwave frequencies are less useful for longer distance because of increased attenuation but are quite adequate for shorter distances.

Satellite Microwave

Physical Description:

- Microwave transmitter- receivers are used to link two or more ground known as earth station, or ground stations.
- A single or orbiting satellite will operate on a number of frequency bands, called transponders.
- **Applications:**
- Television distribution
- Long-distance telephone transmission
- Private business networks.
- **Transmission characteristics:** The optimum frequency range 1-10 GHz.
- Frequency bandwidth 5.925-6.425 GHz for transmission from earth to satellite (uplink).
- Frequency bandwidth 3.7-4.2 GHz for transmission from satellite to earth (downlink).[4/6 GHz band].
- **Properties** :- propagation delay of about a quarter second
- - Broadcast facility.

Broadcast Radio

- **Physical description :**Omnidirectional and does not need dish-shaped antennas.
- **Applications:**
- VHF and part UHF: [3 KHz-30 MHz]-broadcast radio.
- FM, UHF and VHF:[30 MHz-1 GHz]-this range also used for a number of data networking applications.
- **Transmission Characteristics:** The transmission at range [30 MHz-1 GHz] is limited to the line-of-site. The amount of attenuation due distance (equation 4).

FDM

- [**F**requency **D**ivision **M**ultiplexing]:- A number of signals can be carried simultaneously if each signal modulated onto a different carrier frequency and the carrier frequencies are sufficiently separated so that the bandwidth of the signals do not overlap.

Fig.3 Frequency Division Multiplexing

Example 3: [Multiplexing of Voice signal]:

4 KHz is adequate to carry the voice signal and provide a guard band. For (International Telecommunication Union-Telecommunication Standardization Sector [ITU-T] standard), a standard voice multiplexing scheme is twelve 4 KHz voice channel from 60-108 KHZ.

TDM

[**T**ime **D**ivision **M**ultiplexing]: Multiple digital signals can be carried on a single transmission path by interleaving portions of each signal in time. The interleaving can be at the bit level or in blocks of bytes or larger quantities.

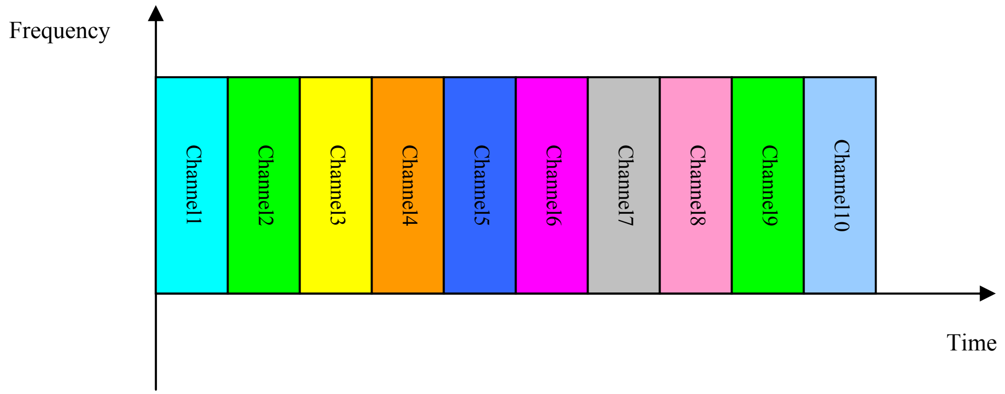


Fig.4 Time Division Multiplexing

Problems

- *Solve the following Problems:*
- Express in simplest form you can: $\sin(2\pi ft - \pi) + \sin(n\pi ft + \pi)$
- Decompose the signal $(1 + 0.1\cos 5t)\cos 100t$ into a linear combination of sinusoidal function, and find the amplitude, frequency, and phase of each component. *Hint:* use the identity for *cos a cos b.*
- What is the channel Capacity for a teleprinter channel with a 300-Hz bandwidth and a signal-to-noise ratio of 3 dB?
- A digital signaling system is required to operate at 9600 bps.
  - If a signal element encodes a 4-bit word, what is the minimum required bandwidth of the channel.
  - Repeat part (a) for the case of 8-bit words.
- Given a channel with an indicated capacity of 20 Mbps, the bandwidth of the channels 3 MHz. What signal-to-noise ratio is required to achieve this capacity.
- Show that doubling the transmission frequency or doubling the distance between transmitting antenna and receiving antenna attenuates the power received by 6 dB.
- If an amplifier has a 30-dB voltage gain, what voltage ratio does the gain represent?
- An amplifier has an output of 20 W. what is its output in dbW.

Appendix A

An important parameter in any transmission systems is the signal strength. The decibels is a measure of the Ration between two signal levels.

$$G_{dB} = 10 \log_{10} \frac{P_{out}}{P_{in}}$$

where G_{dB}- gain, in decibels, P_{in}-input power level, P_{out}-output power level. When G_{dB} is positive, this represents an actual gain power. If the value of G_{dB} is negative, this represents an actual loss in power (L_{dB}).

$$L_{dB} = -10 \log_{10} \frac{P_{out}}{P_{in}}$$

The decibels is also used to measure the difference in voltage $P = \frac{V^2}{R}$. Thus

$$L_{dB} = 10 \log_{10} \frac{P_{in}}{P_{out}} = 10 \log \frac{V^2_{in}/R}{V^2_{out}/R} = 20 \log \frac{V_{in}}{V_{out}}$$

Decibels Values

Power ratio	dB	Power ratio	dB
10^1	10	10^{-1}	-10
10^2	20	10^{-2}	-20
10^3	30	10^{-3}	-30
10^4	40	10^{-4}	-40
10^5	50	10^{-5}	-50
10^6	60	10^{-6}	-60

Decibels values refer to relative magnitude or changes in magnitude, not to an absolute value. The **dBW (decibel-Watt)** is used 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:

$$Power_{dBW} = 10 \log \frac{Power_W}{1W}$$