

Tishk International University (TIU)

Mechatronics Engineering Department

Communication Systems ME 316

Lecture 3 : 28 -10-2019



# Frequency Bands and Radio Wave Propagation

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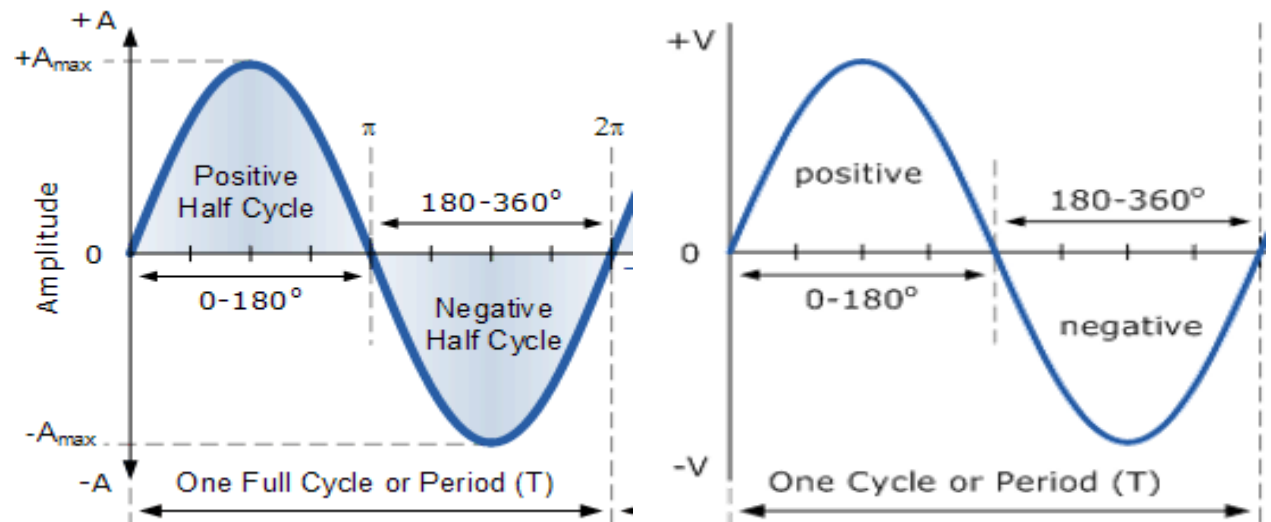
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# Outlines

- Frequency and Frequency Bands
- Bandwidth
- Bandwidth and Wavelength ( $\lambda$ )
- Electromagnetic Waves and Spectrum
- Frequency Band Destinations and Frequency Spectrum
- Regions of Ionosphere
- Radio Waves Propagation

# Frequency ( $f$ )

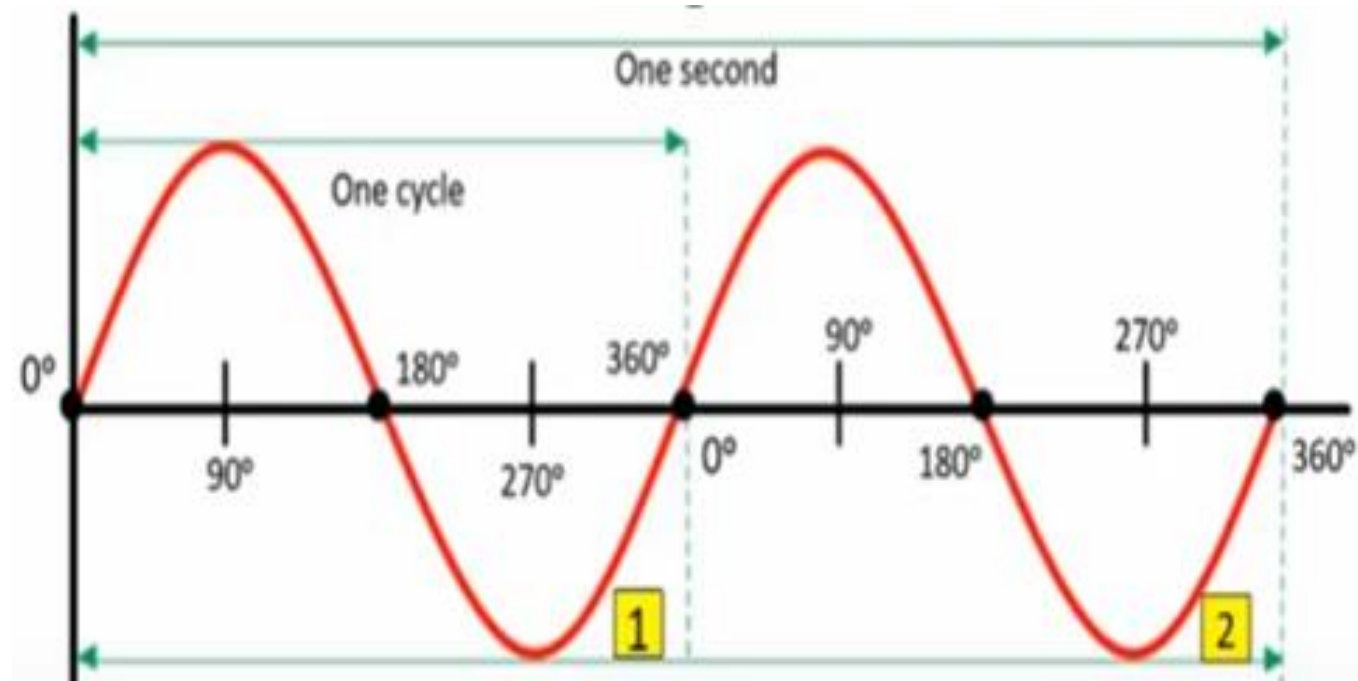
- In general, the frequency based on the waves which means the vibration that carry energy in it when one set positive and negative value complete by alternating current (AC) or voltage (V) or it goes through 360 degree electrical that is mean we have one complete cycle.
  - **Frequency:** is the number of cycles per second in an (AC) sine wave, frequency is the rate of changes direction per second. It is measured in hertz (Hz), an international unit of measure where 1 Hz is equal to 1 cycle per second. At its most basic, frequency is how often something repeats. In the case of electrical signal, frequency is the number of times a sine wave repeats, or completes a positive-to-negative cycle.
- **Hertz (Hz)** = 1 Hz equal to 1 cycle per second.
  - **Cycle** = 1 complete wave of AC or V.
  - **Period** = The time required to produce one complete cycle .



# Frequency ( $f$ )

- How to calculate the frequency ( $f$ ) ?
- The frequency means the complete waves generated per second or the number of cycles per second .

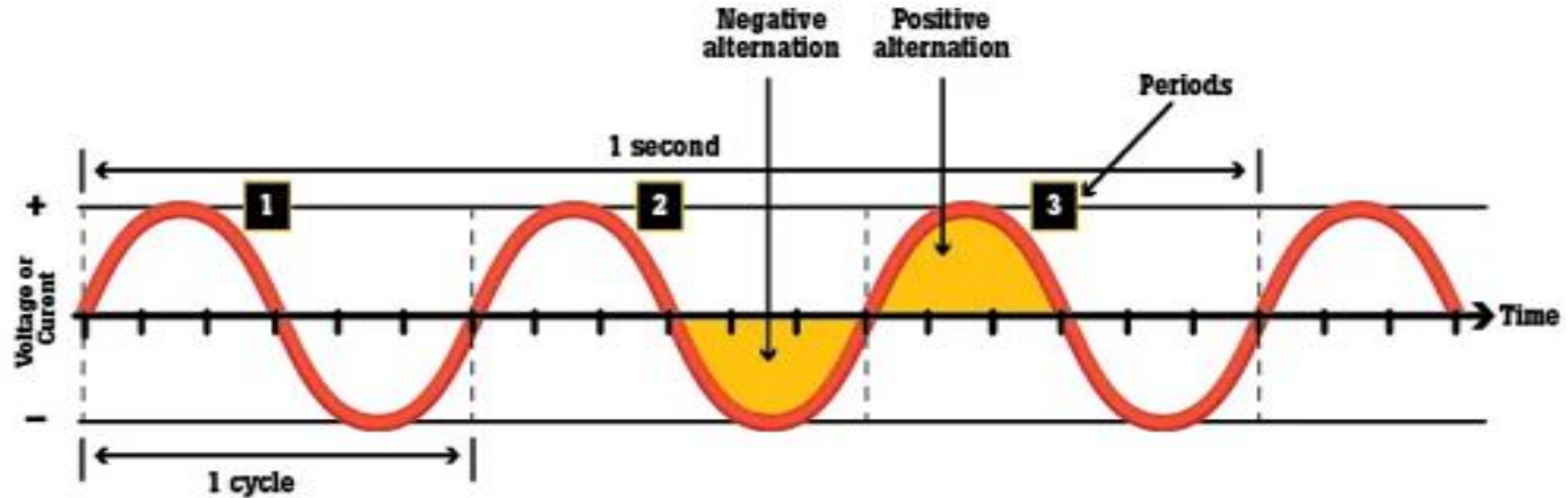
$$f = \frac{\text{Number of waves}}{\text{Time (second)}}$$



- The figure above shows the frequency ( $f$ ) equal **2 Hz** due the No. of waves = **2** per **1** Second .

# Frequency ( $f$ )

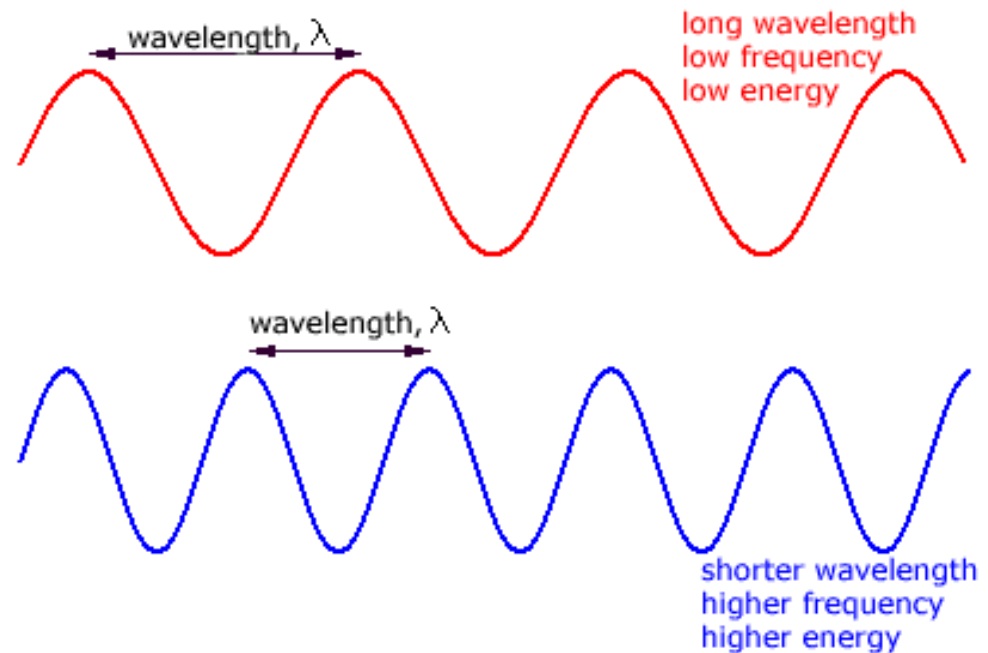
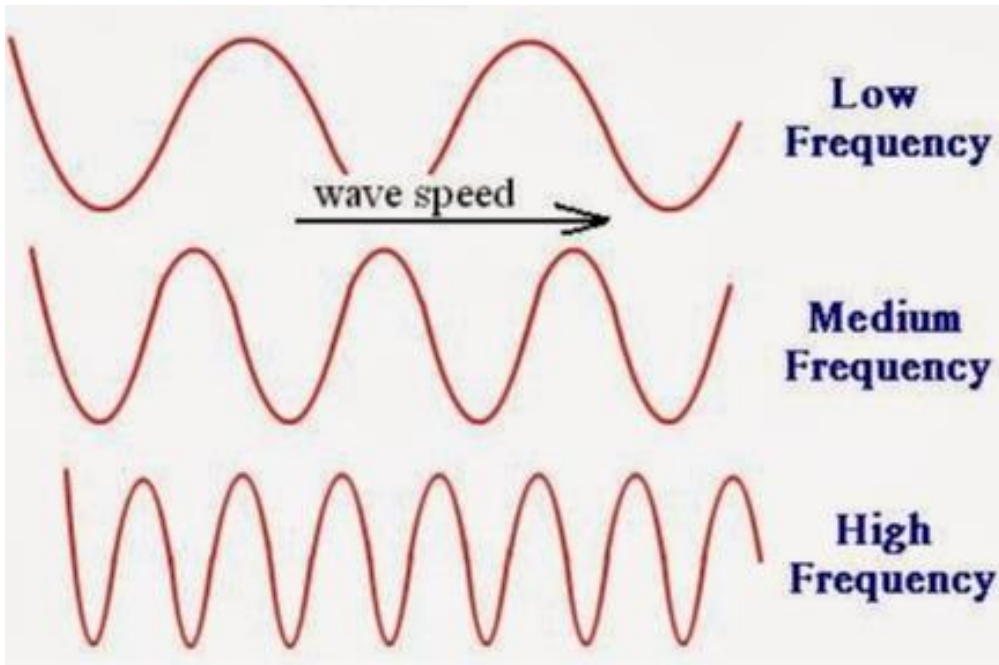
- Q1: what is the frequency value of below figure ?



$$f = ?$$

# Frequency Band

- **Frequency Band** : means the group or collection of frequencies , also called the “ Frequency rang or frequency band destination “ which limited by a lower frequency and higher /upper frequency, this term may refer to the (radio band) such as ( ELF,VLF,LF,MF,HF,...etc. ) or some other frequency bands such as ( L,S,C,X,...etc.).

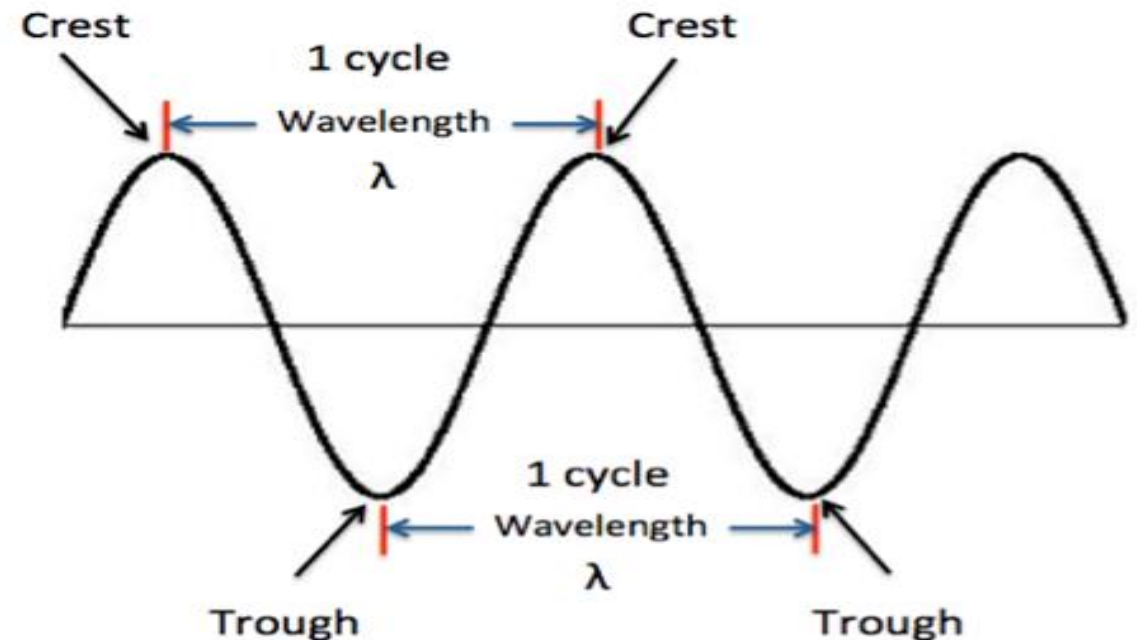


# Bandwidth

- **Bandwidth and frequency** both are the measuring terms of networking. The basic difference between bandwidth and frequency is that bandwidth measures the amount of data transferred per second whereas the frequency measure the number of oscillation of the data signal per second.
- **Bandwidth:** is a term used to measure the maximum amount of data that can be transmitted in per unit time, for example the bandwidth is like a highway and number of vehicles on the highway is the amount of data that transmitted per unit time which means more bandwidth more amount of data can be transmitted per time, it is can also explain as the total range of signal between the higher (maximum) and lower(minimum) frequency that a signal can contain.
- **Example :**
  - The frequency range (300 - 3100 Hz) , so the Bandwidth (**B.W**) = 2800 Hz.

# Bandwidth and Wavelength ( $\lambda$ )

- **In communication system**, the difference between maximum frequency and minimum frequency which transmitted by the system is called the **bandwidth** of the system and the frequency depends on the type of signal, the user can transmit the signal over designed frequency bands which regulations specify, modulation type, bandwidth, power, type of information ... etc.
- **Wavelength:** is the distance from one crest/peak to another, or from one trough/drop to another, of a wave (which may be an electromagnetic wave, a sound wave, or any other wave). Crest is the highest point of the wave while the trough is the lowest. the wavelength is distance/length, it is measured in units of lengths such as (meters (m), centimeters (cm), millimeters (mm), nanometers (nm)...etc.)



# Wavelength ( $\lambda$ )

- How to calculate the Wavelength ( $\lambda$ )
- The wavelength of an electromagnetic wave is generally denoted by the lowercase Greek letter “**lambda**” :

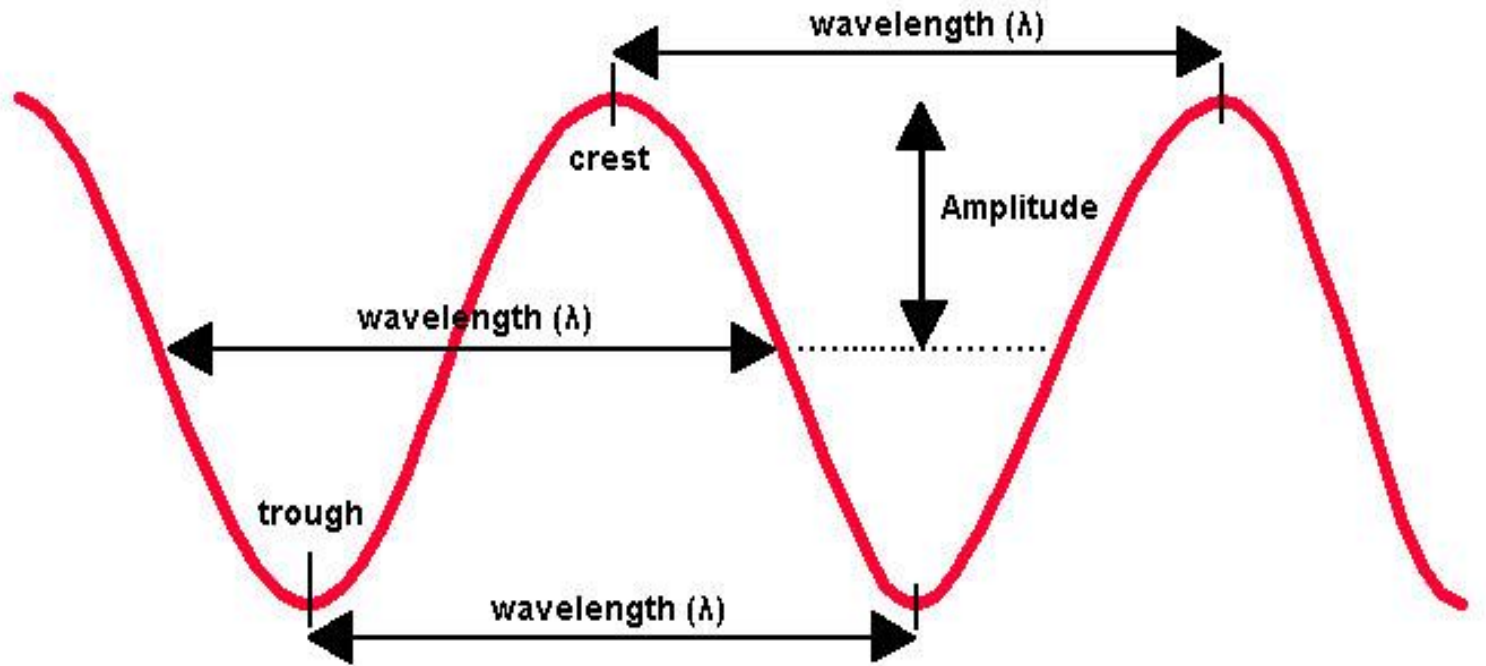
$$\lambda = \frac{c}{f}$$

Where,

$\lambda$  = wavelength

$f$  = frequency of signal

$c$  = the velocity of propagation of an electromagnetic wave

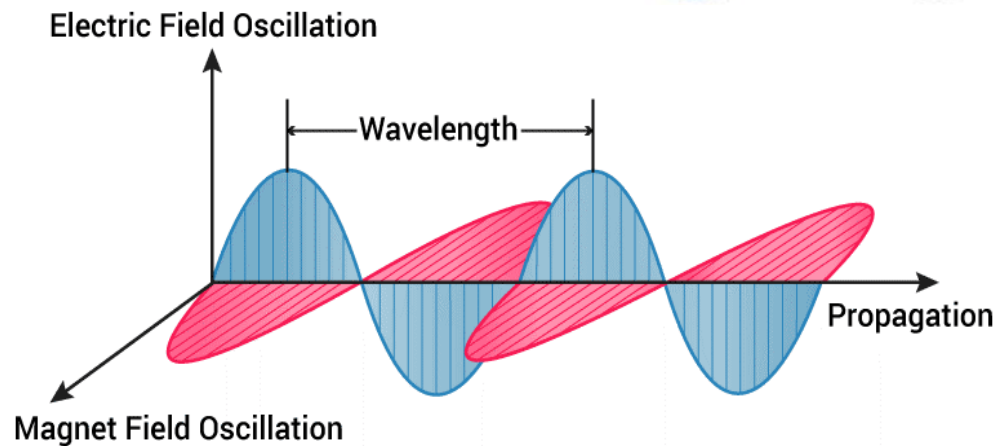
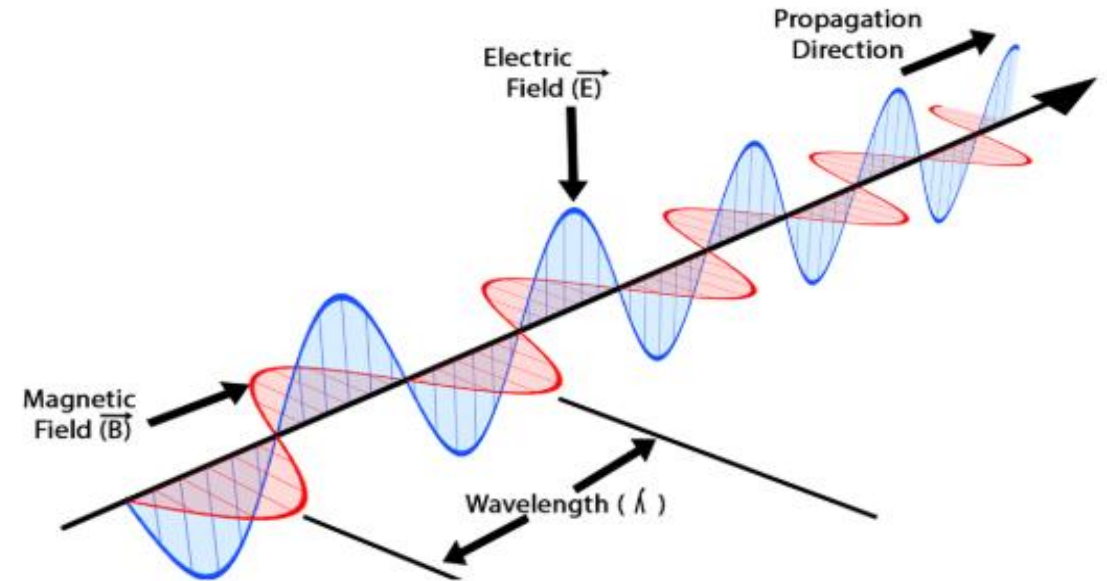


# Electromagnetic Waves

- **Electromagnetic Waves:** are transverse wave composed of two oscillating wave field that vibrate

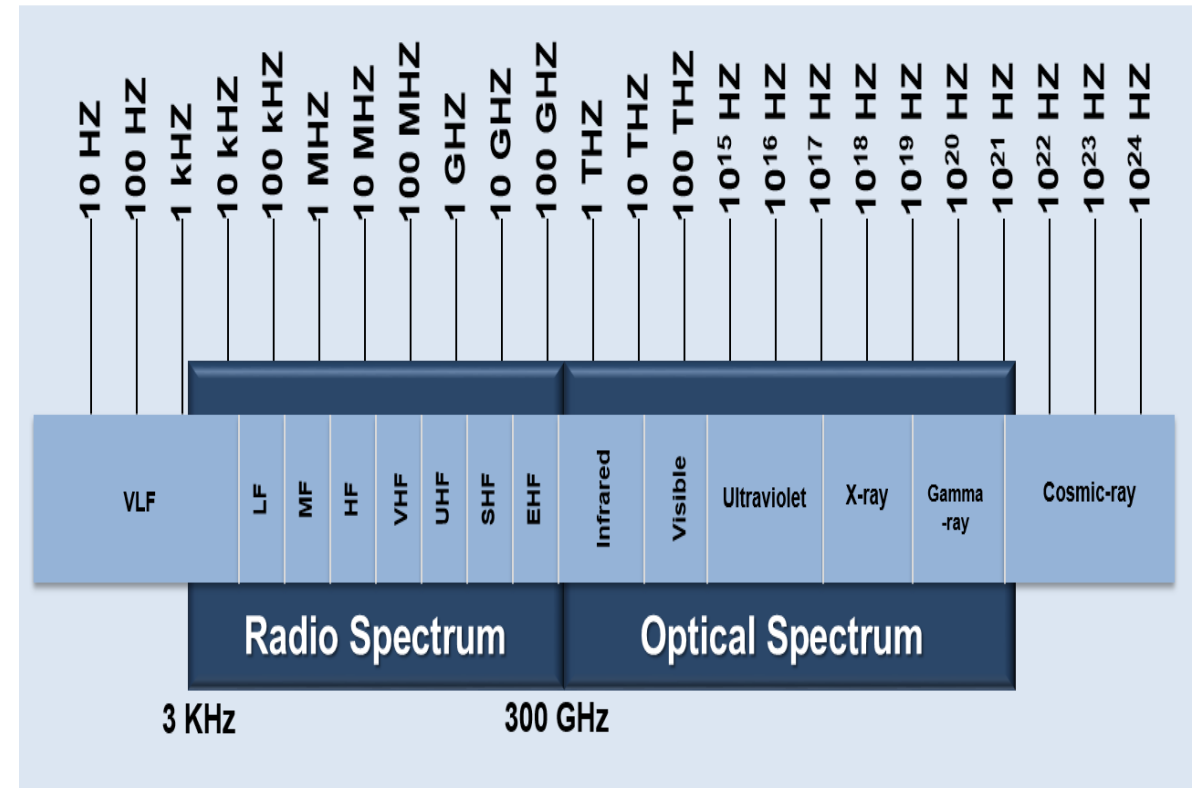
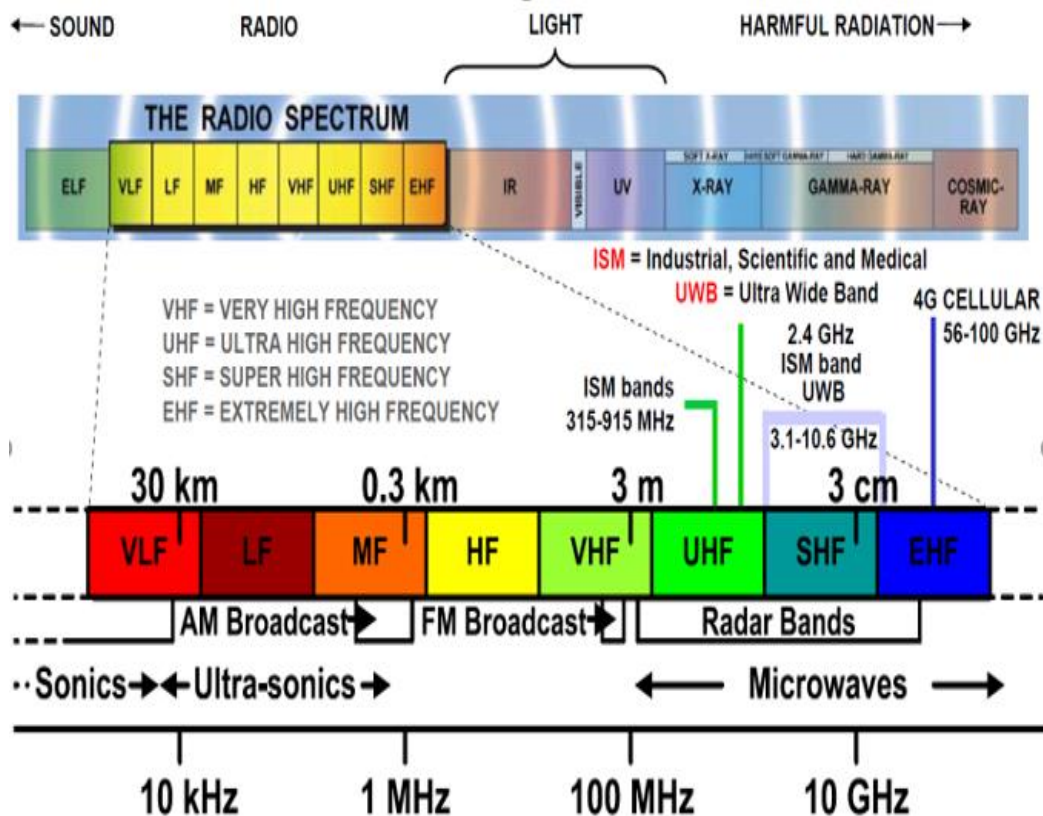
perpendicular/vertical to each other which include :

- Direction of travel ( propagation) on x- axis
- Electric Field (  $E$  ) on y-axis
- Magnetic Field (  $B$  ) on z-axis



# Electromagnetic Spectrum

- **The Electromagnetic Spectrum (EMS)** : It is a range of all types of electromagnetic radiation which divided into regions, this letters were used during the (World War II), to designate various frequency bands, particularly those used for radar. These designations were classified at the time, but have found their way into mainstream use. The band identifiers may be used to refer to a nominal frequency range or specific frequency ranges.



# Frequency Band Destinations

Band	Designation	Frequency Range
Extremely low frequency	ELF	<3 kHz
Very low frequency	VLF	3–30 kHz
Low frequency	LF	30–300 kHz
Medium frequency	MF	300 kHz–3 MHz
High frequency	HF	3–30 MHz
Very high frequency	VHF	30–300 MHz
Ultra-high frequency	UHF	300 MHz–3 GHz
Super-high frequency	SHF	3–30 GHz
Extra-high frequency	EHF	30–300 GHz

Table 1

# Frequency Band Destinations

Label	Nominal Frequency Range	ITU—Region 2
HF	3–30 MHz	
VHF	30–300 MHz	138–145, 216–225 MHz
UHF	300–1000 MHz	420–450, 890–942 MHz
L	1–2 GHz	1215–1400 MHz
S	2–4 GHz	2.3–2.5, 2.7–3.7 GHz
C	4–8 GHz	5.25–5.925 GHz
X	8–12 GHz	8.5–10.68 GHz
Ku	12–18 GHz	13.4–14, 15.7–17.7 GHz
K	18–27 GHz	24.05–24.25 GHz
Ka	27–40 GHz	33.4–36 GHz
R	26.5–40 GHz	
Q	33–50 GHz	
V	40–75 GHz	
W	75–110 GHz	































Table 2

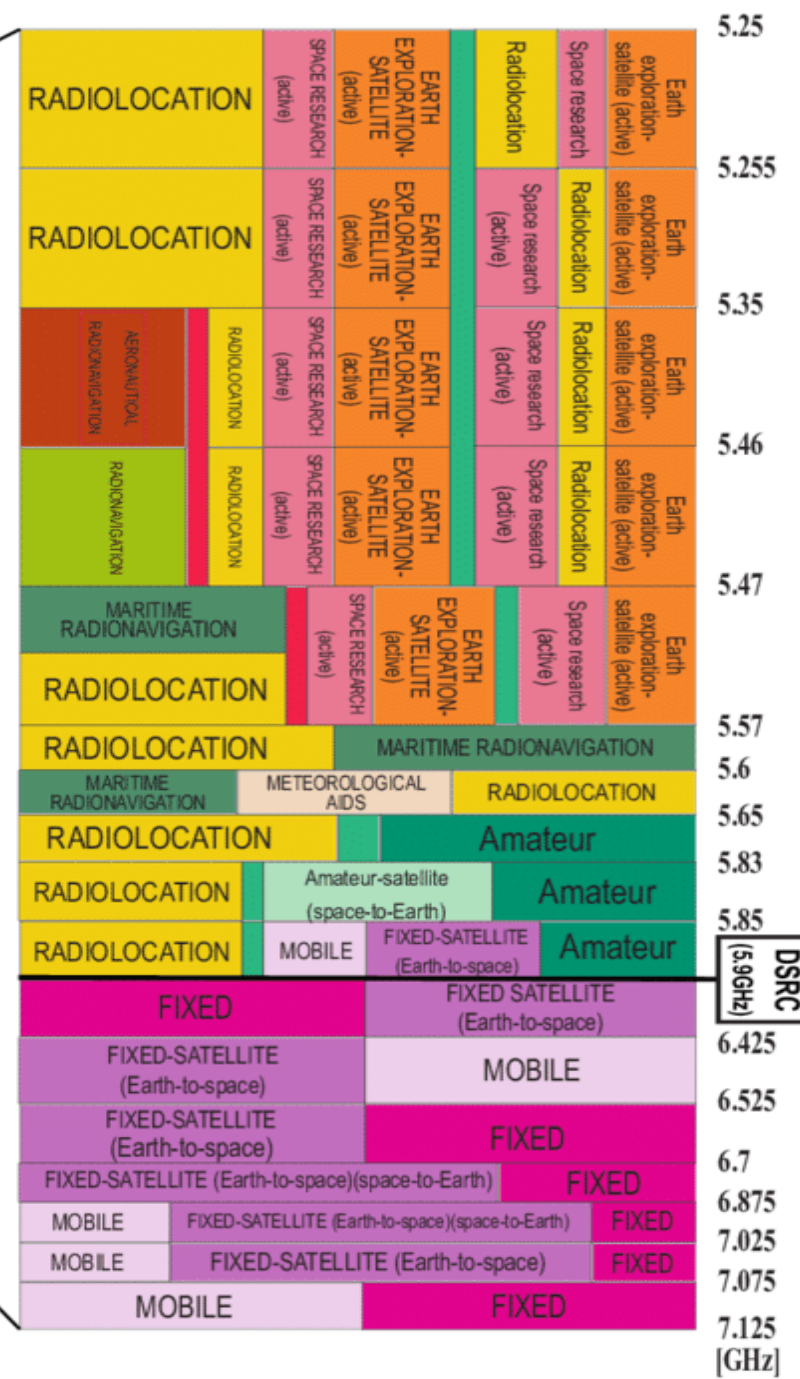
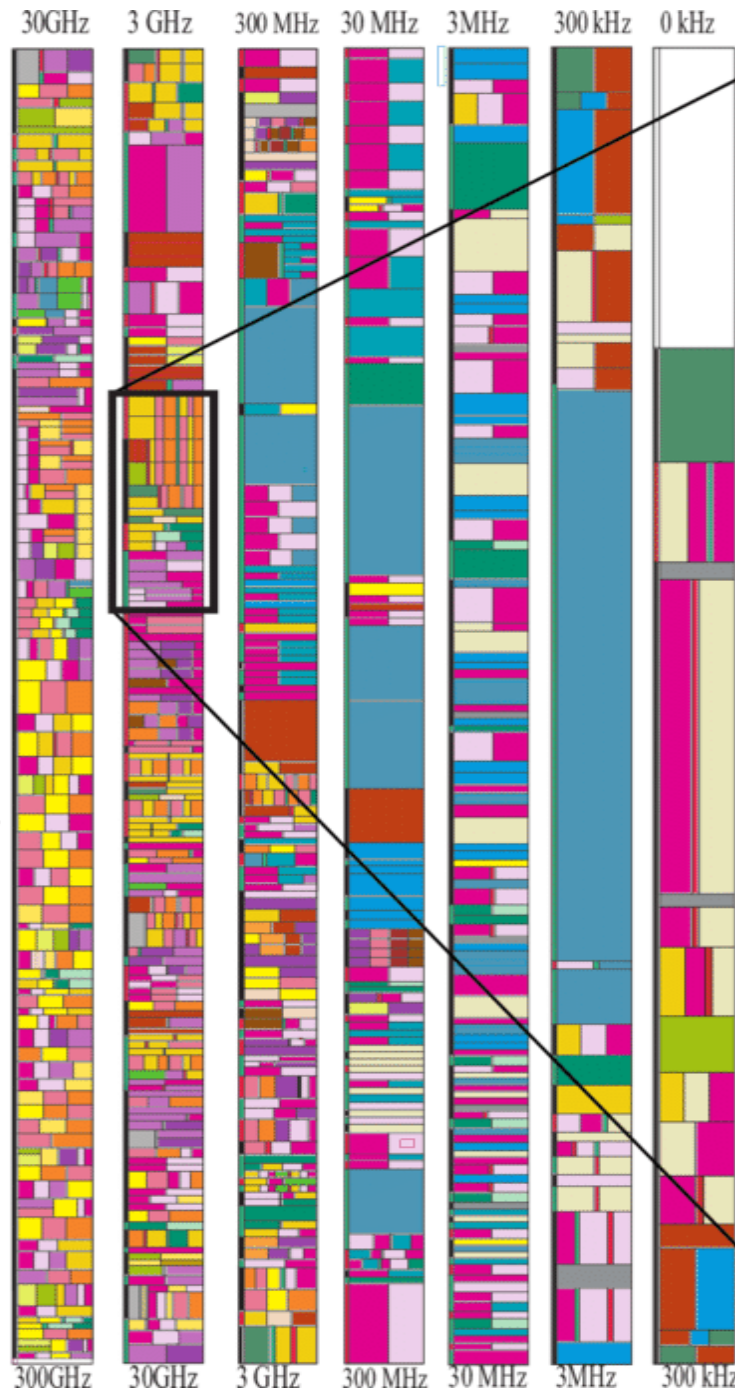
# Frequency Spectrum

- The most important resource in communications is **Frequency Spectrum** which has to be managed for a particular physical medium and has to be shared by a large number of users and applications such as (AM and FM Radio, TV, Mobile. Satellite and air traffic control...etc.).
- **Frequency Spectrum (Frequency allocation)** : is the allocation and regulation of the electromagnetic spectrum into radio frequency bands, which is normally done by governments due to radio propagation does not stop at national boundaries.
- **Radio frequency (RF) spectrum** refers to the rate of oscillation of electromagnetic radio waves in the range from (VLF) 3 kHz to (EHF) 300 GHz, This frequency band that used for communications transmission and broadcasting, Each band has a defined upper and lower frequency limit.
- Frequency assignments and technical standards are set internationally by International Telecommunication Union (ITU).

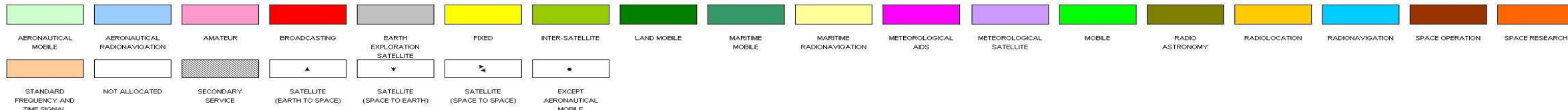


# RADIO SERVICES COLOR LEGEND

		
AERONAUTICAL MOBILE	INTER-SATELLITE	RADIO ASTRONOMY
		
AERONAUTICAL MOBILE SATELLITE	LAND MOBILE	RADIODETERMINATION SATELLITE
		
AERONAUTICAL RADIONAVIGATION	LAND MOBILE SATELLITE	RADIOLOCATION
		
AMATEUR	MARITIME MOBILE	RADIOLOCATION SATELLITE
		
AMATEUR SATELLITE	MARITIME MOBILE SATELLITE	RADIONAVIGATION
		
BROADCASTING	MARITIME RADIONAVIGATION	RADIONAVIGATION SATELLITE
		
BROADCASTING SATELLITE	METEOROLOGICAL	SPACE OPERATION
		
EARTH EXPLORATION SATELLITE	METEOROLOGICAL SATELLITE	SPACE RESEARCH
		
FIXED	MOBILE	STANDARD FREQUENCY AND TIME SIGNAL
		
FIXED SATELLITE	MOBILE SATELLITE	STANDARD FREQUENCY AND TIME SIGNAL SATELLITE



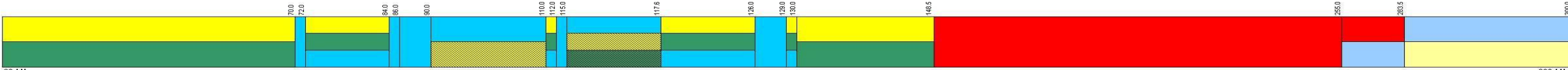
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VLF



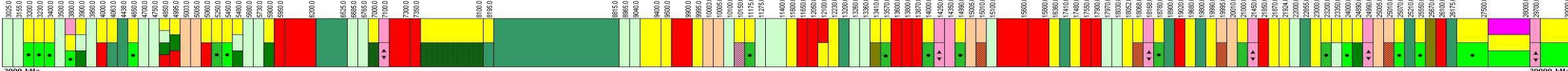
**LF**



MF



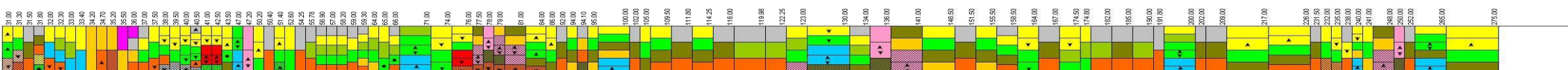
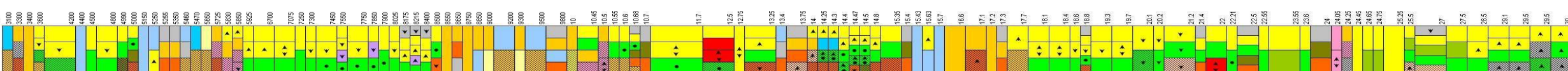
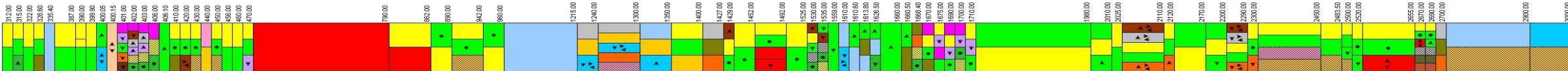
HF



VHF

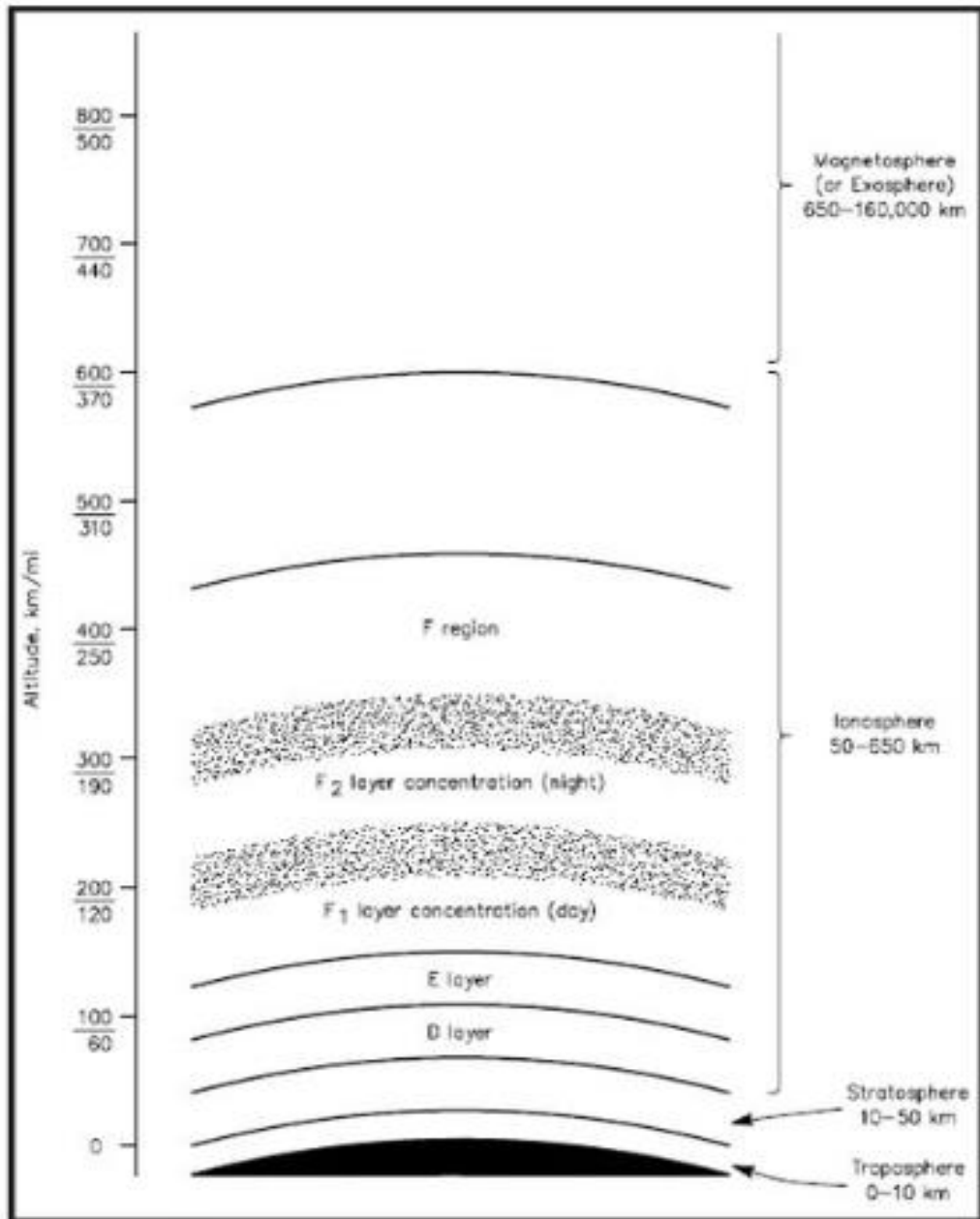


**LIVE**



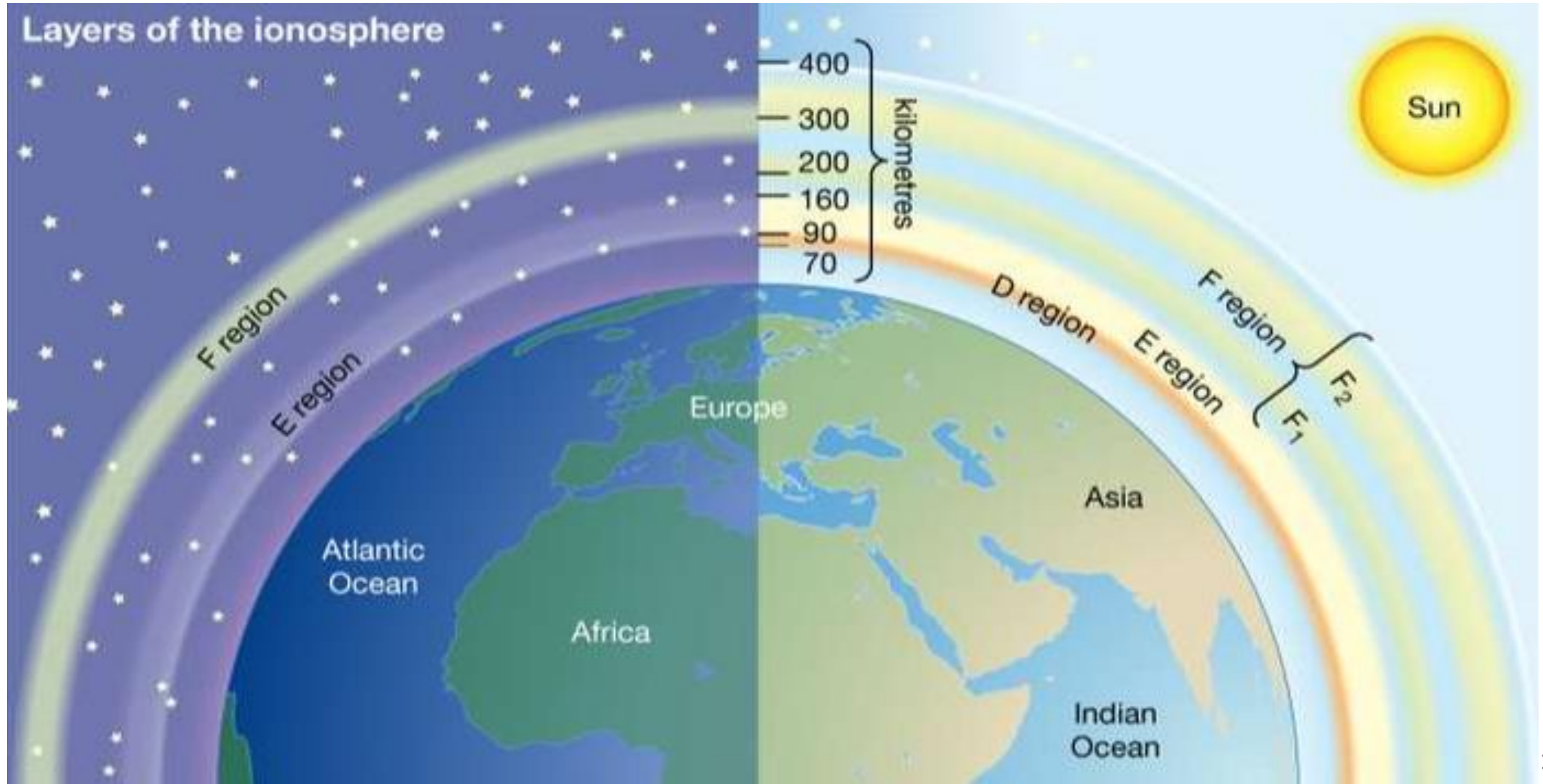
EHP

# Regions of Ionosphere



- The layer of the earth's Ionosphere contains a high concentration of ions and free electrons above the earth's surface.
- The ionization caused by Ultra-Violet (UV) ray from the sun .  
the regions of this ionization change from day to night period .
- Those several regions/layers able to reflect the radio waves.
- Dominant regions are named as (D, E, F) .

# Regions of Ionosphere



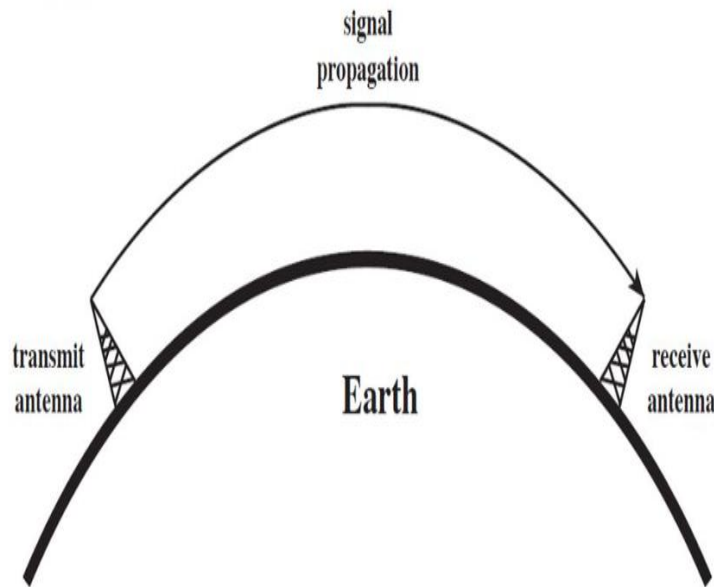
# Regions and Layers of Ionosphere

Region	Approximate high rang in (KM)	Layer	Approximate high rang in (KM)	Availability
D	50 – 90	D	70-90	Day Only
E	90 – 140	E	100-120	Day and Partially at night
F	140 – 350	F1	140-200	24 Hours (day and night)
		F2	200-350	24 Hours (day and night)

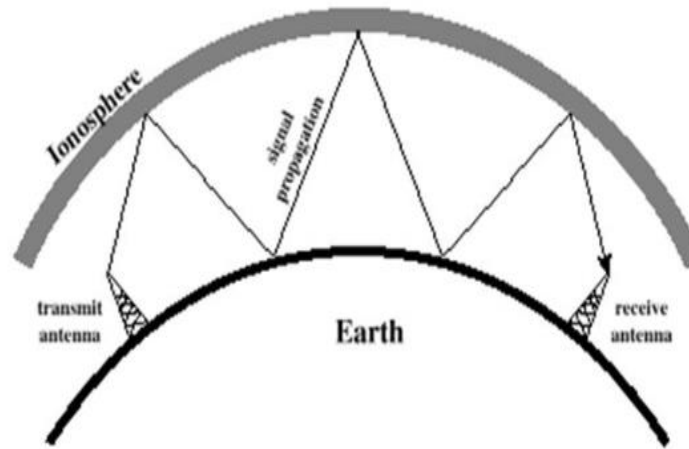
Table 3

# Radio Waves Propagation

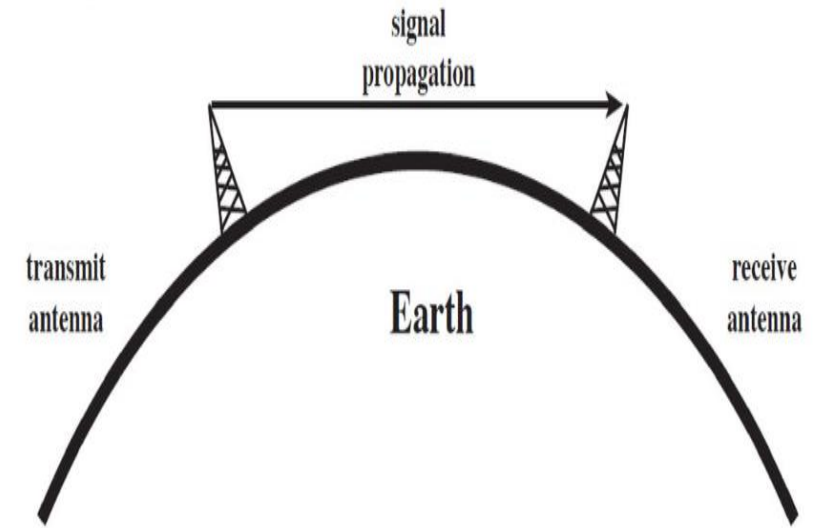
- The radio waves are a kind of electromagnetic radiation , the propagation of radio signals act like light in free space and wireless channels , the waves classified based on carrier frequency as following:



Ground Wave Propagation



Sky Wave Propagation

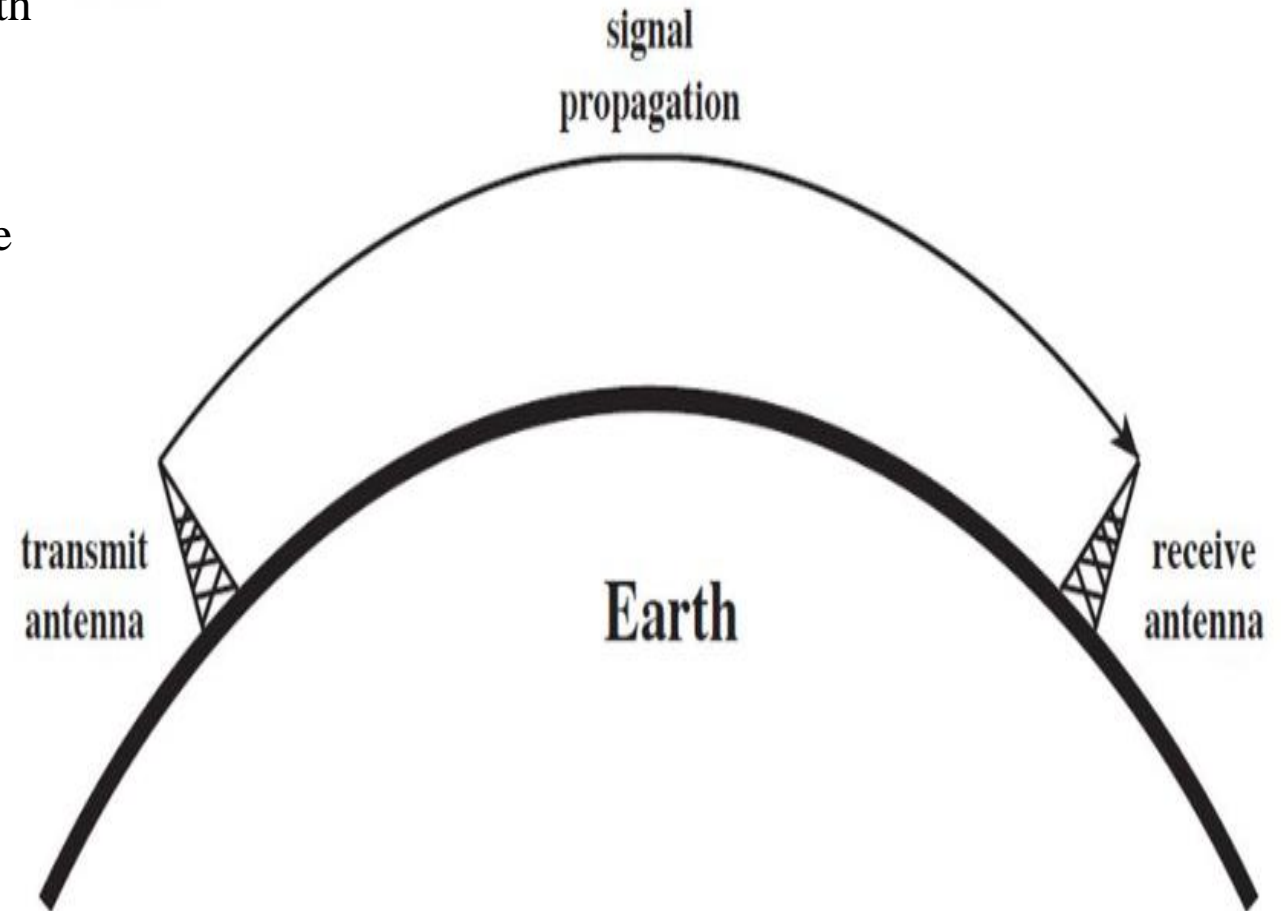


Line Of Sight Propagation

# Radio Waves Propagation

- Ground wave Propagation

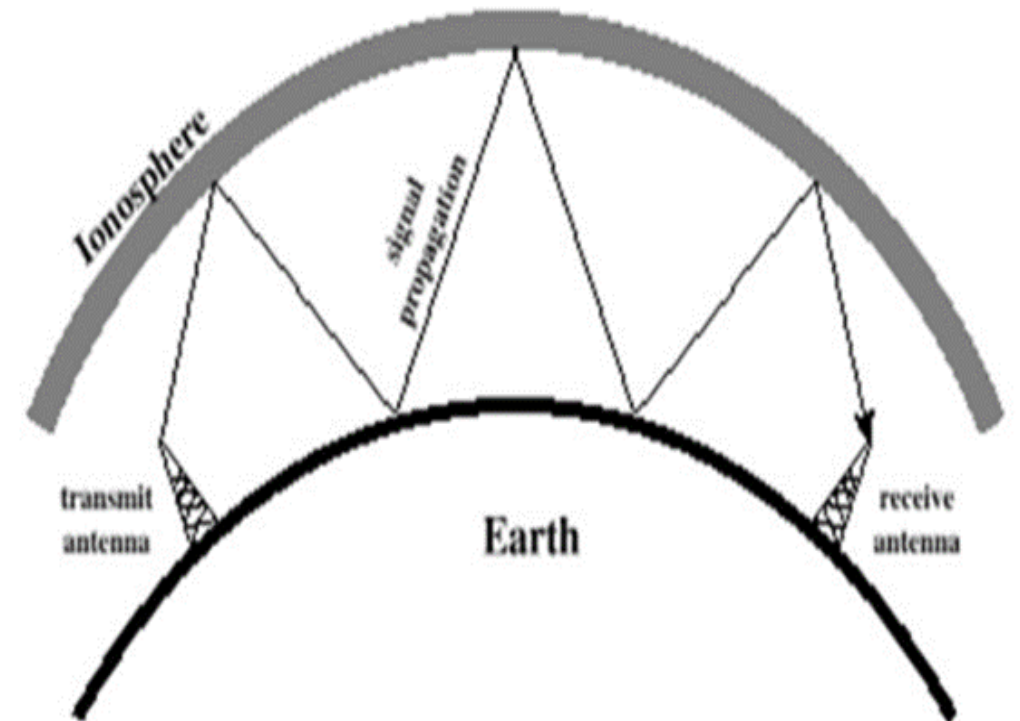
- This wave uses the area between the surface of the earth and the ionosphere for transmission.
- The propagation along the surface of earth helps by the diffraction of D layer waves.
- The frequency band (LF – MF) .
- Frequencies up to 2 MHZ.
- Follows contour of earth.
- **Example:**
- AM Radio



# Radio Waves Propagation

- Sky wave Propagation

- This waves radiate to the ionosphere then they are reflected back to the earth.
- The propagation is the surface caused primarily by reflection from the F layer.
- The frequency band (MF – HF) .
- Frequencies 2- 30 MHZ.
- Can travels a thousand of kilometers .
- **Example:**
  - Amateur Radio
  - Military Communications.



# Radio Waves Propagation

- Line of sight propagation
  - Transmitting and receiving antenna must be within line of sight
  - The propagation is in the straight lines directly from antenna to antenna .
  - The frequency band (VHF-THF)
  - Frequencies above 30 MHZ.
  - The signal path must be above the horizon and the receiver antennas need to be placed on tall to get the signals/waves..
  - **Example:**
    - Satellite
    - Optical communications.

