Chapter 6

Navigation Systems

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From previous Chapter

STUXnet

- https://www.youtube.com/watch?v=TGGxqjpka-U

F-117

1. Introduction

- The dictionary definition of navigation is a good one.
  - ***Navigation*** *- The act, science or art of directing the movement of a ship or aircraft.*
- Navigation thus involves both control of the aircraft's flight path and the guidance for its mission.
  - Measurement of the aircraft's attitude with respect to the horizontal plane in terms of the pitch and bank angles and its heading
  - Autopilot system (e.g., Attitude and Heading Hold modes, Autoland, etc.) navigation system and the weapon aiming system.
  - Accurate knowledge of the aircraft's position in terms of its latitude/longitude coordinates, ground speed and track angle, height and vertical velocity.
- High accuracy navigation systems are thus essential and form a key part of the flight management system.

1. Introduction

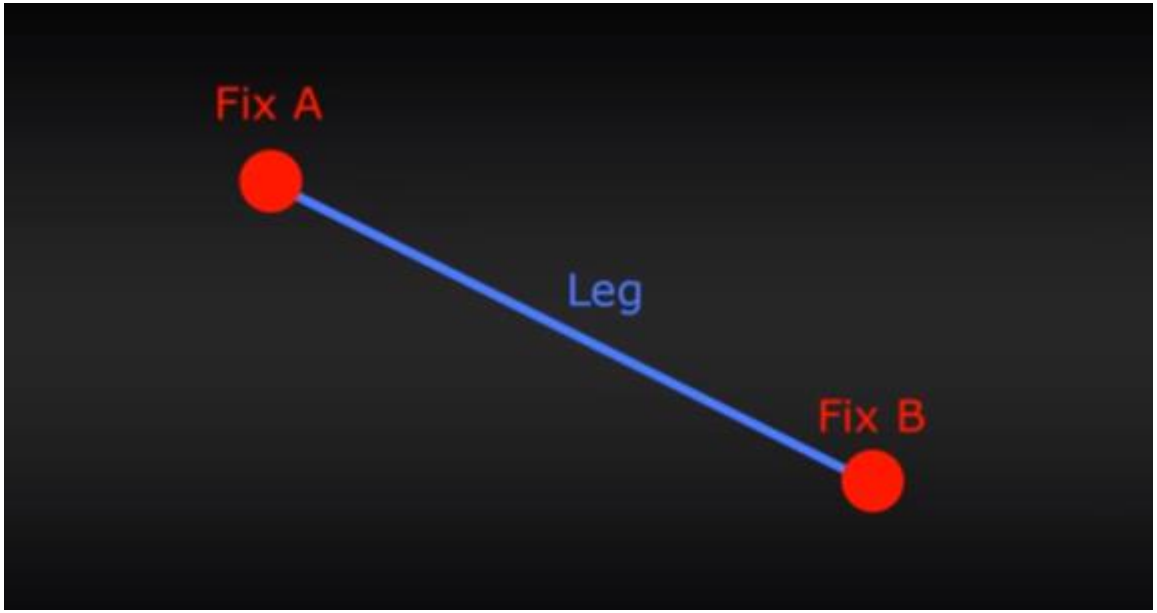
- For civil aircrafts, a ‘four’ dimensional accuracy is required to follow the ATC’s ‘tube in the sky’ within the aircrafts own time slot.
- For military operations, very accurate navigation systems are essential to enable the aircraft to fly low and take advantage of terrain screening from enemy radars, to avoid known defenses and in particular to enable the target to be acquired in time.
- There are two basic methods of navigation namely **dead reckoning (DR) navigation** and **position fixing navigation** systems. Both systems are used to achieve the necessary integrity.
- DR navigation is the process of continually computing a vehicle’s position as the journey proceeds from a knowledge of the starting point position and the vehicle’s speed and direction of motion and the time elapsed.

1. Introduction

- **DR navigation** is the process of continually computing a vehicle's position as the journey proceeds from a knowledge of the starting point position and the vehicle's speed and direction of motion and the time elapsed. It is essentially an incremental process of continually estimating the changes that have occurred and updating the present position estimate accordingly.
- The main types of airborne DR navigation systems are categorized below on the basis of the means used to derive the velocity components of the aircraft (in order of increasing accuracy).
  - ~~Air data based DR navigation – heading, wind speed & true speed.~~
  - ~~Doppler/heading reference systems- ground speed & drift angle.~~
  - ~~Inertial navigation systems- integrated horizontal component of aircraft acceleration wrt time, measured using acclr & gyros.~~
  - ~~Doppler inertial navigation systems- combination of Doppler and INS outputs.~~

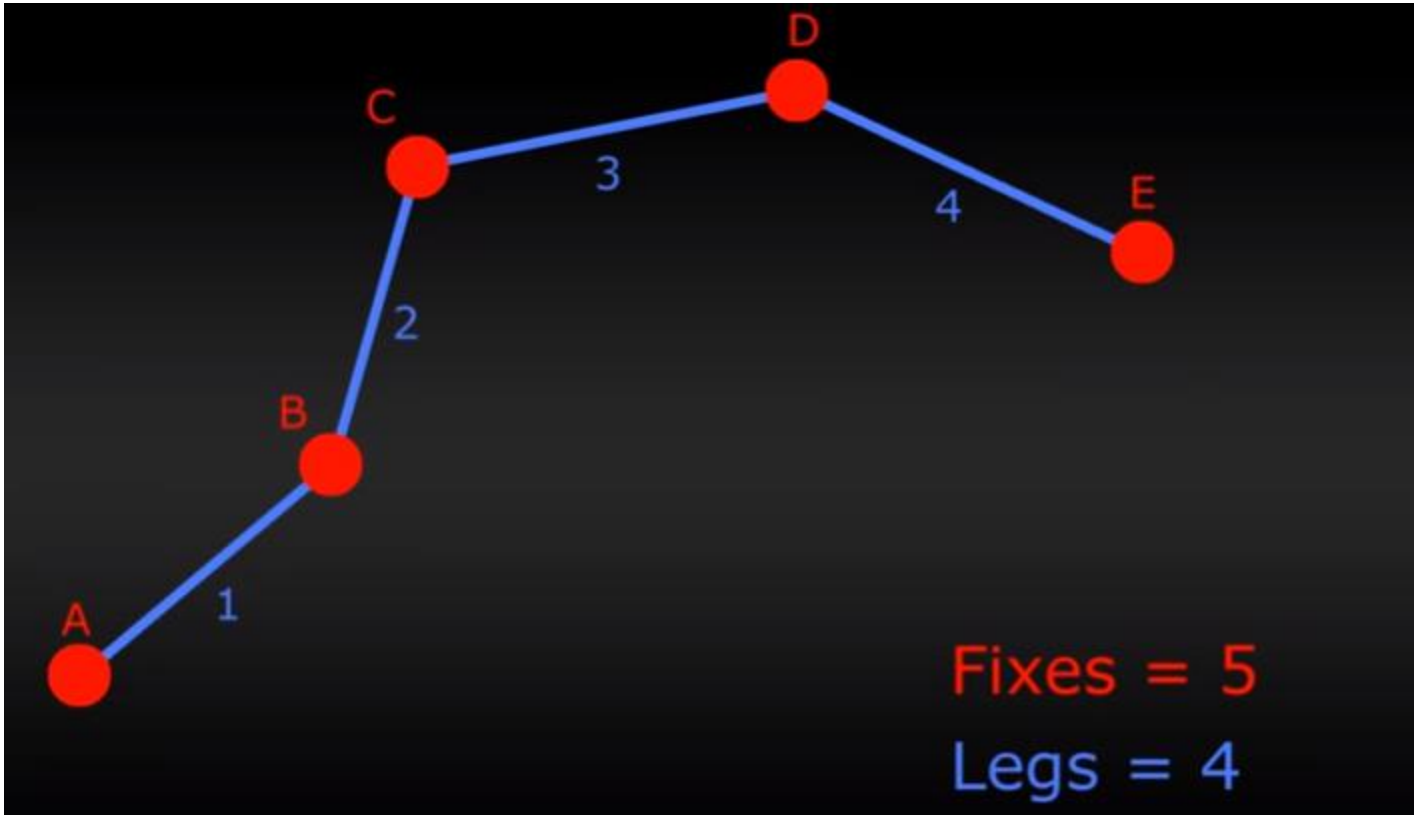
1. Introduction

- **Navigation Terminology**
  - Fix : A fixed reference point on the ground, “ Landmark”
  - Leg: The route between two fixes



1. Introduction

- **Navigation Terminology**
  - How many Fixes and Legs?



1. Introduction

- **Navigation Terminology**
  - Fix : A fixed reference point on the ground, " Landmark"
  - Leg: The route between two fixes
  - Course and Track: Direction of the leg
  - IAS: Aircraft Speed Displayed in Cockpit
  - TAS: Takes account of temperature and altitude of air.
  - GS: Speed of the aircraft relate to ground

1. Introduction

- **Step by Step: Dead Reckoning**
  - Plan the Leg, note down Course and Distance
  - Set IAS and Altitude, Calculate TAS
  - Find Wind Speed and Direction
  - Calculate Heading and GS by using E6B
  - Calculate the time required to complete the journey.

1. Introduction

- The primary DR navigation system which is also the primary source of very accurate attitude and heading information is the Inertial Navigation System (INS).
- The term Inertial Reference System (IRS), is also used in civil aircraft. The IRS can have a lower inertial navigation accuracy of up to 4 NM/hour error compared with 1 to 2 NM/hour for a typical INS.
- The attitude and heading accuracy, however, is still very high. The terminology INS/IRS is used to show that they are essentially the same.
- The INS/IRS also derives the aircraft's velocity vector in conjunction with the Air Data System which provides barometric height information. This is of great assistance to the pilot when displayed on the HUD.
- The INS/IRS is thus a key aircraft state sensor for both military and civil aircraft. Large civil airliners operating on long haul, over water routes, have triple IRS installations to ensure availability and the ability to detect failures or degradation of performance by cross-comparison.

1. Introduction

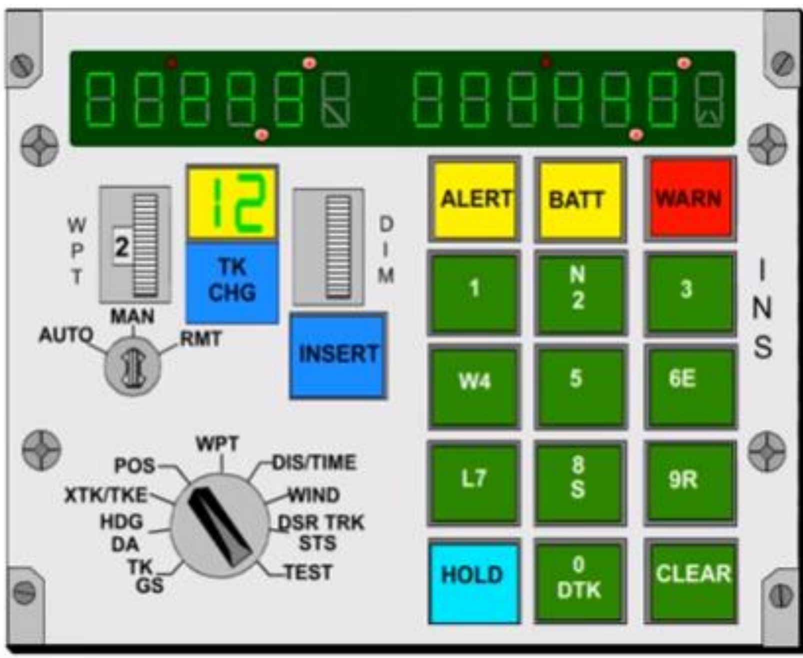
- A fundamental characteristic of DR navigation systems is that their accuracy is time dependent. For example, a good quality INS has an accuracy of 1 NM/hour so that the aircraft position uncertainty after five hours would be 5 NM.
- A position fixing system is thus required to constrain the error growth of a DR navigation system and correct the DR position errors.
- A position 'fix' can be obtained by recognizing a prominent landmark or set of terrain features either visually, possibly using an infrared imaging sensor, or from a radar-generated map display. Alternatively, a suitable position fixing navigation system can be used.
- **Position fixing navigation** systems depend on external references to derive the aircraft's position. For example, radio/radar transmitters on the ground, or in satellites whose orbital positions are precisely known. Unlike DR navigation systems, their errors are not time dependent. The errors are also independent of the aircraft's position in most position fixing systems.

1. Introduction

- The main position fixing navigation systems in current use are briefly summarized below.
- **Range and Bearing ('R/θ') Radio Navigation Aids**- DME (distance measuring equipment) is co-located with VOR (VOR [VHF omni-directional range]) and provides the distance from an aircraft to the DME transmitter.
- **Satellite Navigation Systems, GPS (Global Position System)**- most important and accurate position fixing system developed to date.
- **Terrain Reference Navigation (TRN) Systems**- correlating the terrain measurements made by a sensor in the vehicle with the known terrain feature data in the vicinity of the DR estimated position . The terrain feature data is obtained from a stored digital map database.

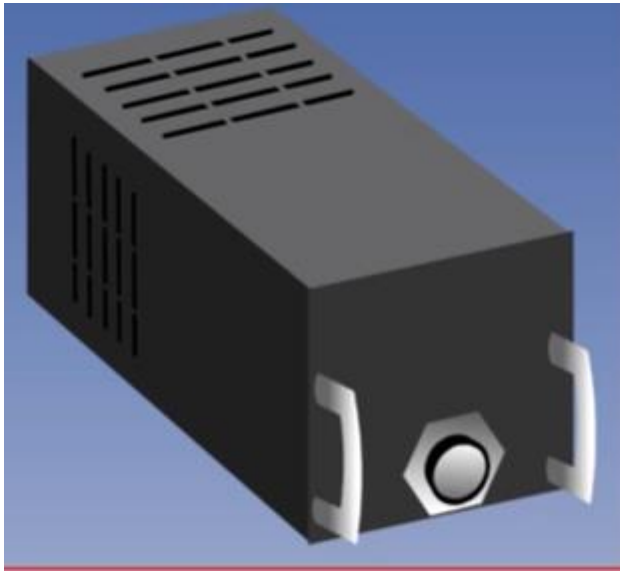
2. Inertial Navigation

Mode Selector Unit (MSU)



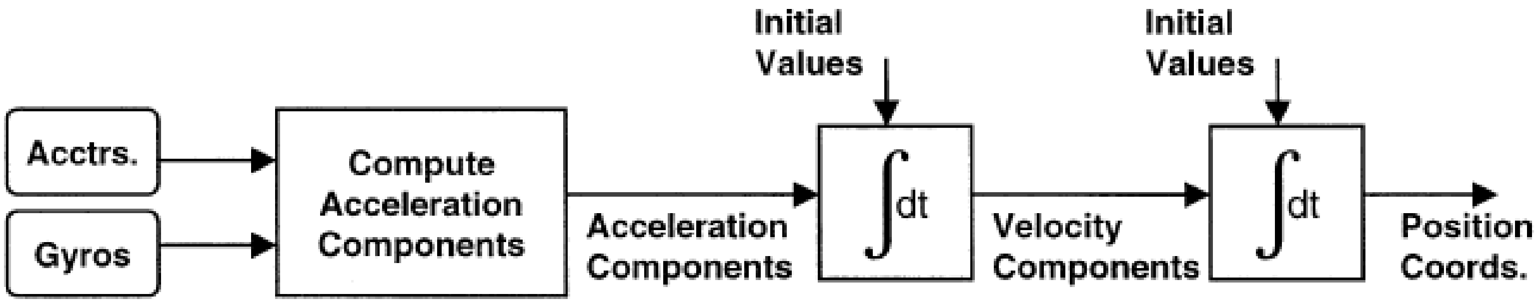
Control and Display Unit (CDU)

2. Inertial Navigation



Inertial Measurment Unit (IMU)

2. Inertial Navigation

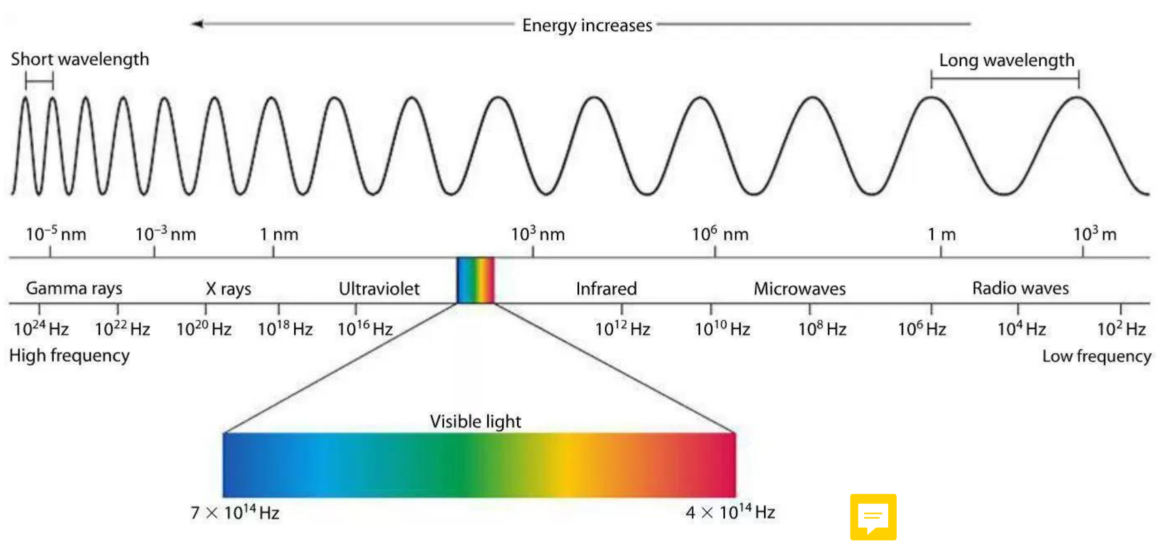


Basic Principle of IN

Propagation Theory-Electromagnetic Waves

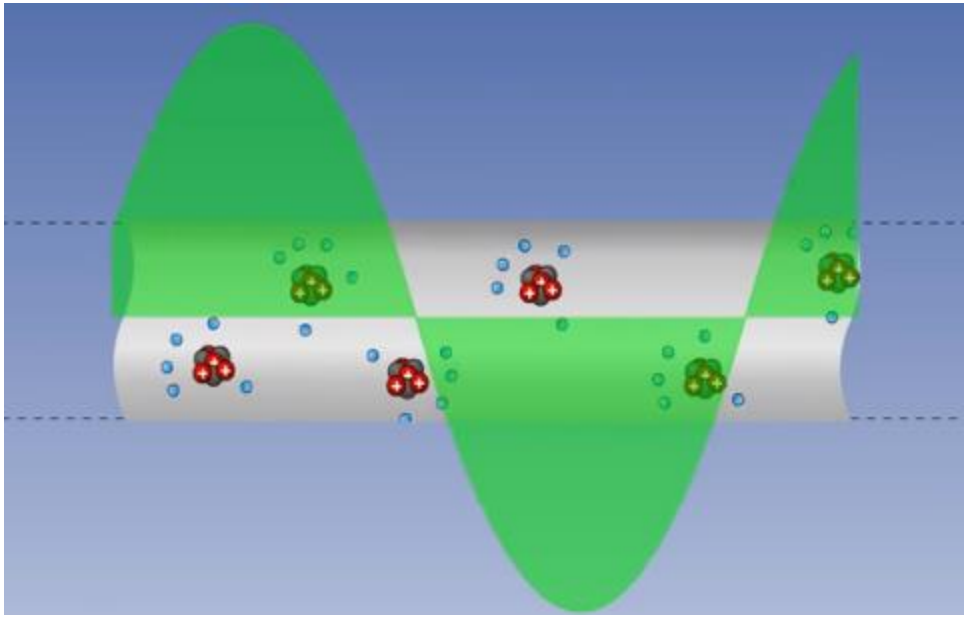
This is a important chapter as we need to understand why different radio frequencies are used for different purposes.

Lets start with Radio Wave in Contest with different other waves



Propagation Theory-Electromagnetic Waves

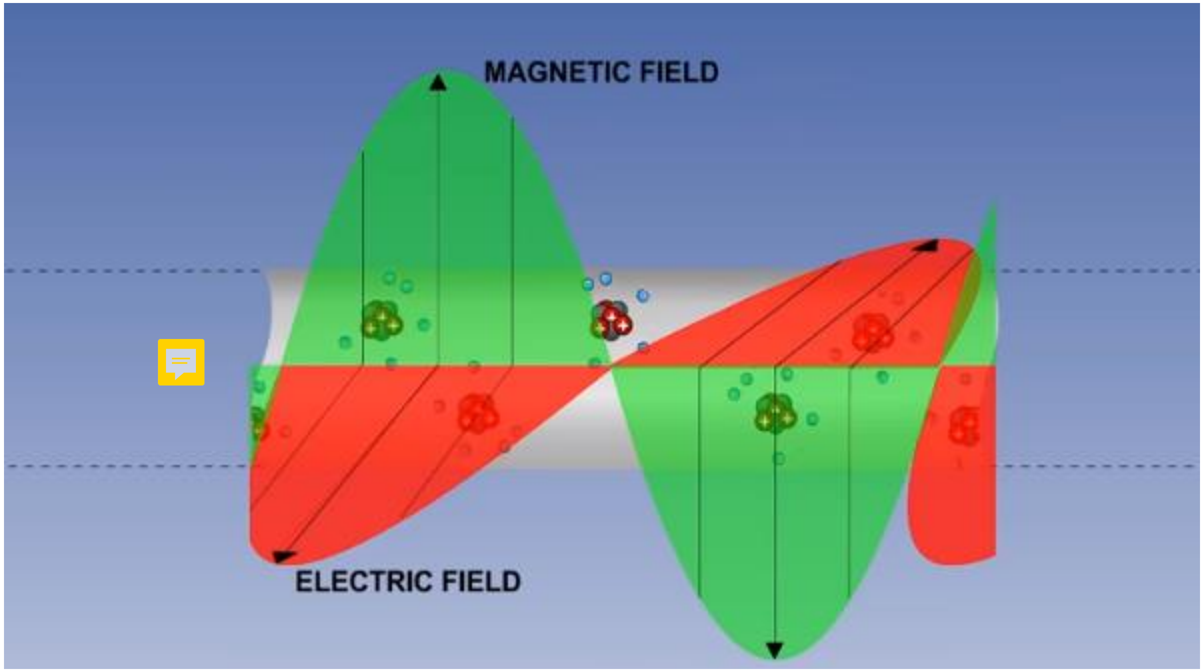
When electric charge is moved they give rise to a magnetic field perpendicular to the flow of the current.



In the case of direct current the electrons move continuously in the same direction and the magnetic field also moves in that direction.

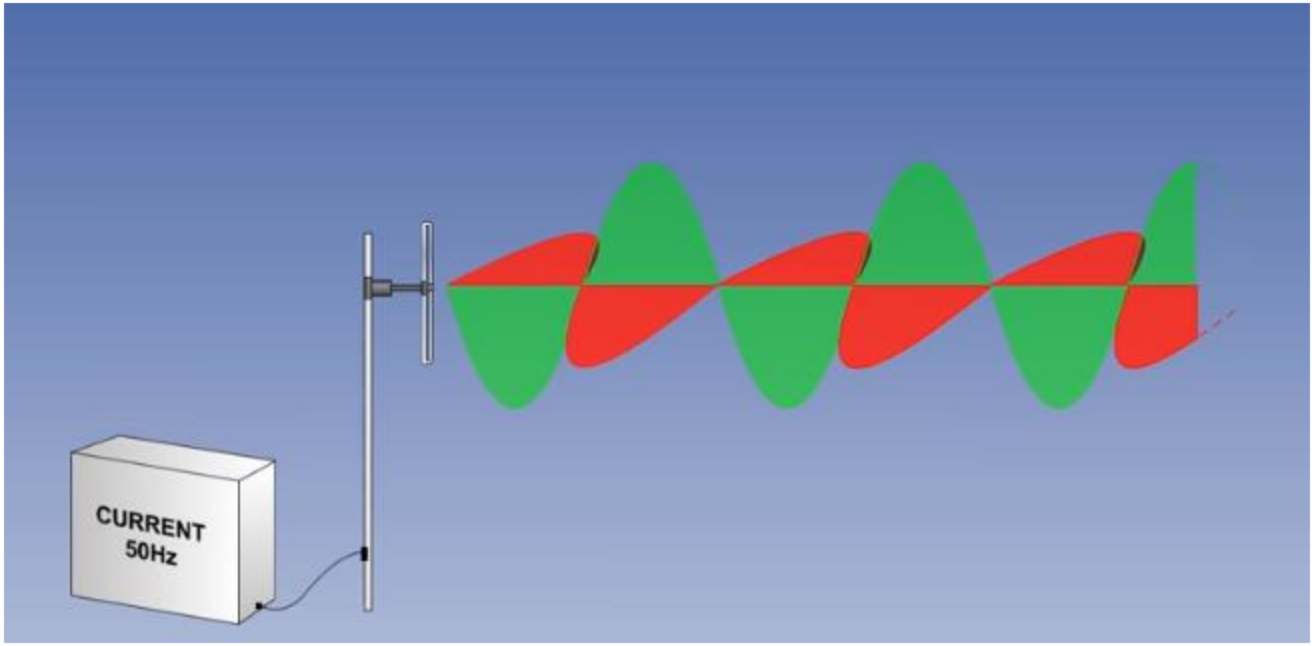
Propagation Theory-Electromagnetic Waves

However if the motion of the current is changing as an AC current then the magnetic field oscillates and in turn it produces an electric field perpendicular to the magnetic field this electric field also oscillates.



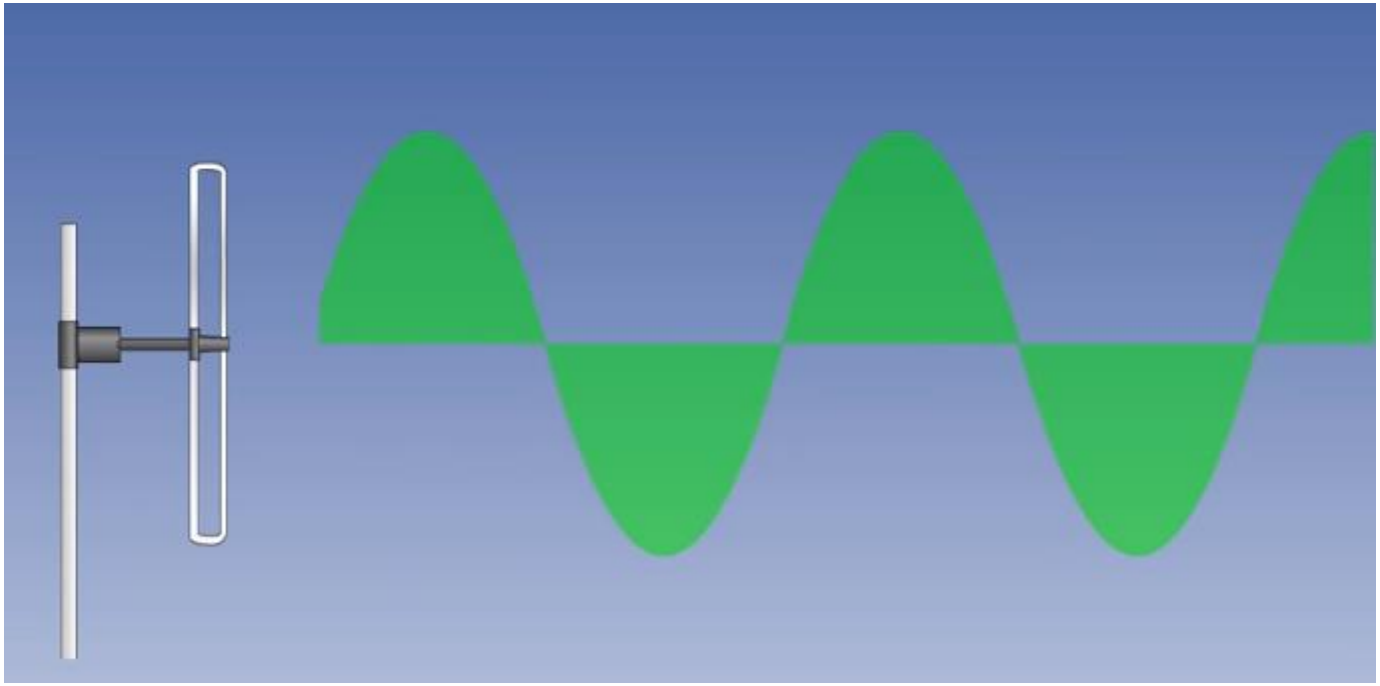
Propagation Theory-Electromagnetic Waves

Where both magnetic Field H and an electric field E exist the two fields are collectively known as **Electromagnetic Radiation** and frequency of these electromagnetic waves is the same as that of the electric charge which created them.



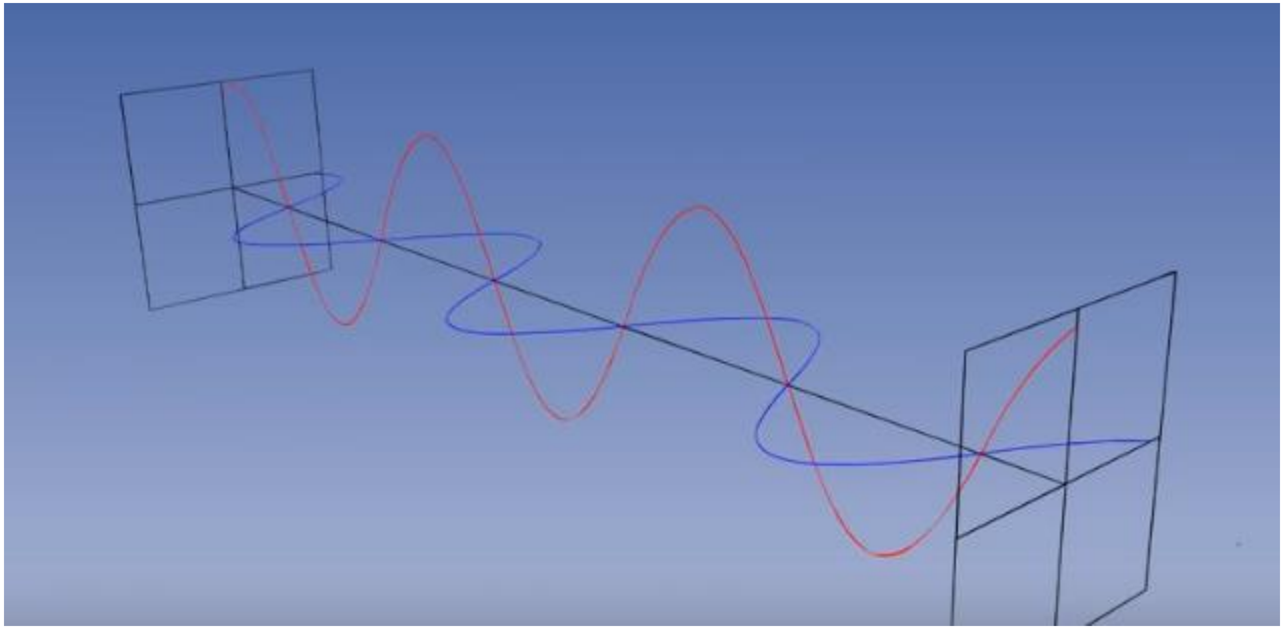
Propagation Theory-Electromagnetic Waves

If an AC current at low frequency is passed through any wire such as an aerial (Antenna), the magnetic field will move one way in a wave and then reverse and collapse with the currents.



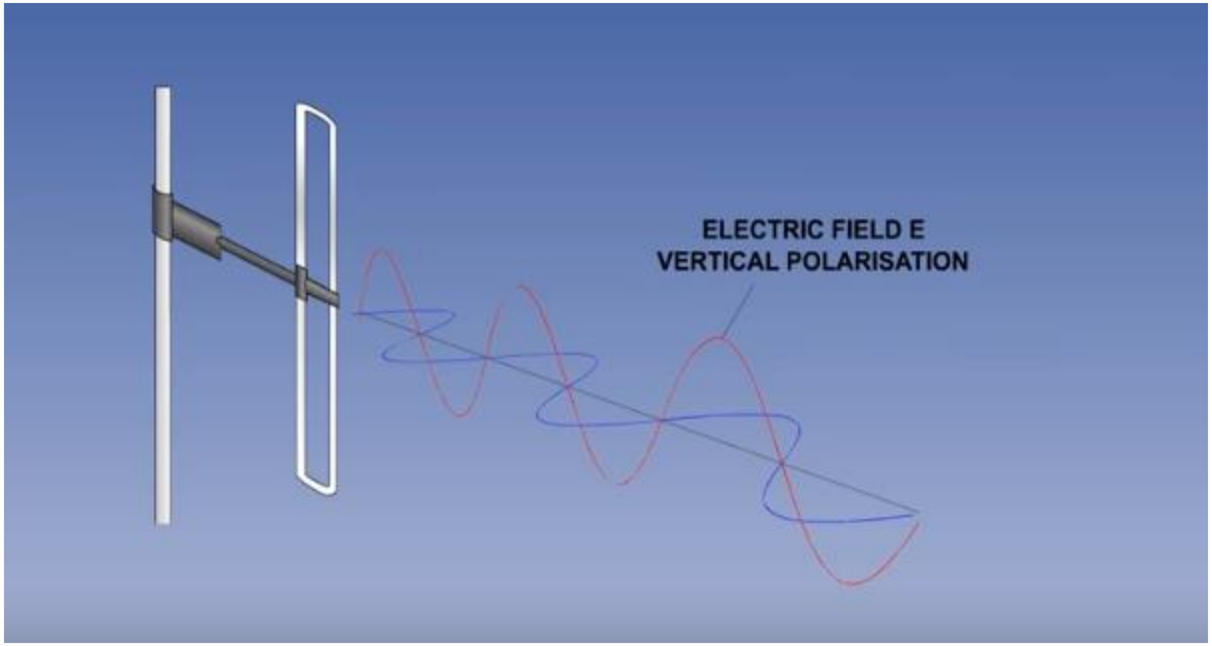
Propagation Theory-Electromagnetic Waves

But as frequency increases the magnetic field will not have collapsed completely before the reverse field starts to establish itself and energy will start to travel outwards from the aerial in the form of electromagnetic waves.



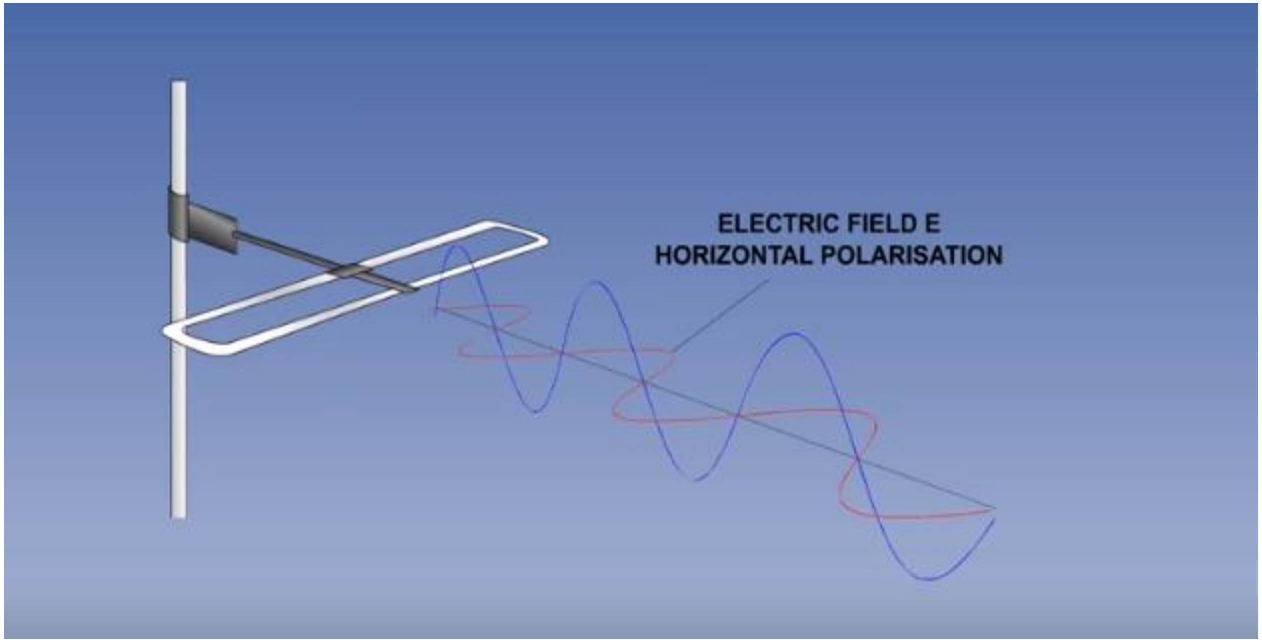
Propagation Theory-Electromagnetic Waves

The direction in which electromagnetic waves travel out from the aerial depends upon the orientation of the aerial, if the aerial is vertical then the electric field E also travels in a vertical wave form this is called **vertical polarization.**



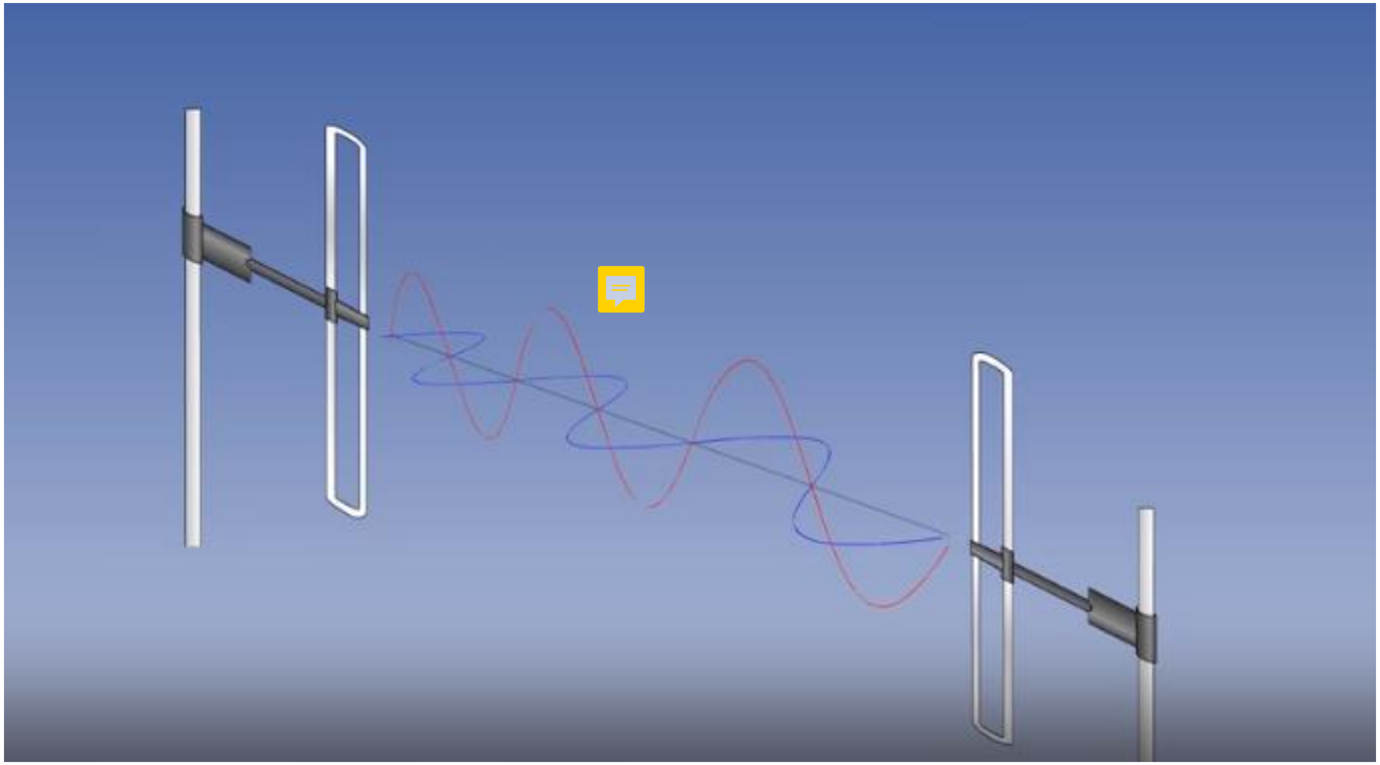
Propagation Theory-Electromagnetic Waves

If the aerial is horizontal then the electric field E also travels in a horizontal wave form this is called **horizontal polarization.**



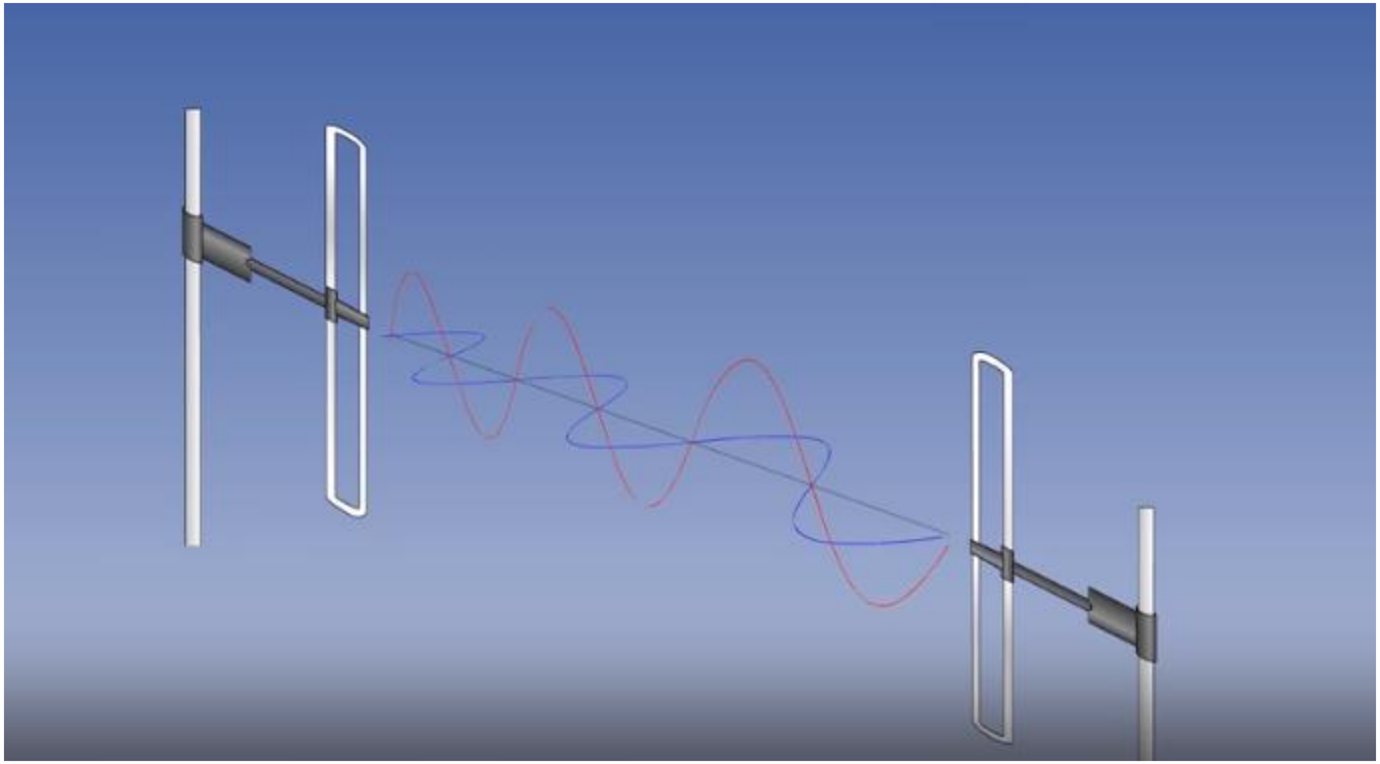
Propagation Theory-Electromagnetic Waves

To receive maximum signal strength from a incoming radio wave it is essential in the same plane as polarization of the wave so vertically polarized radio wave would require a vertical aerial



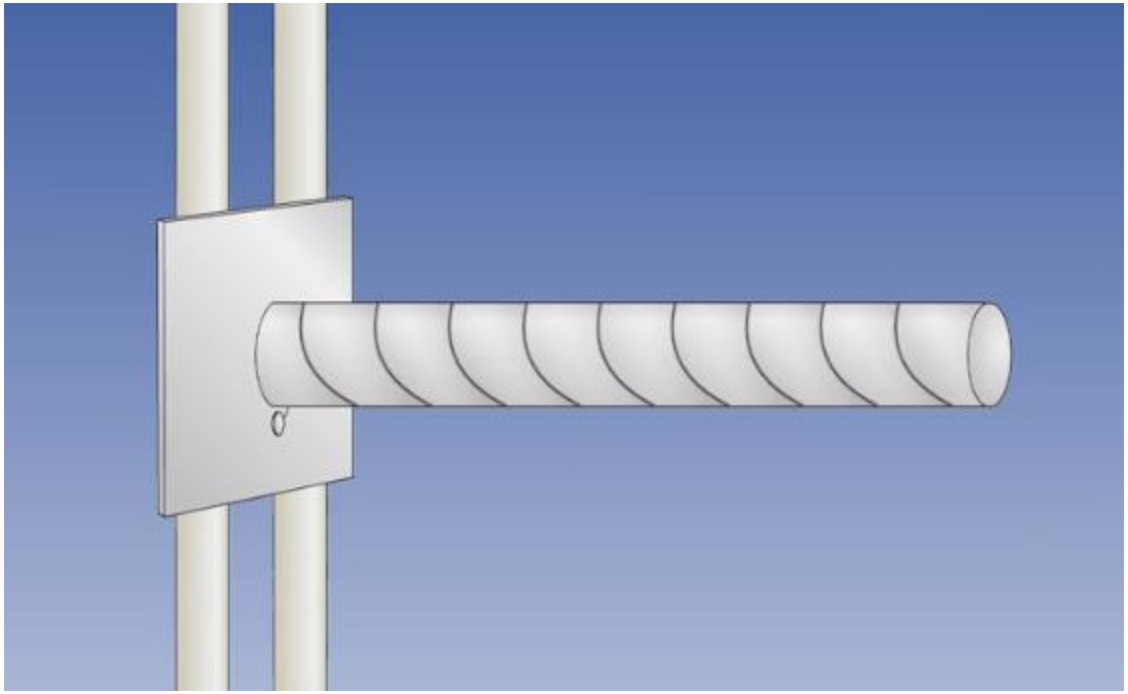
Propagation Theory-Electromagnetic Waves

The magnetic field H which is also created by the AC travels at the right angles to the electrical wave but, but we do not consider Magnetic field as it is only the electrical field that carries the radio message.



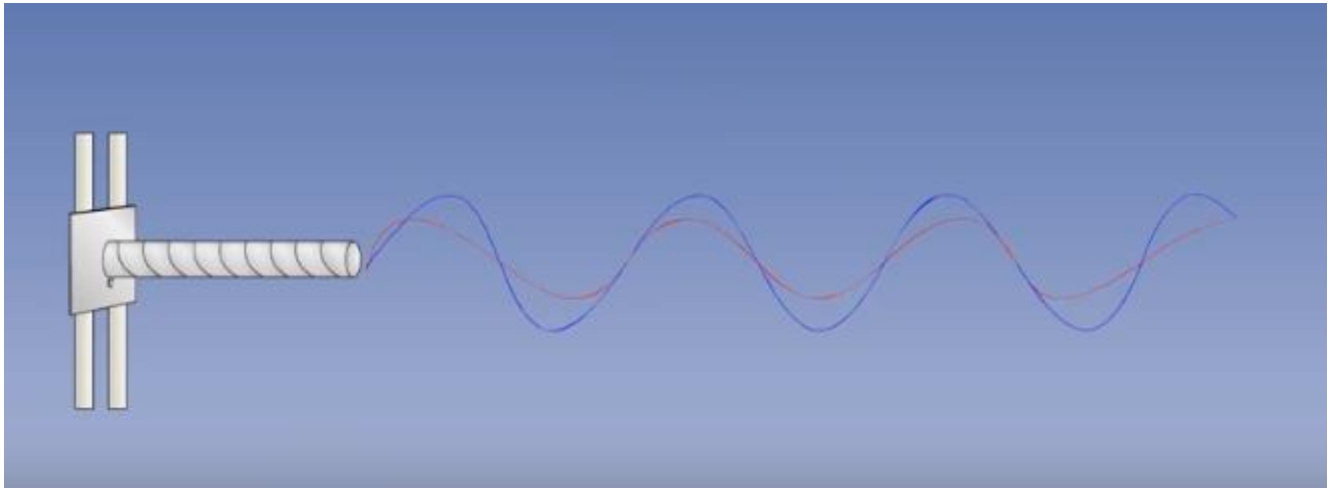
Propagation Theory-Electromagnetic Waves

Circular Polarization is produced by winding a wire in a helix shaped around an insulator this is called a helical antenna



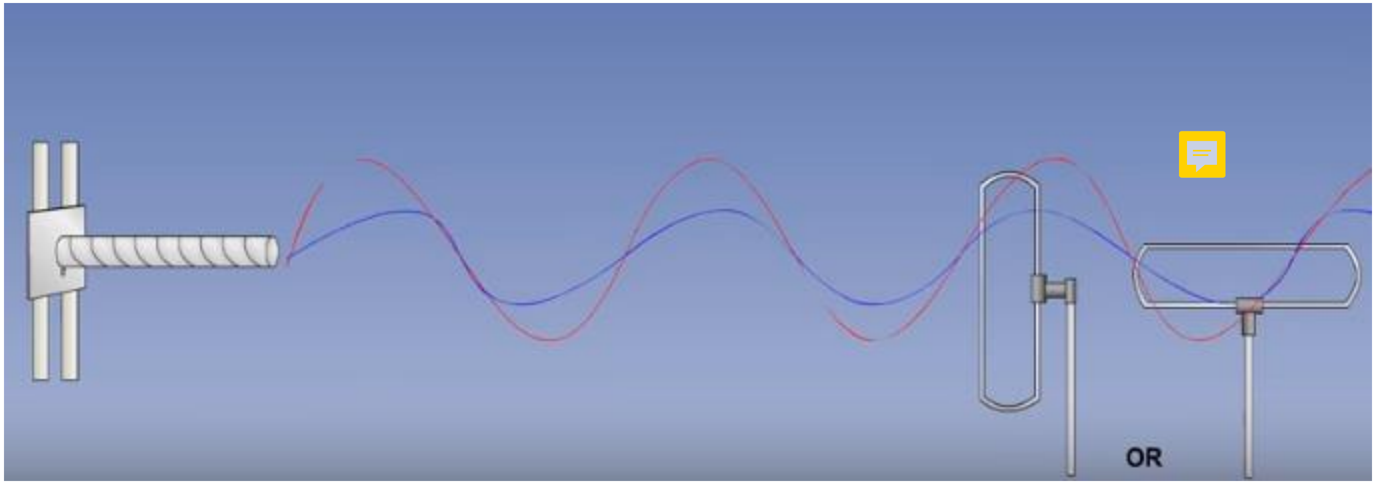
Propagation Theory-Electromagnetic Waves

The helical antenna has the advantage of transmitting in both vertical and horizontal planes and in all planes in between



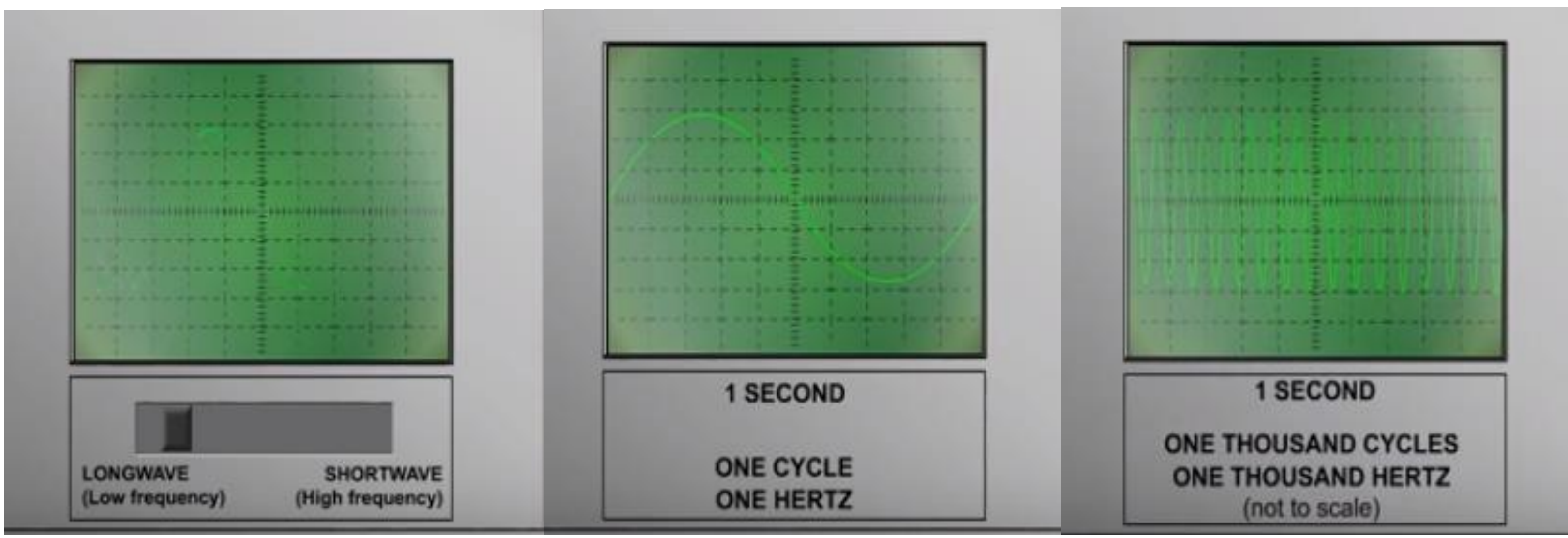
Propagation Theory-Electromagnetic Waves

So circular polarization is useful where a transmission in a single plane. But range is less as it consumes more power due to which it is mostly used in rainy weather and linear polarization in good weather in Radar.



Propagation Theory-Radio Waves

Sinusoidal Wave, Each complete pattern is cycle, the time it takes to complete each cycle in period (τ) and is measured in microsecond (μs) i.e. $10^{6.}$ The number of cycles per second is frequency and is measured in Hertz. The device used to display frequency is Oscilloscope



Propagation Theory-Radio Waves

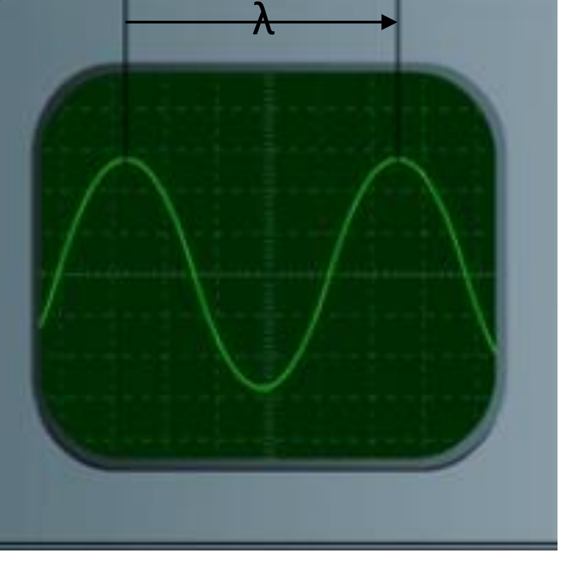
Kilo-Hertz (kHz)- 1000 Hz- 10^3 Hz

Mega-Hertz (MHz)- 1,000,000 Hz- 10^6 Hz

Giga-Hertz (GHz)- 1,000,000,000 Hz- 10^9 Hz

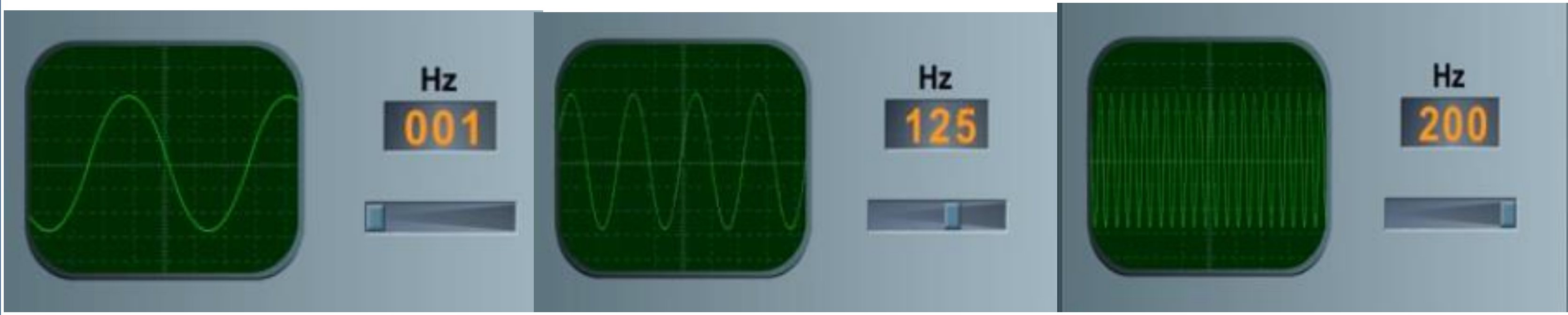
So instead of saying 8,000,000 cycles per second = 8 MHz

Wavelength: It is the distance between the start and end of the cycles. Generally, distance between two peaks of the two identical waves and denoted by the symbol λ.



Propagation Theory-Radio Waves

Relation between Frequency and Wavelength. Wavelength and frequency is inversely proportional to each other.

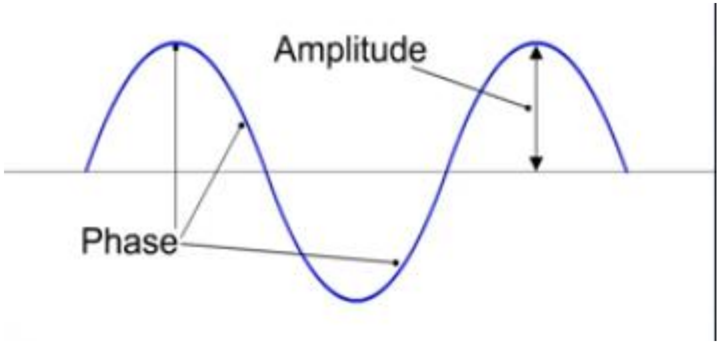


Propagation Theory-Radio Waves

Frequency Band	Frequency	Wavelength	Civil Aeronautical Usage
Very Low Frequency (VLF)	3-30 kHz	100-10 km	Nil
Low Frequency (LF)	30-300 kHz	10-1 km	NDB/ADF, LORAN C
Medium Frequency (MF)	300-3000 kHz	1000-100 m	NDB/ADF, long range communication
High Frequency (HF)	3-30 MHz	100-10 m	High Range Communication
Very High Frequency (VHF)	30-300 MHz	10-1 m	Short Range Communication, VDF, VOR, ILS, Localizer, Marker Beacon
Ultra High Frequency (UHF)	300-3000 MHz	100-10 cm	ILS glide path DME, SSR, SATCOM, GNSS, Long Range Radars
Super High Frequency (SHF)	3-30 GHz	10-1 cm	RADALT, AWR, MLS, Short Range Radar
Extremely High Frequency (EHF)	30-300 GHz	10-1 mm	Nil

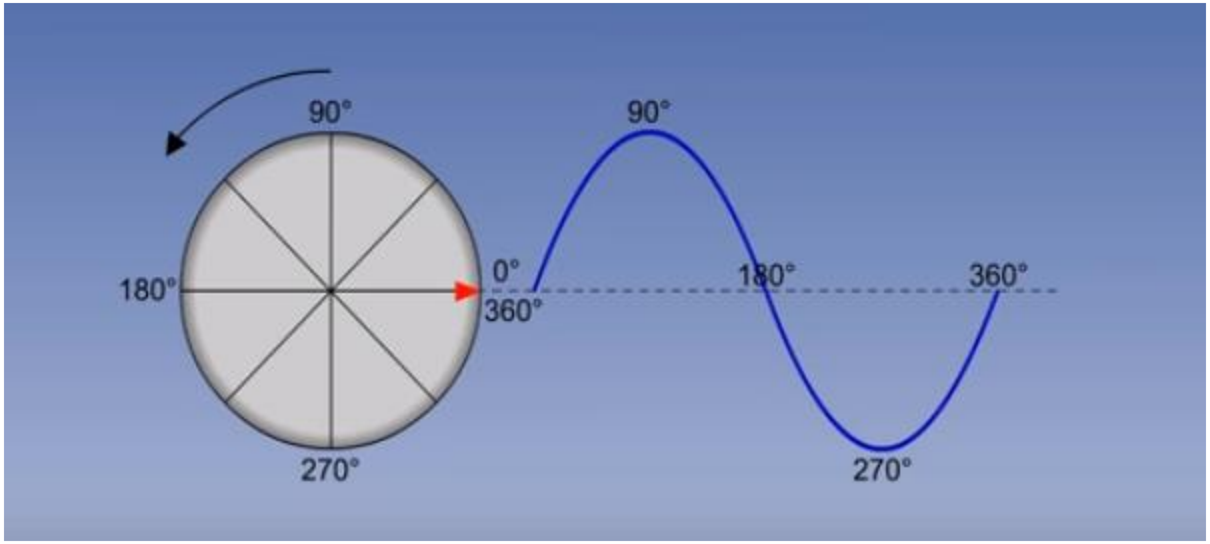
Propagation Theory-Radio Waves

When considering sinusoidal wave such as Radio Waves or AC it is convenient be able to denote a particular point or **phase** on the sinusoidal waveform. It is also necessary to know that the amount by which the wave moves away from its zero or start position is called **amplitude.**



Propagation Theory-Radio Waves

Sinusoidal waves are constructed by tracing the progress of a given point on the circumference of the circle for a 360 degree of a circle are used to represent an equivalent position on the sinusoidal wave.

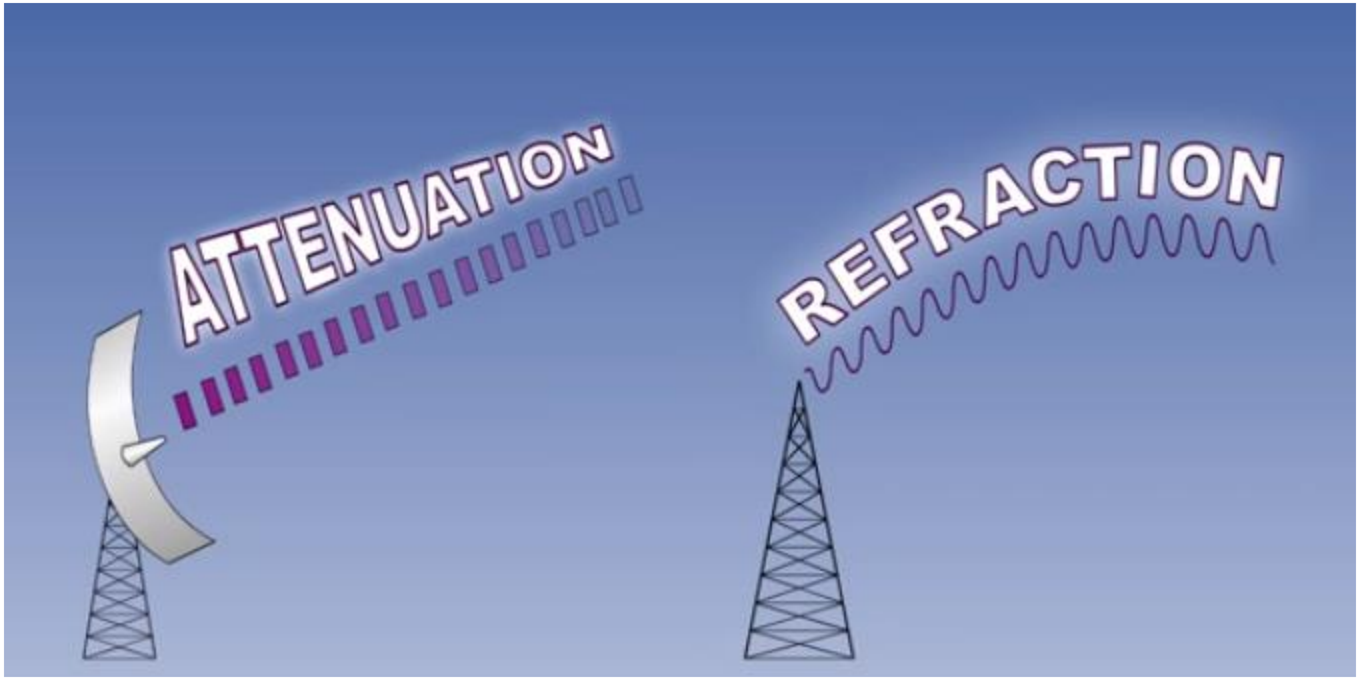


Propagation Theory-Propagation Paths

The factors that affect the propagation of radio waves. These factors fall into 2 categories

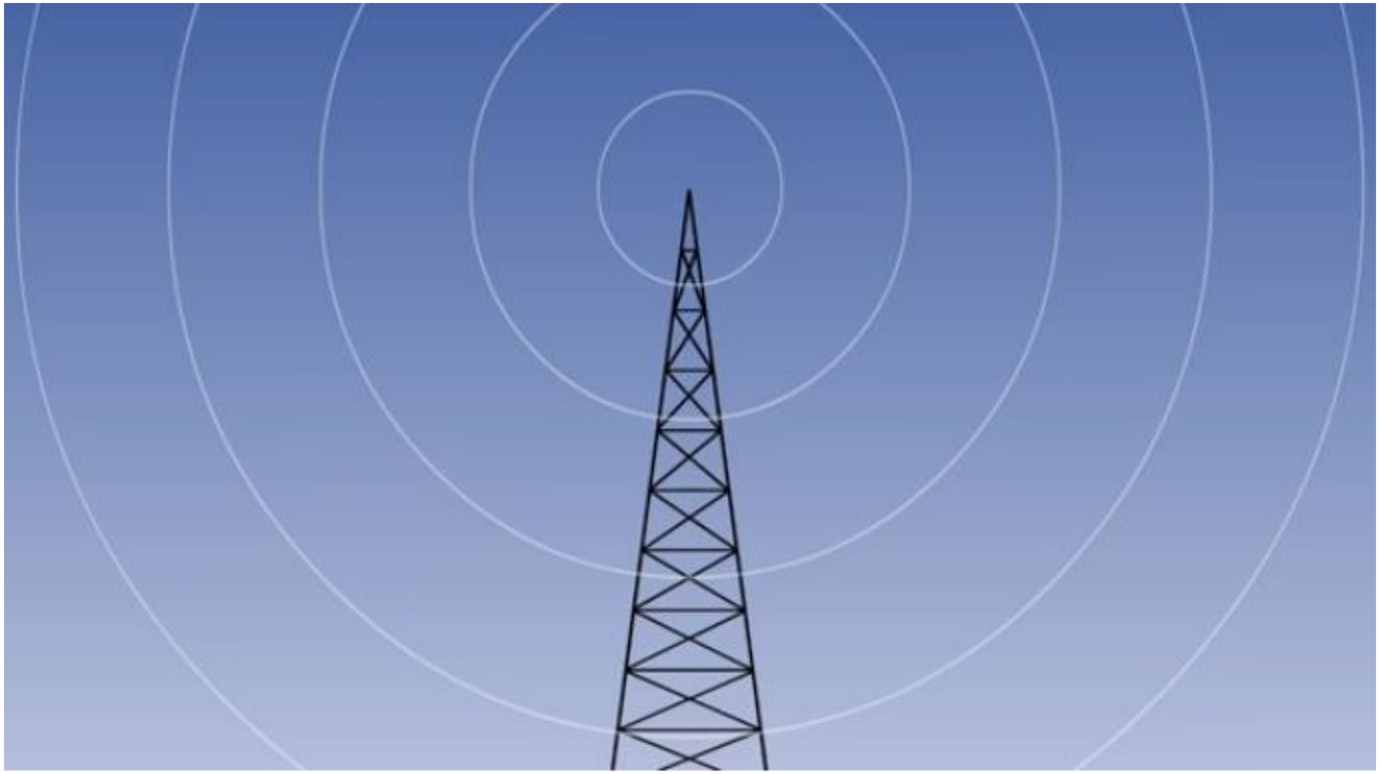
Attenuation: **Weakening of the wave**

Refraction: **Bending of the wave.**



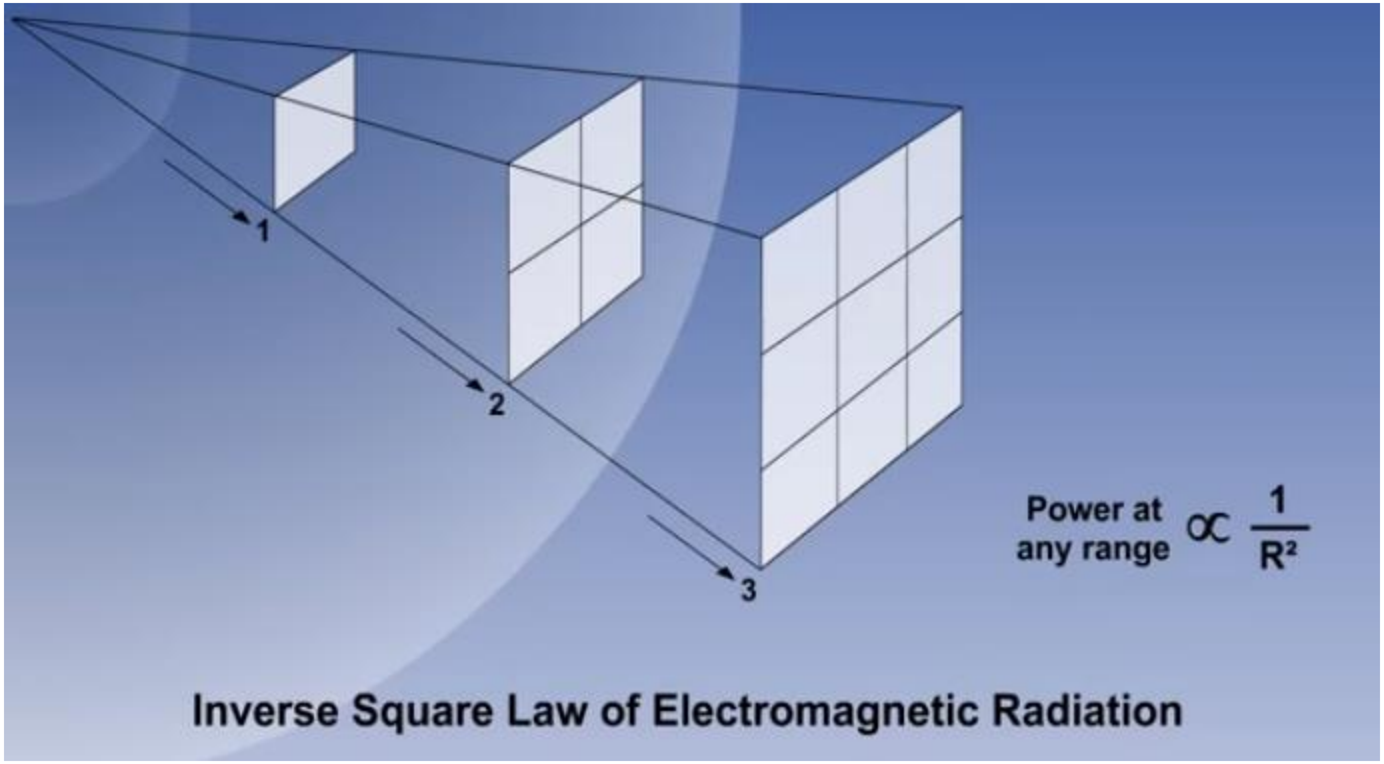
Propagation Theory-Propagation Paths

Attenuations occurs in several ways as the wave travels further away from the transmitter it simply becomes weaker like the waves in a pond emanating from where a stone is thrown. As range increases the field strength of the wave decreases.



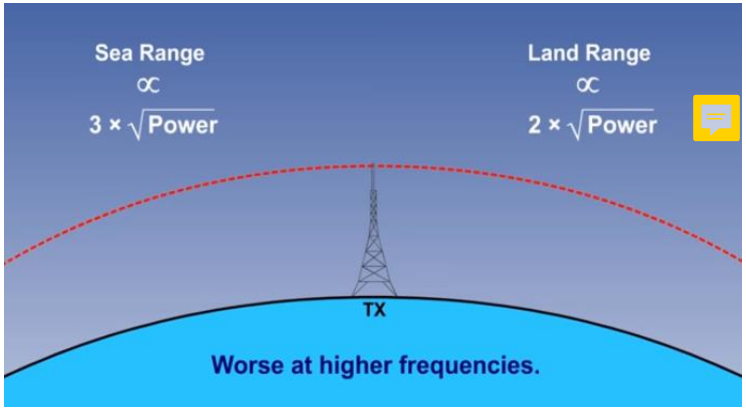
Propagation Theory-Propagation Paths

Attenuation is proportional to the inverse square of the range. This means if the range is to be doubled then the power required should be quadrupled.



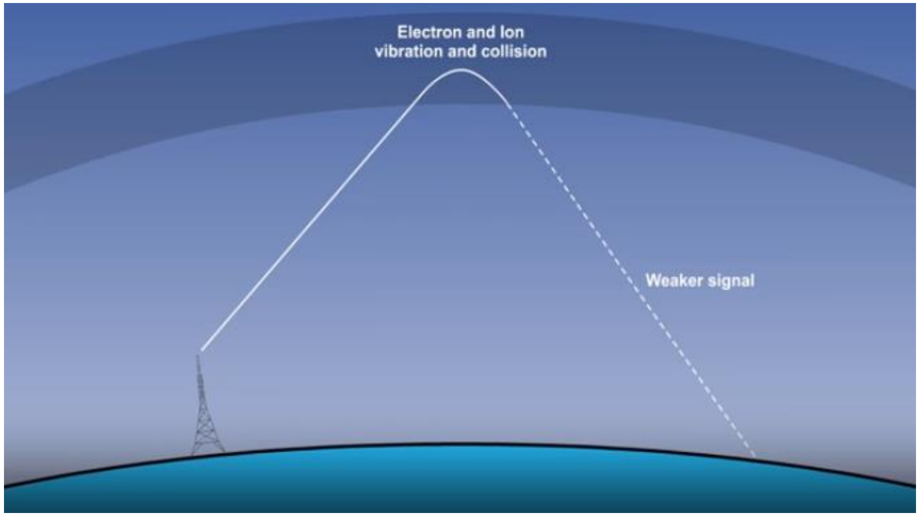
Propagation Theory-Propagation Paths

Surface Attenuation occurs when a wave travels over the earth surface. Its strength would be attenuated by contact with the earths surface because the wave induces a voltage in the earth which takes energy away from the wave as it moves away from the transmitter. To reduce this attenuation vertical polarized fields are used which merely dip into and out of the earths surface whereas horizontally polarized field is in constant contact with the surface of the earth and the wave is completely attenuated within a short distance. The nature of the surface of the earth over which the wave travels is also a factor in attenuation. Radio waves attenuate **more** over land than over the sea. Mountains forests and desert cause the greatest attenuation of radio waves. Surface attenuation increases as the frequency of the signal increases and so frequencies above 2 MHz are of little use for long distance transmissions.



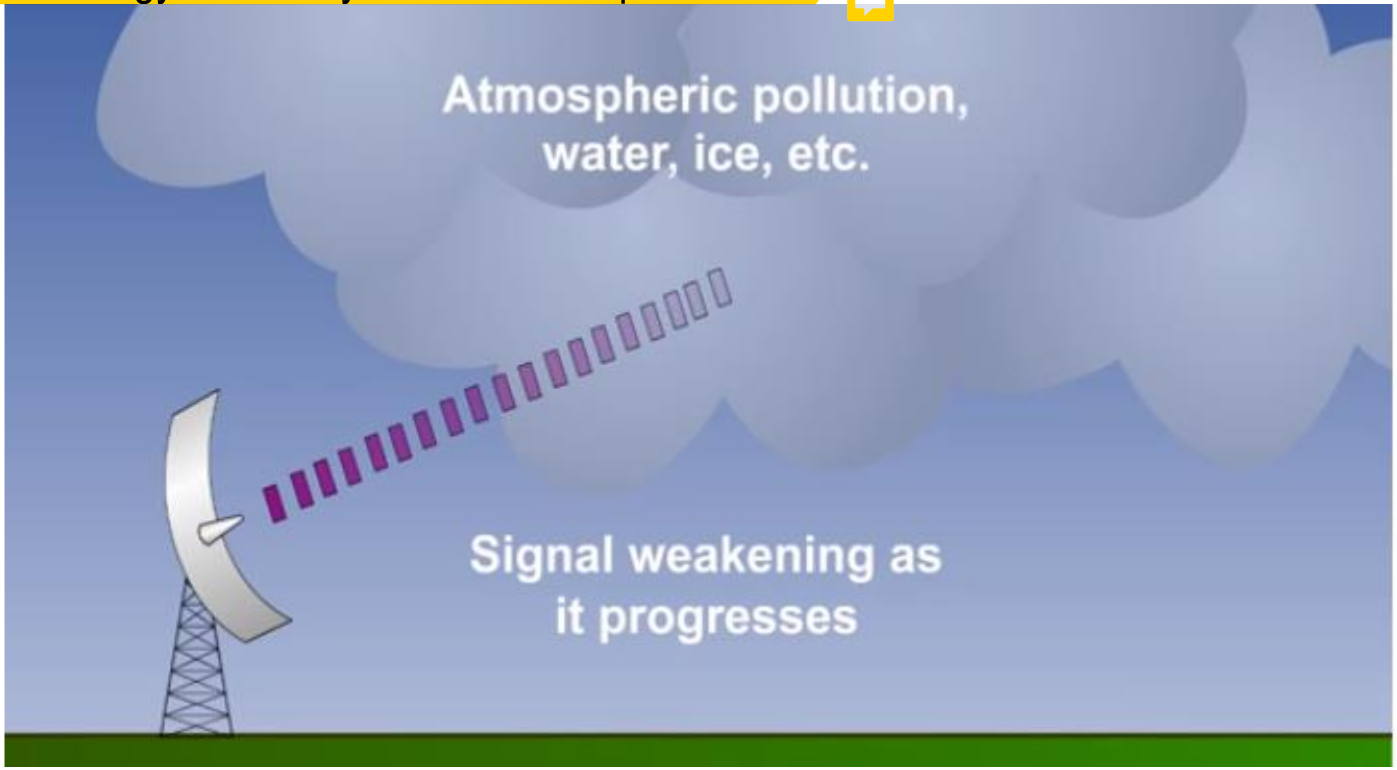
Propagation Theory-Propagation Paths

Ionospheric Attenuation occurs when radio waves penetrate the ionosphere which is diffused with free electrons as radio signals propagate through the layers of the ionosphere they begin to transfer energy to these electrons setting them in motion. This results in electron vibrating which can cause them to collide with other molecules, ions and electrons. Each collision dissipated a small amount of radio signal strength as energy is transferred from wave to particle and the radio wave returning to earth will have lost some of its strength. The frequency and hence the wavelength of the radio waves is important, the longer the wavelength the greater the ionospheric attenuation. Note: this is the reverse of ground or surface attenuation.



Propagation Theory-Propagation Paths

Atmospheric Attenuation (SCATTER) occurs because atmosphere contains solid particles such as water pollutants and ice, these will reflect and scatter radio waves of a sufficiently high frequency those above 5 GHz. In this frequency band, the wavelength is around 1-10 cm, and the water droplets in the atmosphere are of these sizes due to which energy carried by the wave dissipates here.

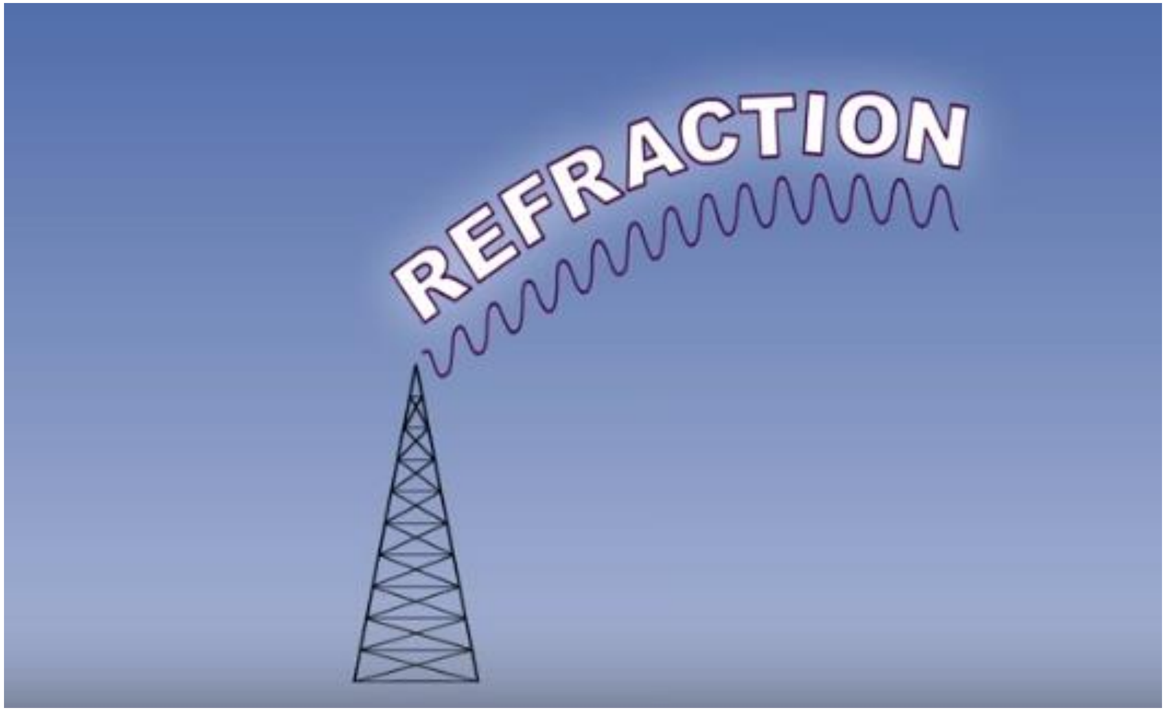


Propagation Theory-Propagation Paths

Reflections also attenuates signals such as Buildings, so aerials should be positioned sufficiently high to avoid this. Static interference (Rain, Thunderstorm etc.) also attenuates radio signals.

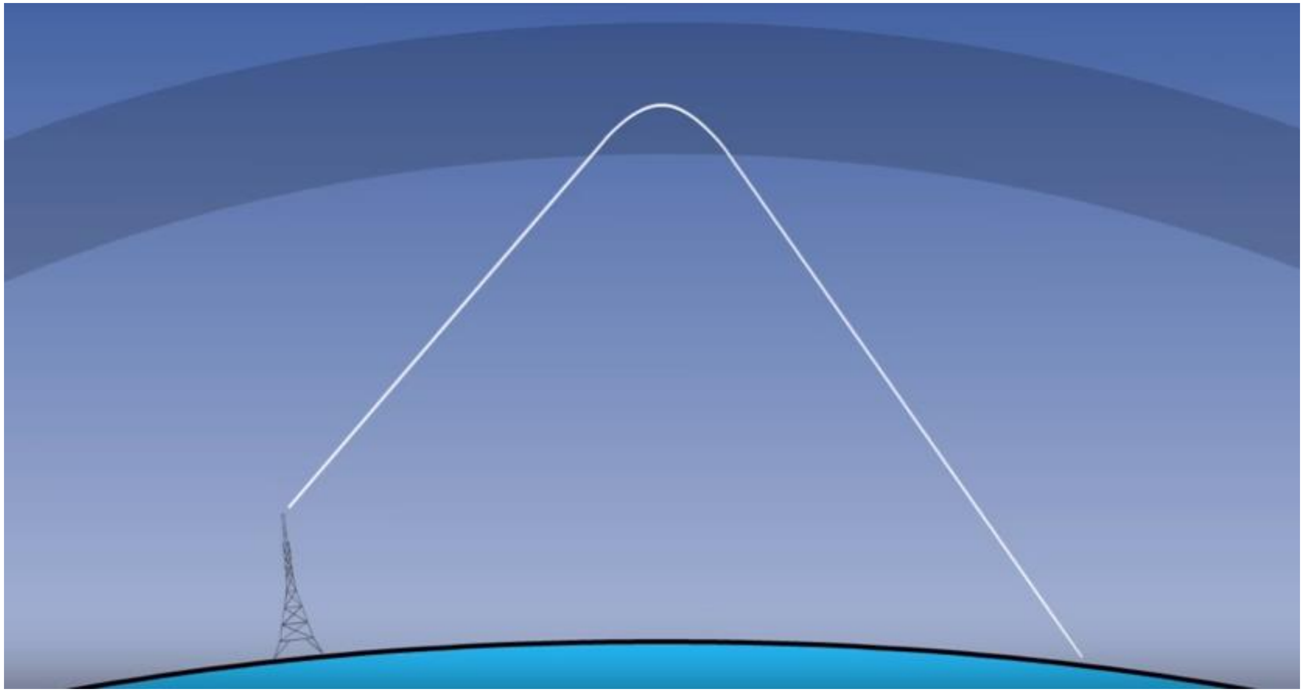
Propagation Theory-Propagation Paths

Refraction this can happen in several in hindrance or it may be a help to radio wave propagation in radio waves or lights through one medium and then through another because of change of velocity.



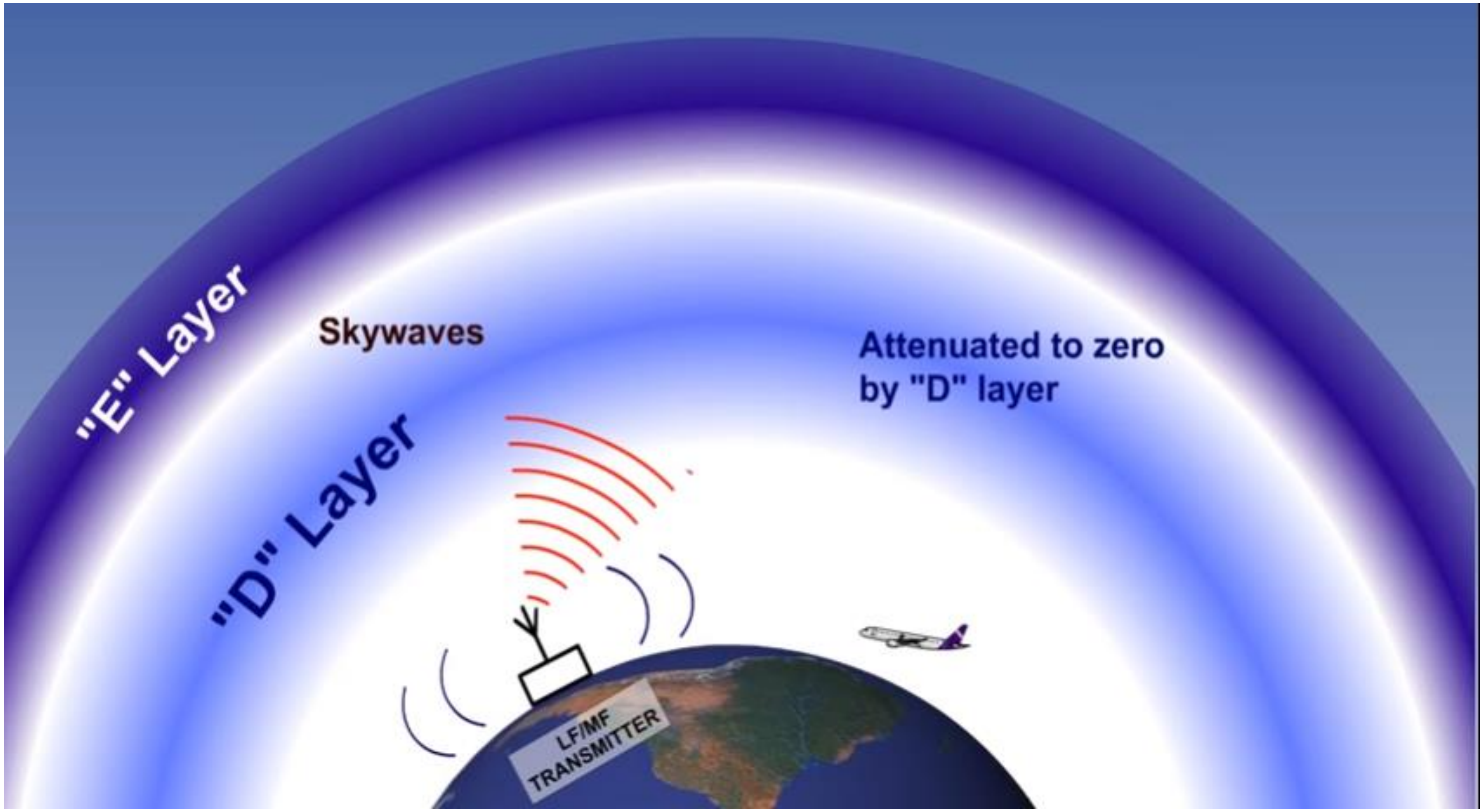
Propagation Theory-Propagation Paths

~~Refraction occurs in the same way for the radio waves as for the light waves in water. The ionosphere is densely ionized that is negatively charged. This ionosphere reaction is very useful as it bends back the wave into earth.~~ Refractions decreases as frequency of the radio signal increases.



Propagation Theory-Propagation Paths

Equally useful is atmospheric diffraction in the low and medium frequency bands radio waves tend to refract or bend to such an extent that they remain in contact with the earths surface which increases range possibly to thousands of kilometers.



Propagation Theory-Propagation Paths

The Refractions or bending also occurs in the VHF band during some meterological condition which results in a radio wave hugging the earth and increasing range and this effect is known as **Super Refractions.** The necessary condition are :

- **Decrease in relative humidity with height**
- **Temperature falling more slowly than standard**
- **High Pressure System**
- **Warm Air flowing over cooler surface.**

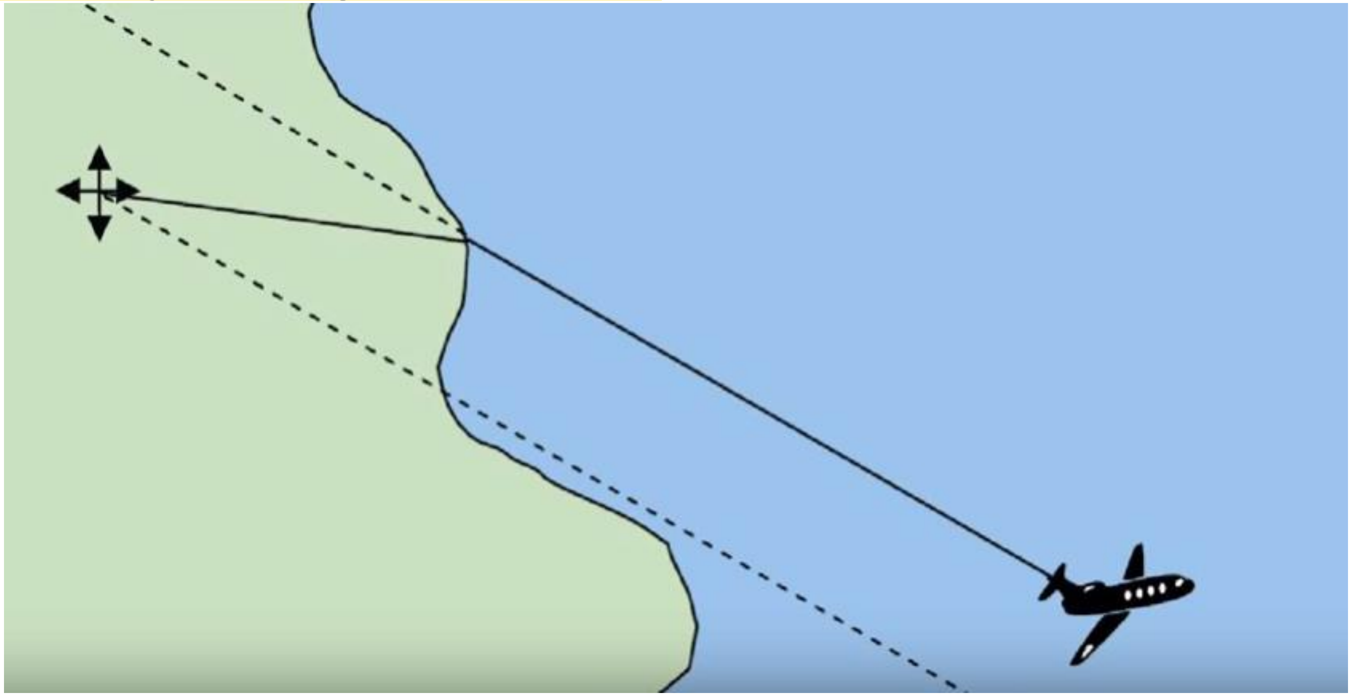
Sub Refractions occurs in conditions of

- **Increases relative humidity**
- **Lower than ISA temperature**
- **Low Pressure**
- **Cold Air flows over a hot surface**

Which results in reduced range.

Propagation Theory-Propagation Paths

However not all refraction is beneficial, coastal refraction occurs because a radio wave travels faster over the sea than it does over the land. As a result, any wave that crosses a coast line at other than 90 degrees will bend slightly towards the medium in which it travels slower namely the **Landmass. Again, the degree of refraction decreases if the frequency of the signal is increased.**

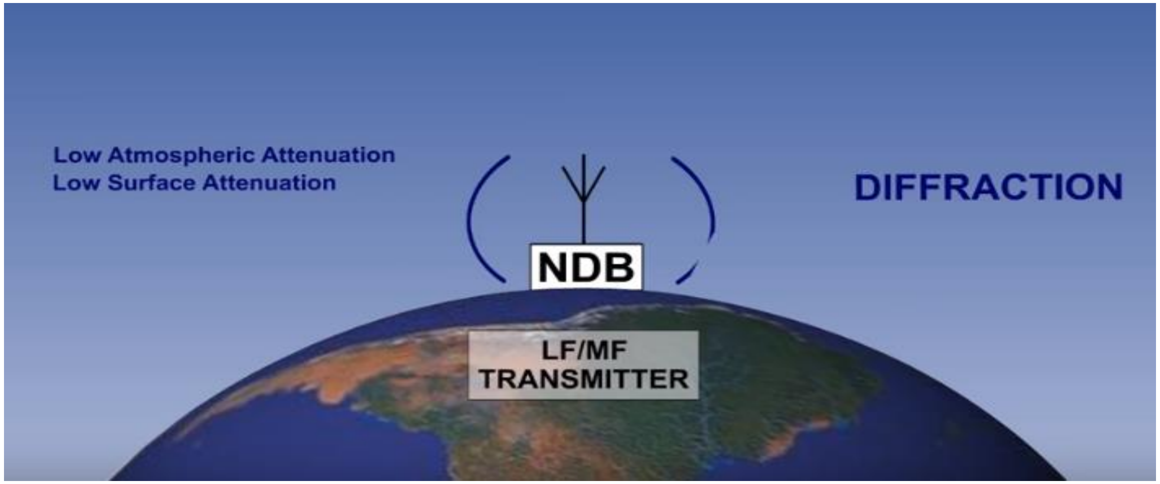


Propagation Theory-Propagation Paths

- Propagation
  - Non- Ionospheric
    - Surface Wave (20kHz-50MHz) Used 20kHz-2MHz)
    - Space Wave >50 MHz
  - Ionospheric
    - Skywave (20kHz-50MHz) Used 2-30MHz
    - Satellite UHF, SHF
    - ~~Ducting~~ ~~< 20kHz~~

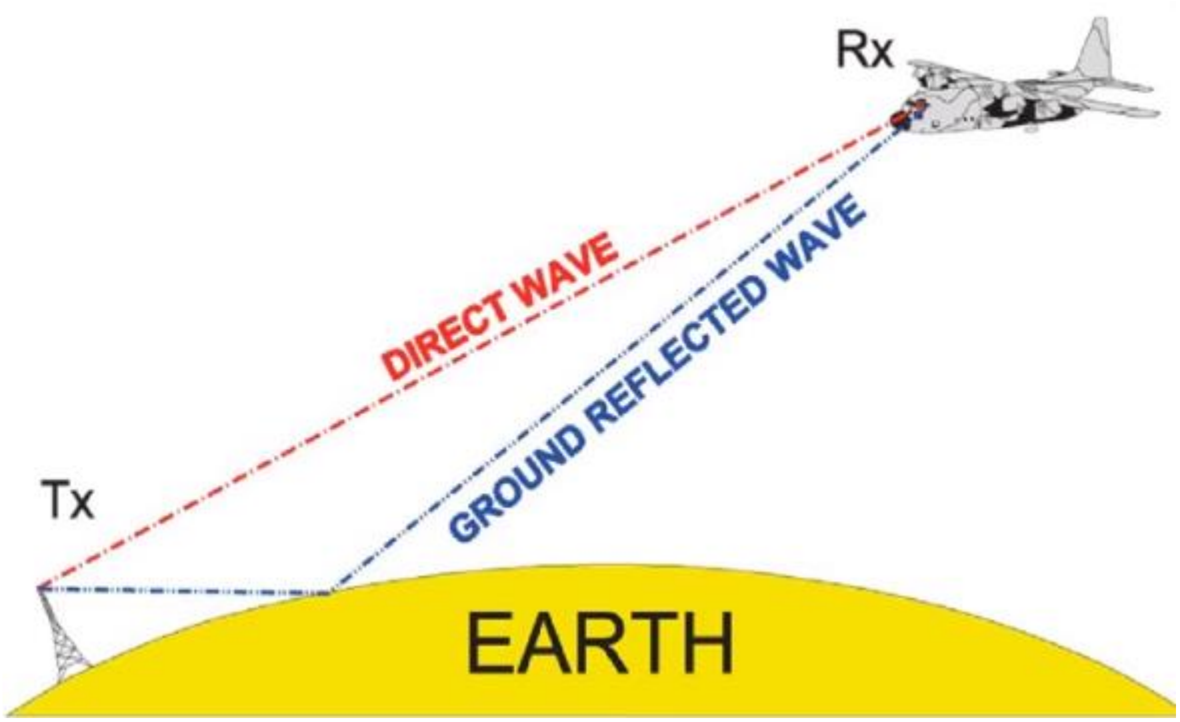
Propagation Theory-Propagation Paths

Starting with Surface Wave, these exist at frequencies from about 20 KHz to 50 MHz, **w**hich is from the upper end a very low frequency through long wave, medium wave and high frequency to the lower end of very high frequency. They travel across the earth by the process of **diffraction**. The range achievable is dependent upon several factors as the radio wave frequency increases surface attenuation increases. Surface waves are effectively non-existent above high frequency that is above 30 MHz. Surface waves are therefore used in the low frequency for NDB transmission. In the medium frequency for NDB and long range communication and in the high frequency for long range communications.



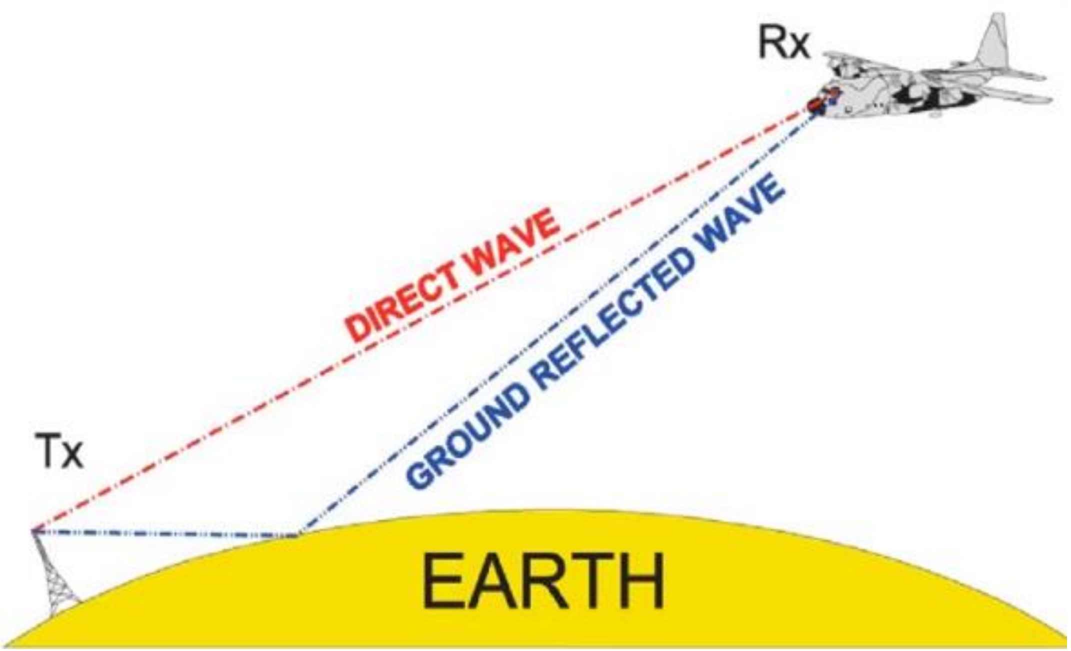
Propagation Theory-Propagation Paths

Second type of Non-Ionospheric wave is Space Wave, which is made up two parts a ground reflected wave and direct wave..



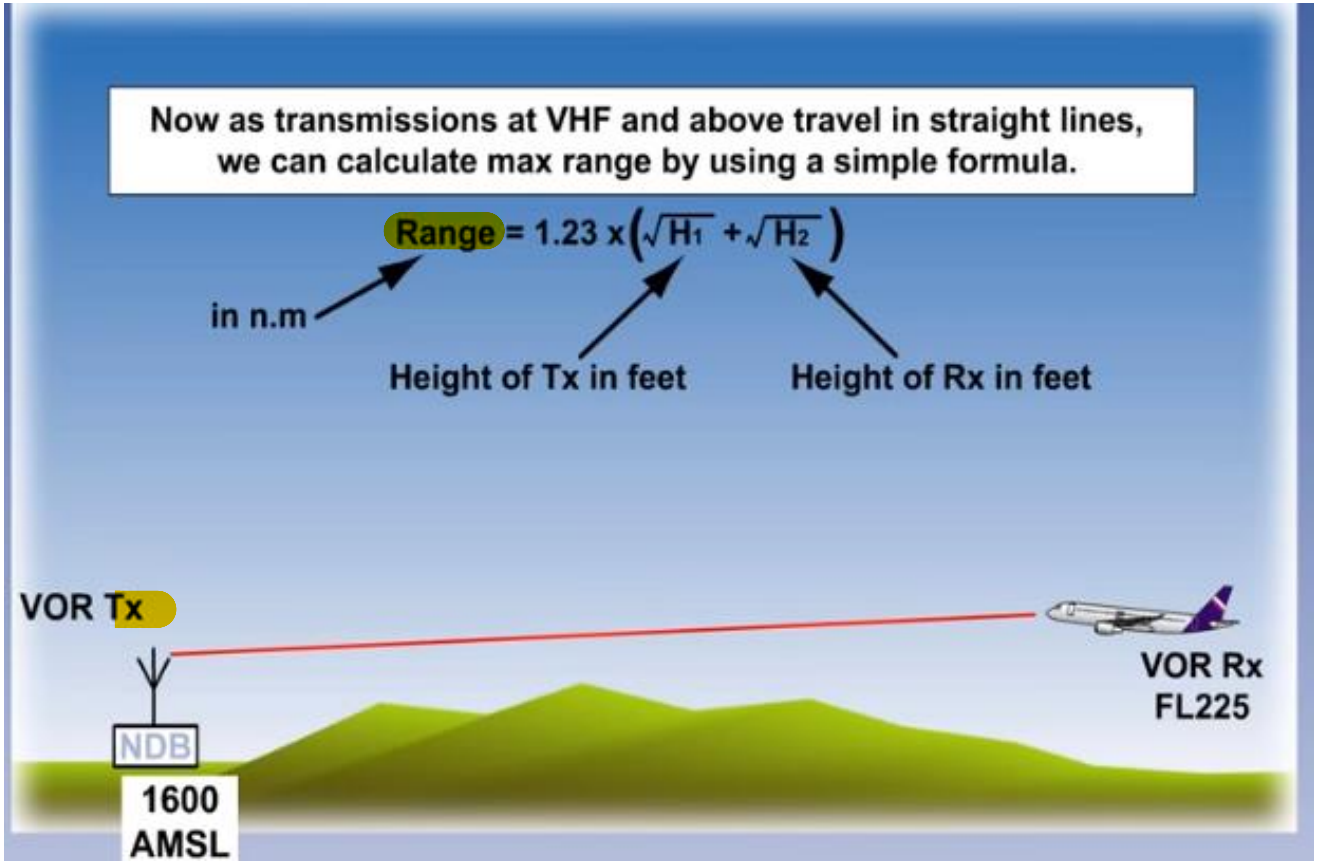
Propagation Theory-Propagation Paths

At frequencies of VHF and above , radio waves start to behave more like visible light and in the same way the light has a visible horizon, radio waves also have a horizon, so only propagation at these frequencies is Line of Sight (LOS). There is some atmospheric refractions which causes the radio waves to bend towards the earth and this does increase the range slightly beyond the geometric horizon but as radio frequency increases refraction reduces



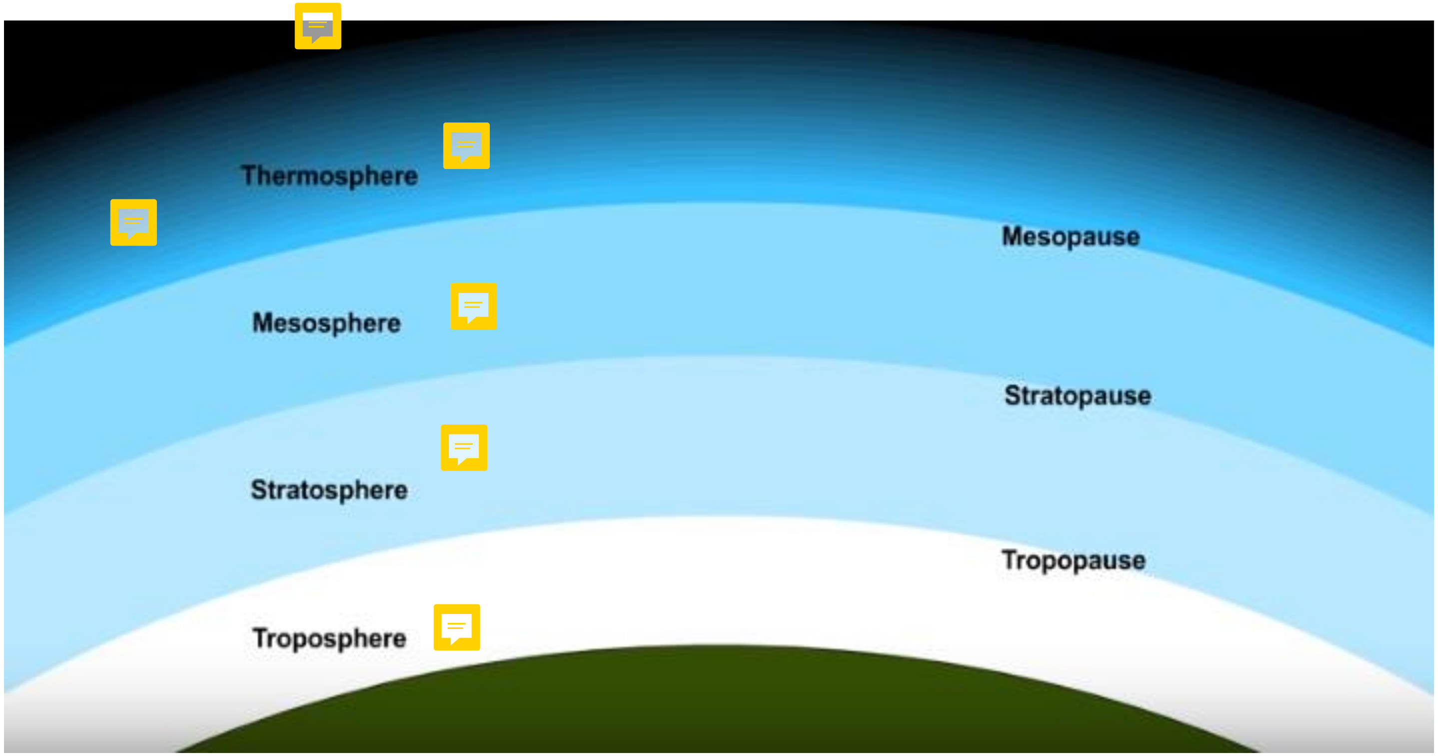
Propagation Theory-Propagation Paths

Range formula in Nm



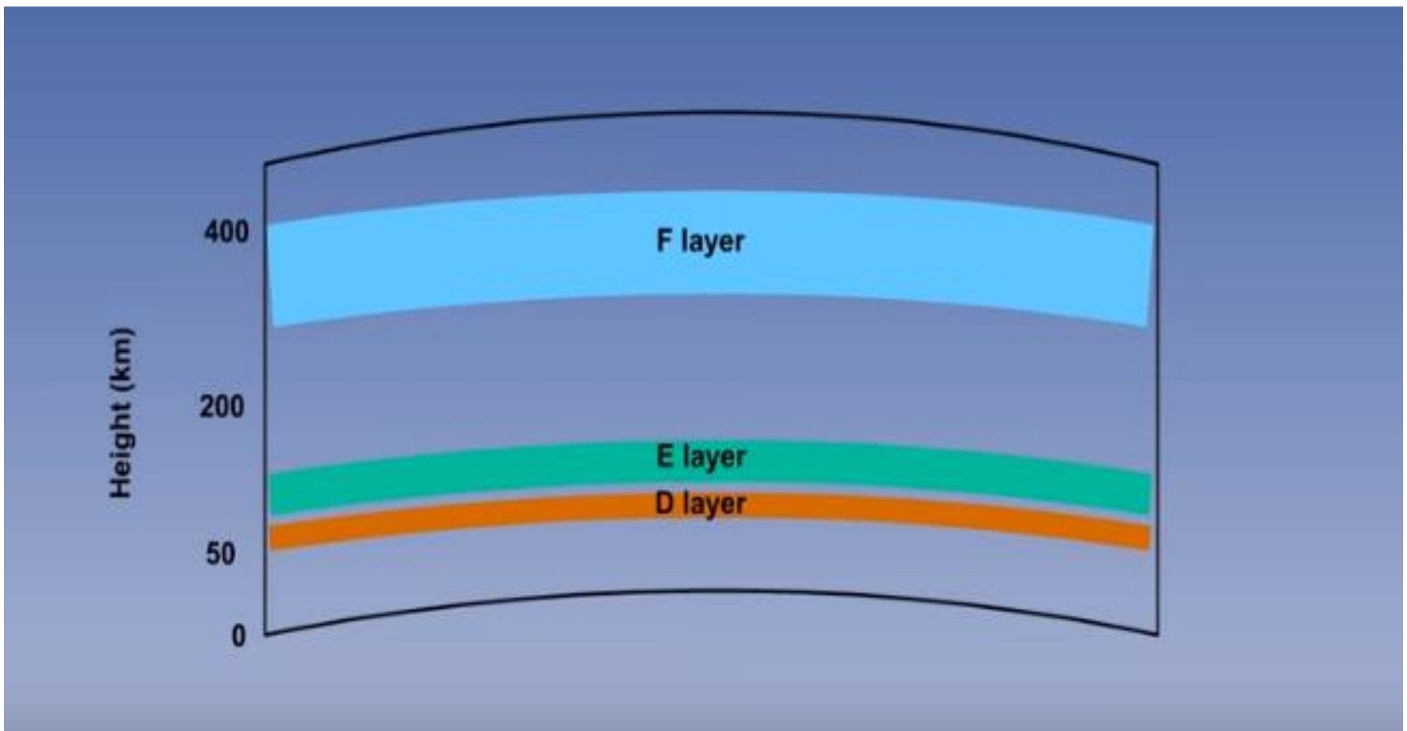
Propagation Theory-Propagation Paths

Moving on to Ionospheric Propagation, first lets have a look at what earths atmosphere is made of. Progressively Fewers atoms of gases with height above the earth from



Propagation Theory-Propagation Paths

Ionosphere Layers- D, E and F layers.



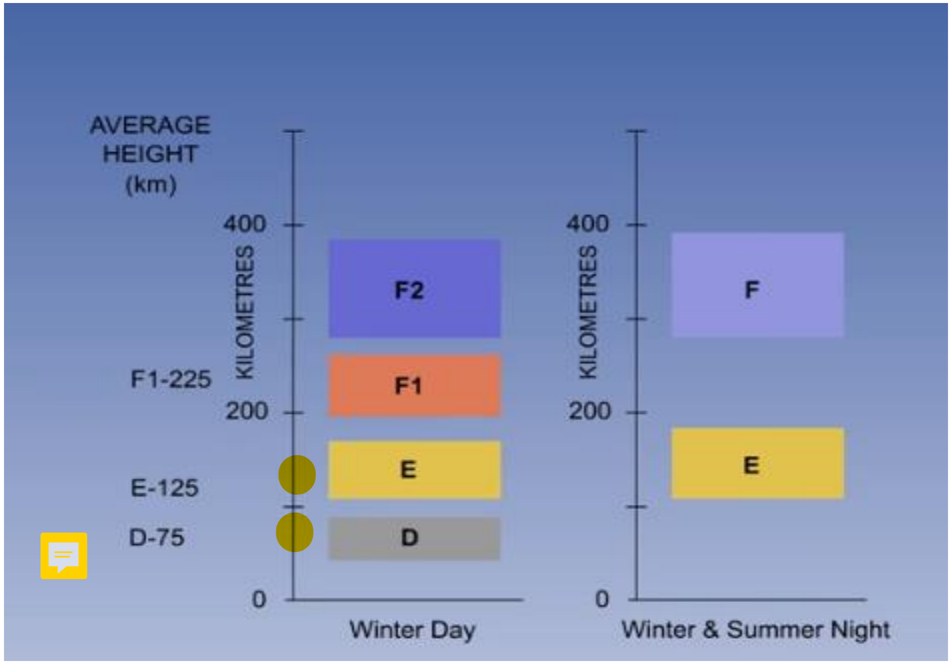
Propagation Theory-Propagation Paths

Ionosphere Layers- D, E and F layers.

F Layers (aka Appleton layer) Contains F1 and F2 (During the day they are different, but combine at night) average height of 200 Km

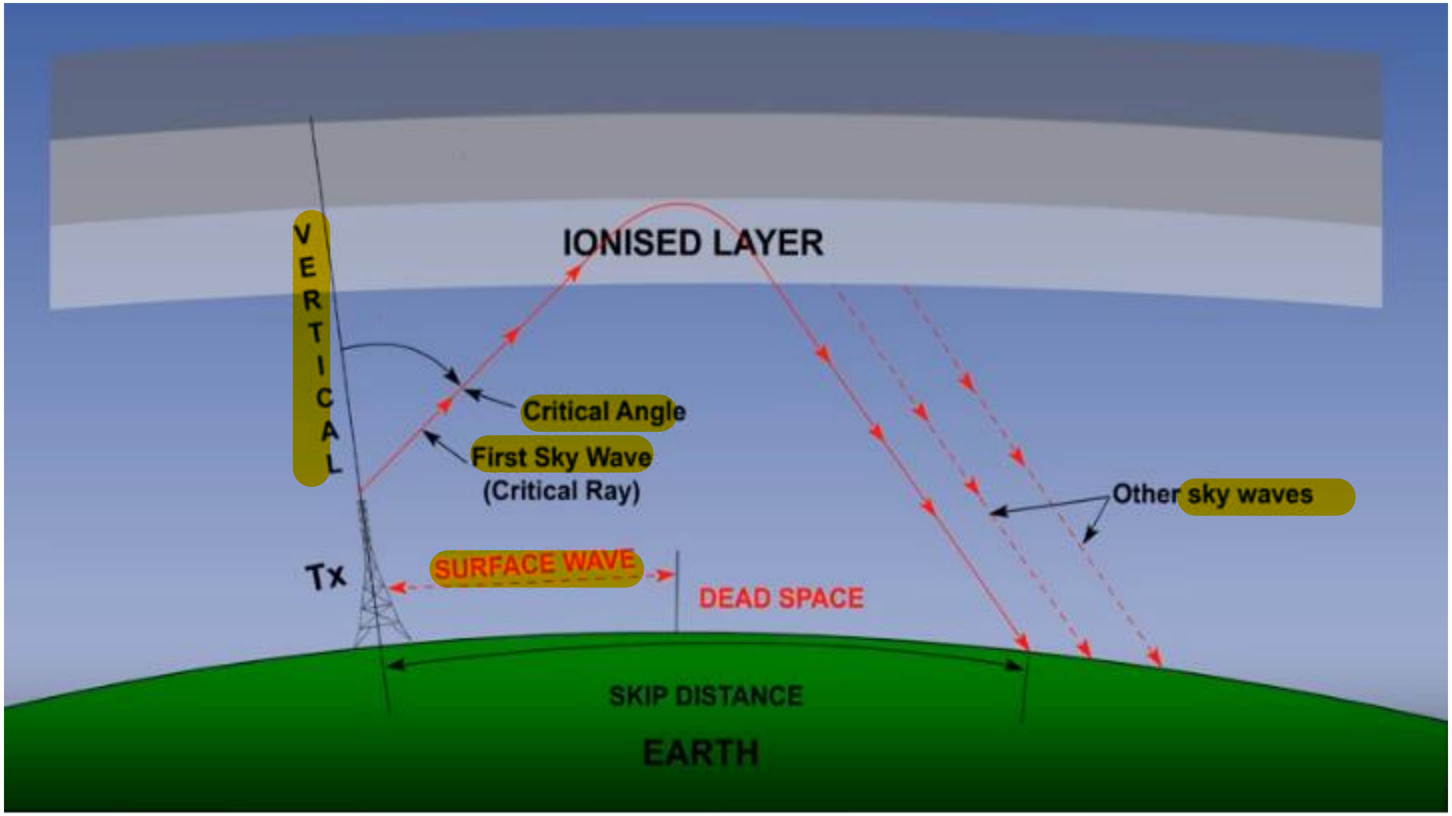
Layer D is found at average height of 75 Km in the atmosphere, Ionization is low

Layer E (aka Kennely Heaviside Layer) found at an average height of 125 Km.



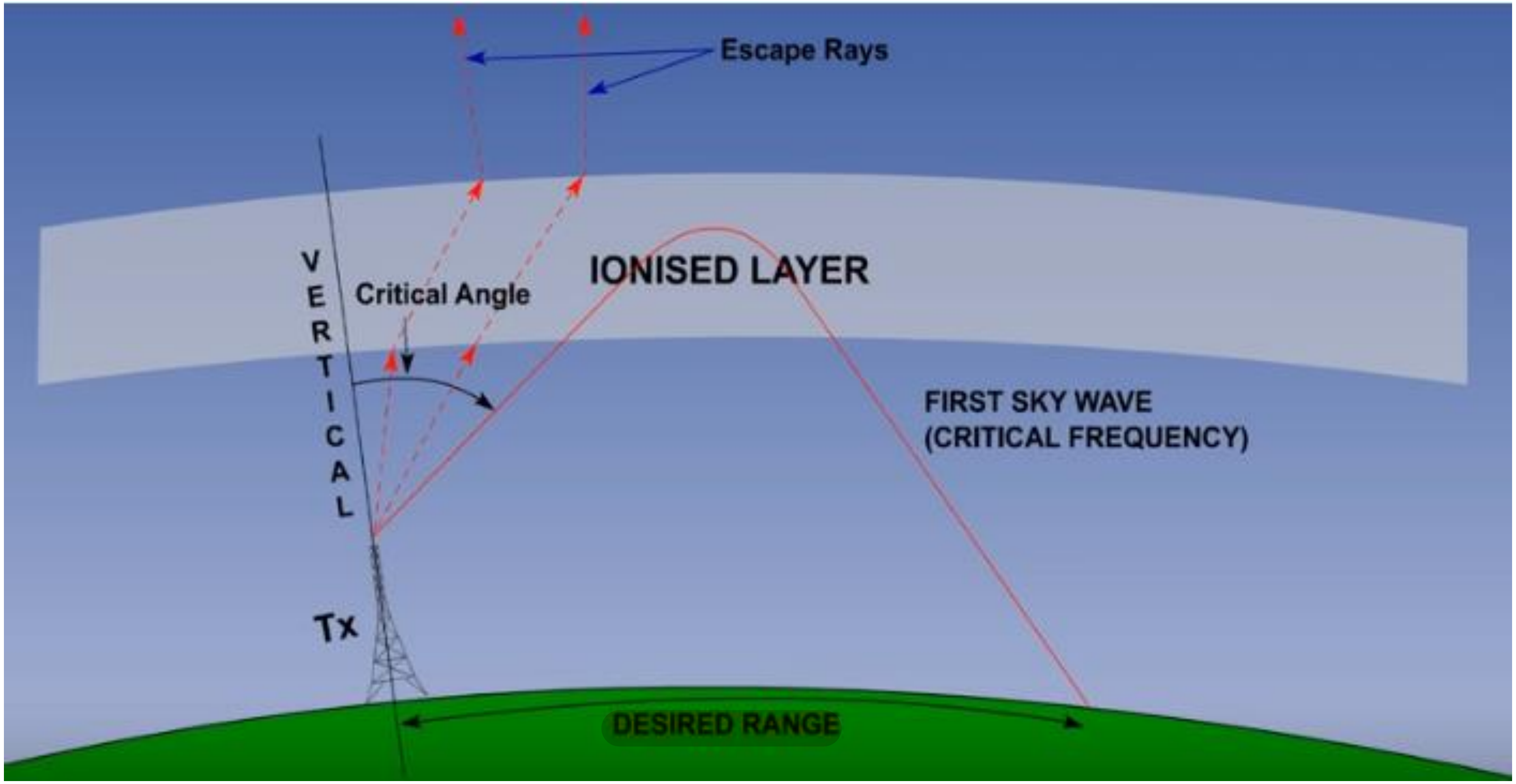
Propagation Theory-Propagation Paths

When a radio wave is transmitted into ionized layer and it returns it is called a sky wave. The bending occurs because there is an abrupt change in the velocity of the radio wave.



Propagation Theory-Propagation Paths

Critical Frequency: Maximum frequency in which wave can be refracted. Thus the range achieved at that time is desired range.

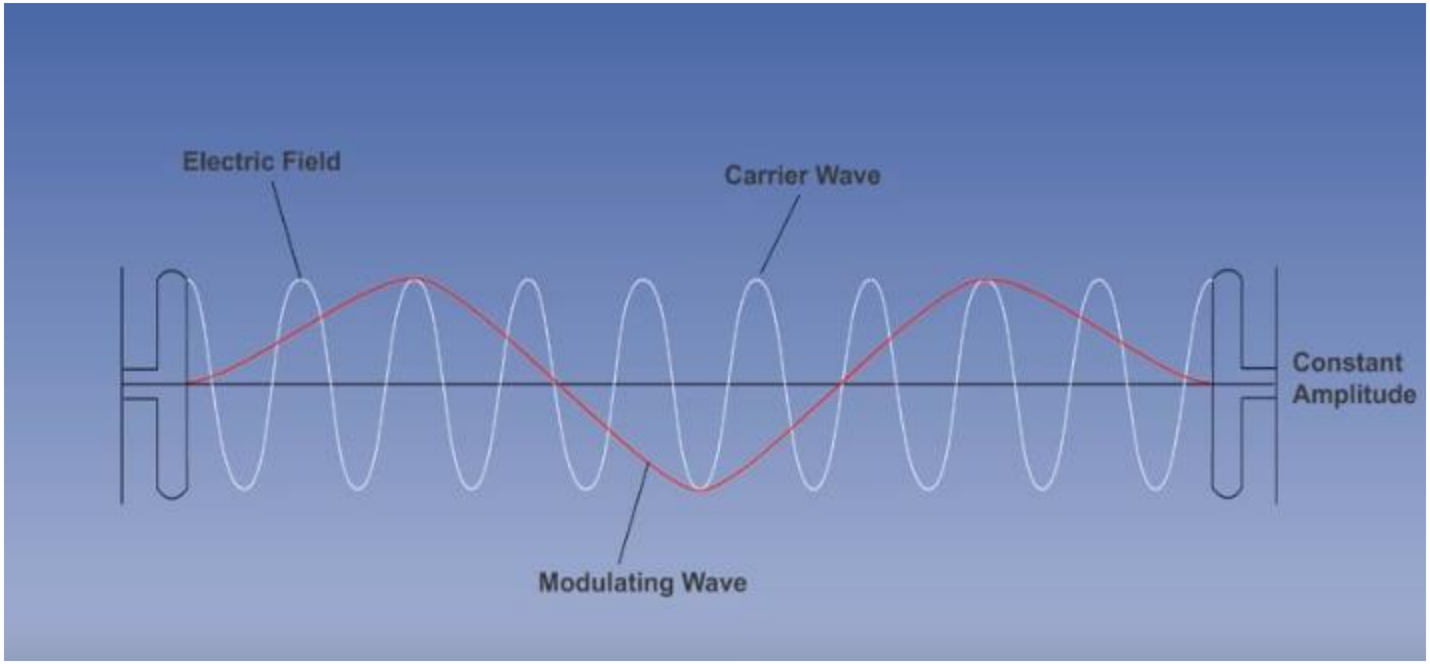


Propagation Theory-Propagation Paths

Fading is caused by variations in signal strength because of distance, low transmission power, weather, terrain, and signal to aerial polarization matching. **Multipath fading** occurs when sky waves contaminated the surface waves in the low frequency and MF bands. **Space diversity** is the process of positioning two antennae's in the aircraft to avoid Multipath Fading in which at least one antennae will receive a good signal. It also can be overcomed by using 2 Tx and 2 Rx each pair tuned to different frequencies which is called **frequency diversity.**

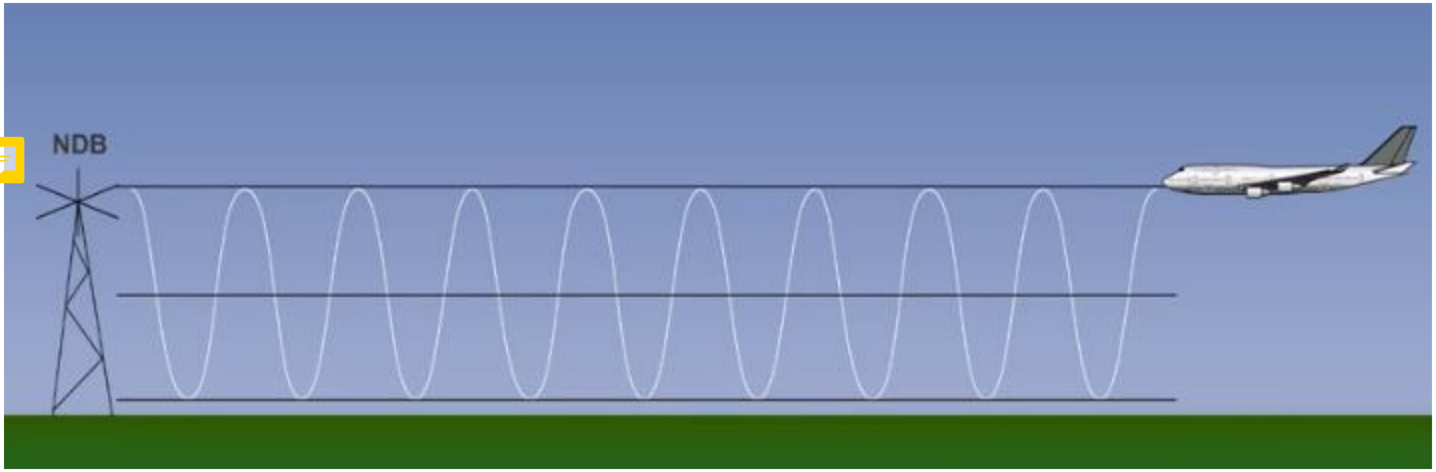
Propagation Theory-Modulation

Lets look how information called intelligence is superimposed onto the radio wave, when this is done the radio wave is termed as carrier wave. The intelligence is said to be in modulated into it



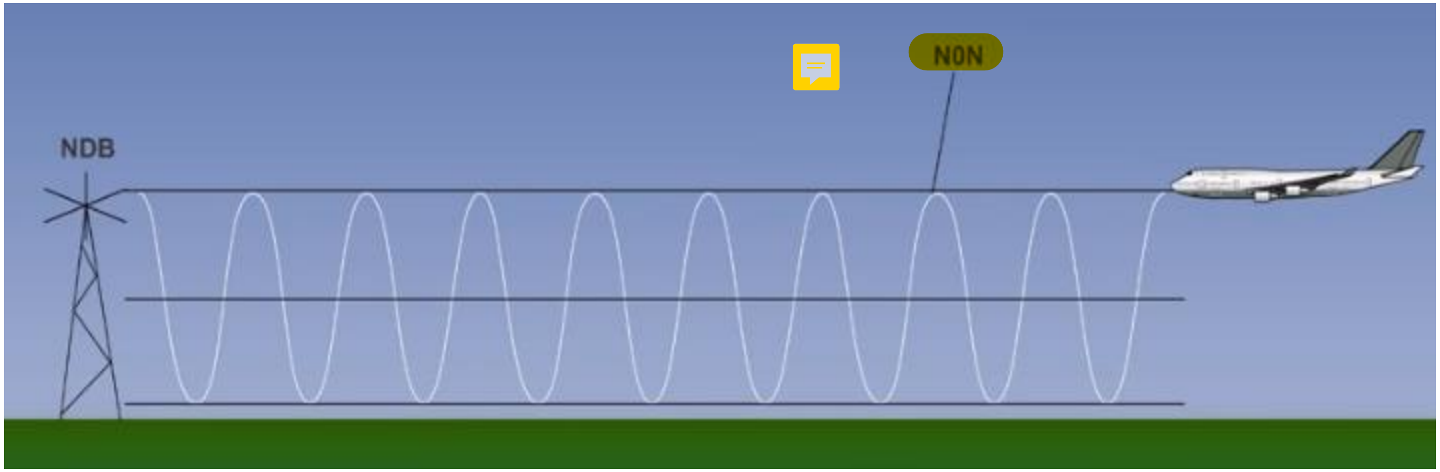
Propagation Theory-Modulation

If a radio wave is unmodulated it would simply be a radio wave to constant amplitude and frequency. This type of signal is ideal for Direction Finding Equipment such as the ADF (Automatic Direction Finder), its wave form would like the given figure. If the carrier wave were transmitted at the frequency in the audible range one would a hear continuous tone (long beep)



Propagation Theory-Modulation

Radio signals are designated according to their characteristics, the unmodulated carrier wave is designated n0n (n ‘zero’ n)



Propagation Theory-Modulation

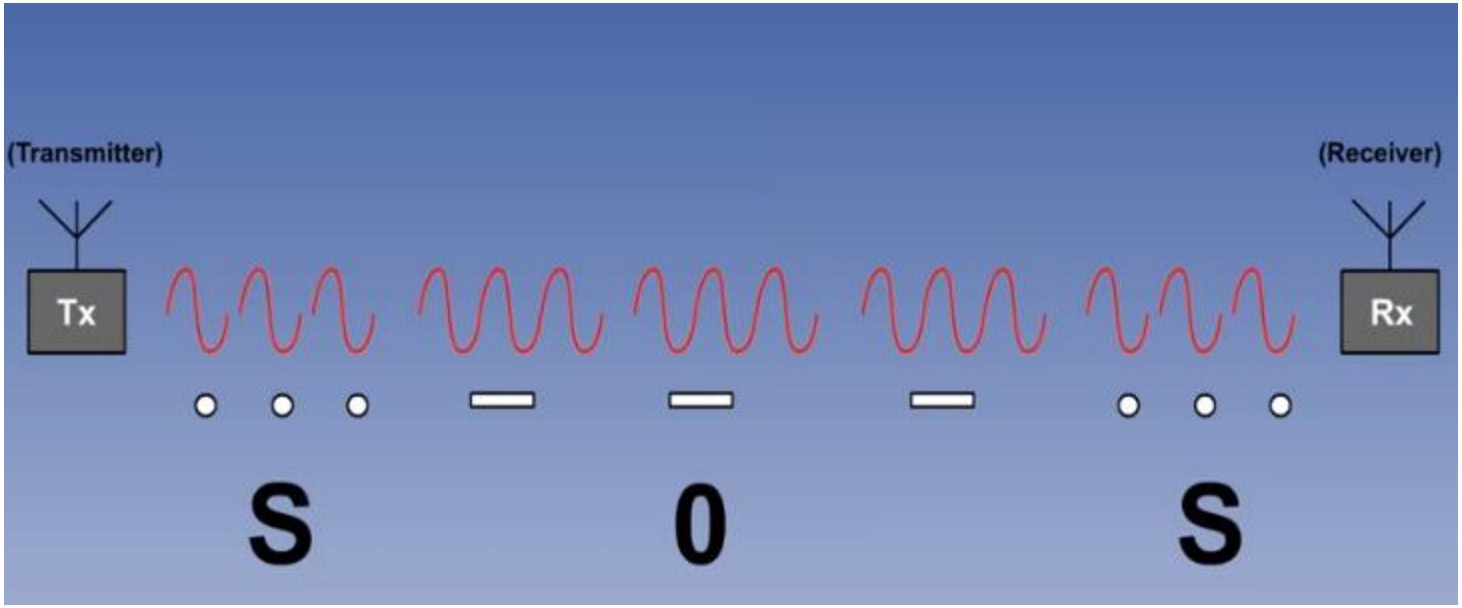
Radio Emission Characteristics.

https://en.wikipedia.org/wiki/Types_of_radio_emissions

EQUIPMENT	Code
ADF	N0N A1A or N0N A2A
VHF RTF	A3E
HF RTF	J3E
VOR	A9W
ILS	A8W
Marker Beacon	A2A
DME	P0N
ILS	N0XG1D

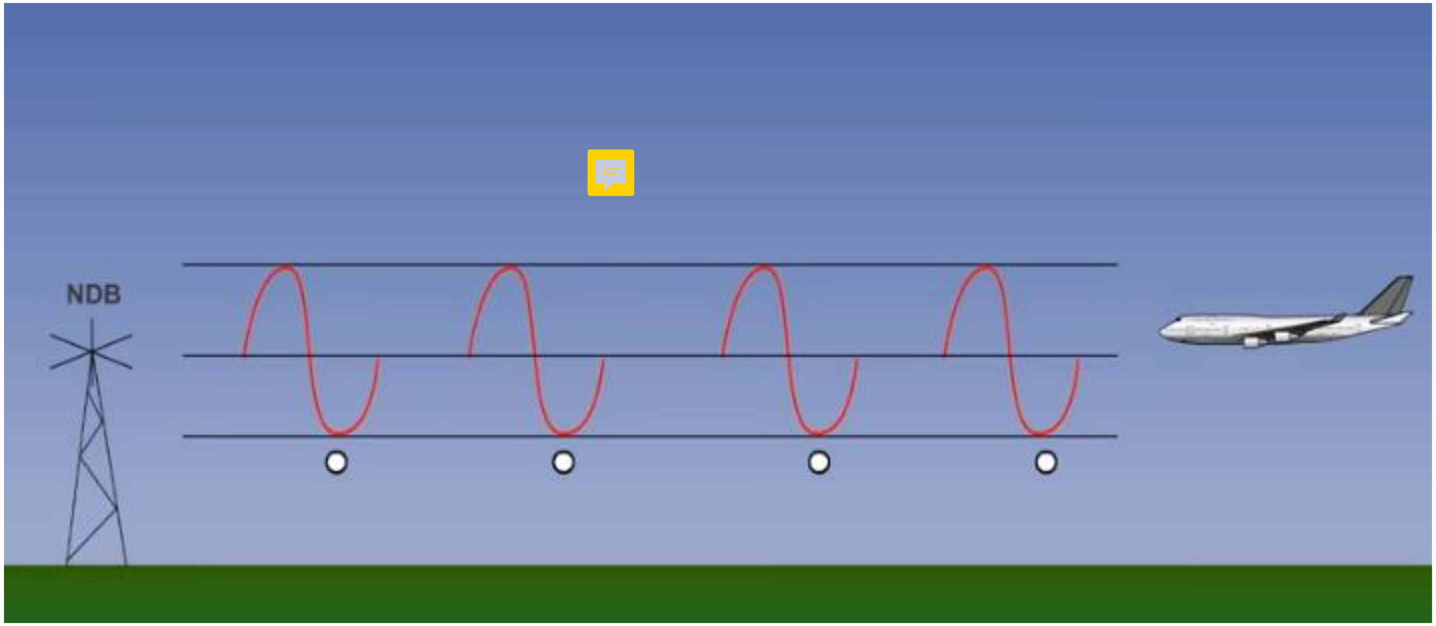
Propagation Theory-Modulation

The simplest form of modulation is to switch the electric current on and off, this is called **keying**, Moarse message can be sent this way.



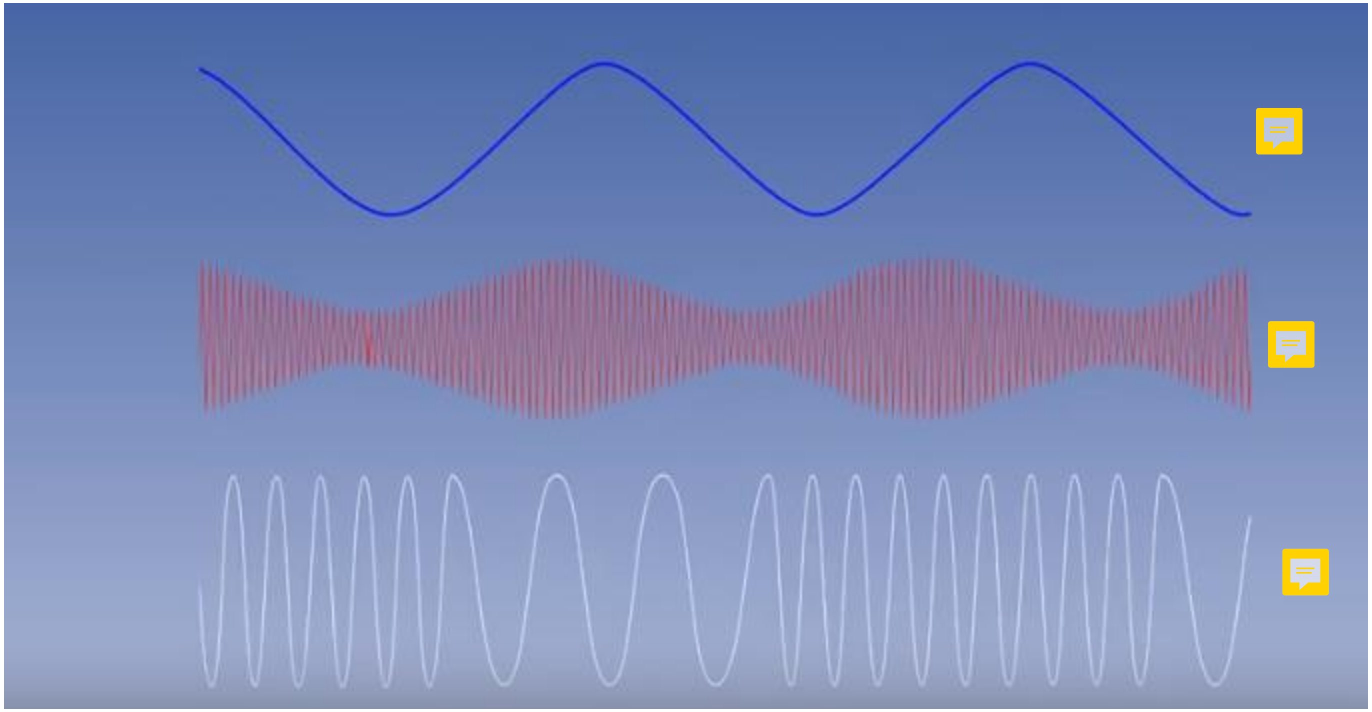
Propagation Theory-Modulation

Keyed carrier waves are designated A1A and they are used mostly for long distance NDBs as all of the transmitted power is in the carrier wave.



Propagation Theory-Modulation

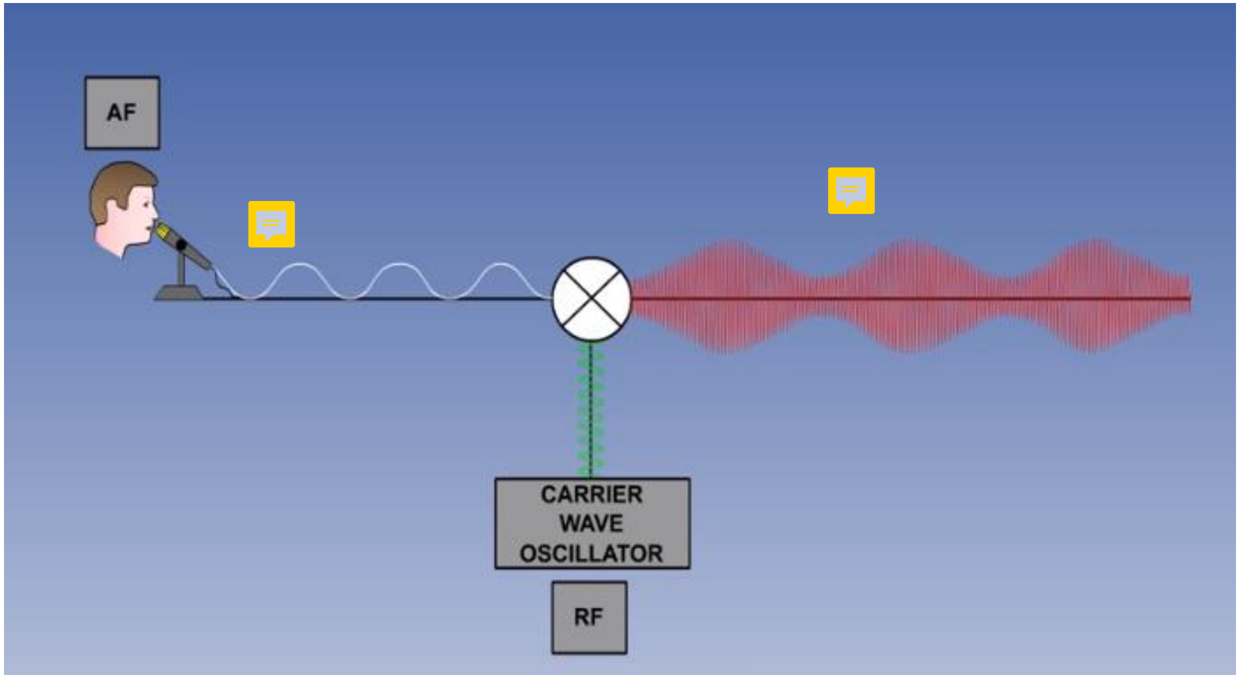
More sophisticated intelligence can be superimposed upon a carrier wave by modulating either the amplitude of the carrier wave (A.M) or modulating its frequency (F.M)



Propagation Theory-Modulation

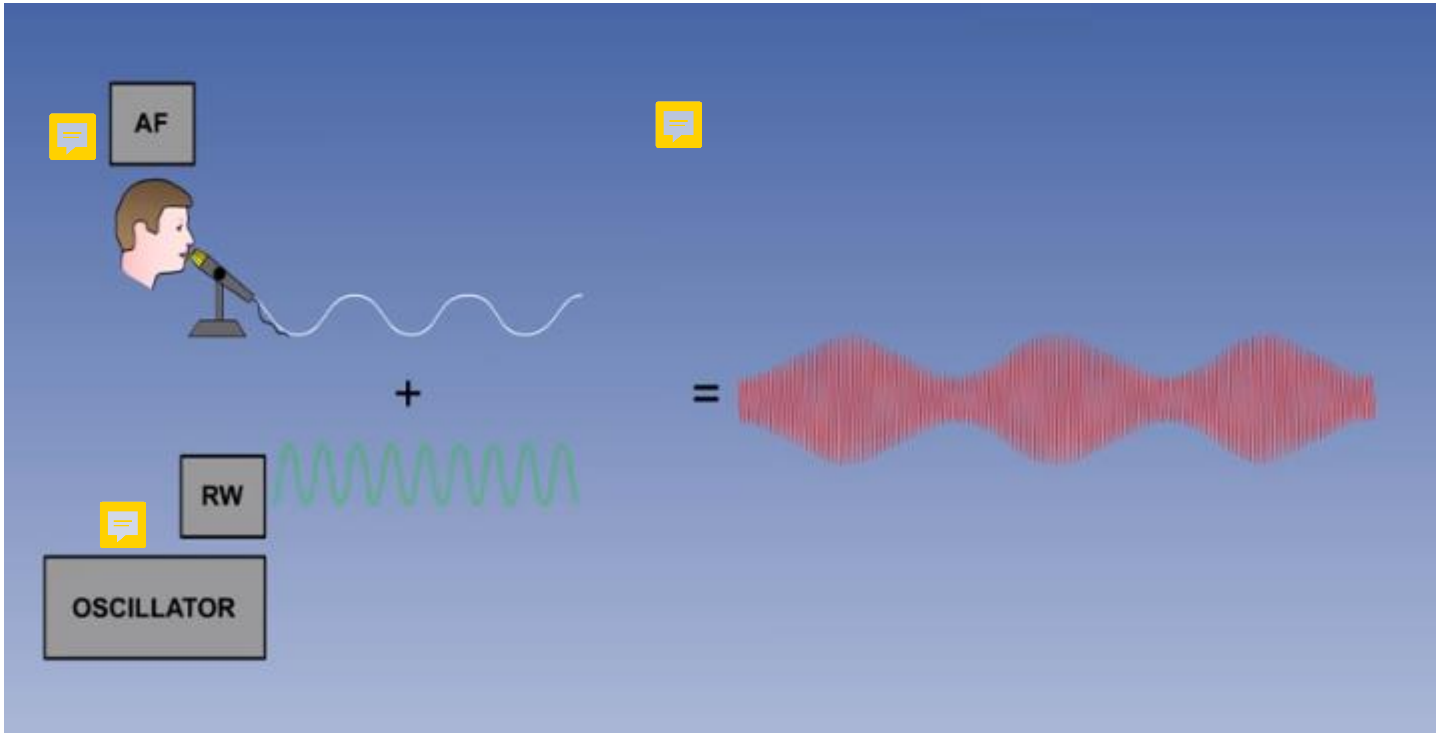
AM and FM are familiar, AM means Amplitude Modulated Radio and refers to the medium wave broadcast band 300 to 3000 KHz.

If an electromagnetic wave in the radio wave frequency bands is mixed with the lower frequency wave such as an audio frequency, the amplitude of the audio wave will modify the amplitude of the radio frequency, it does this by varying the strength of the transmitted radio current according to the pitch and loudness of the speech wave



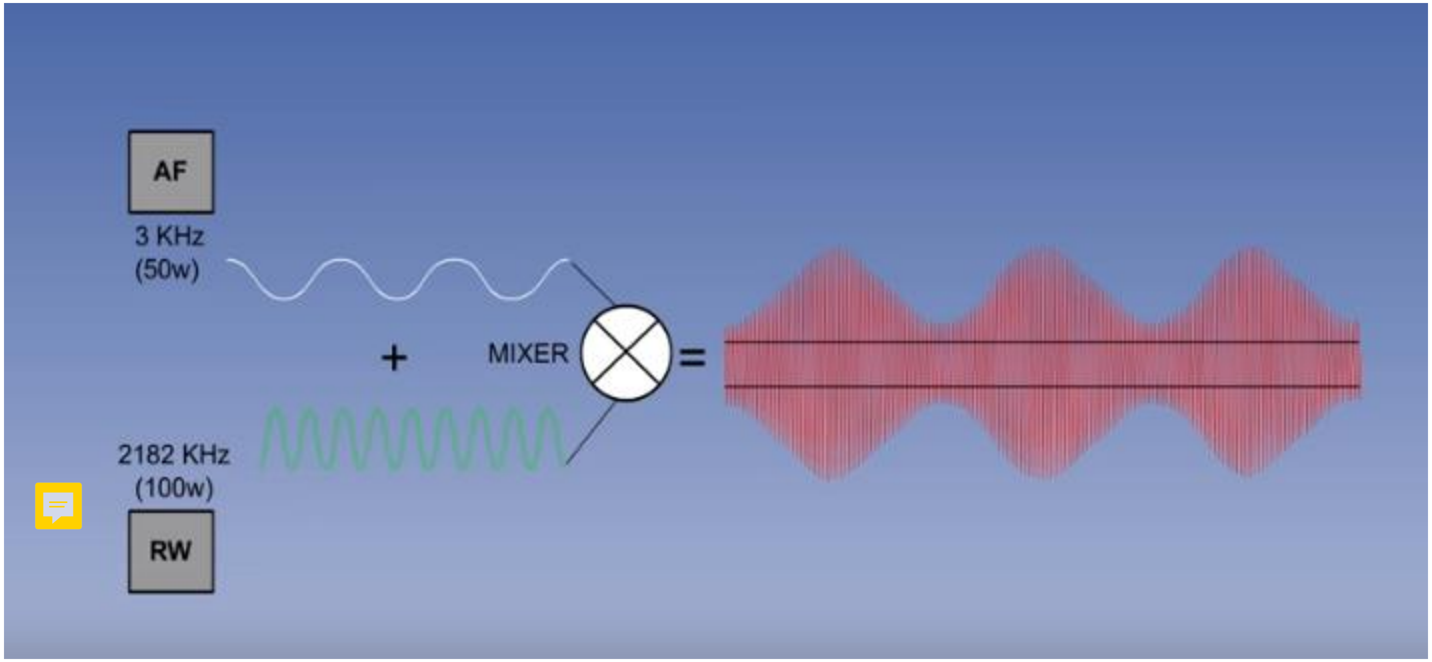
Propagation Theory-Modulation

The process of superimposing one sine wave upon another such as an audio frequency on a radio frequency is known as **heterodyne (Hetrodyning)**. The process combines the two frequencies, leaving the radio frequency unchanged for producing new frequencies of the sum and difference of the two frequencies.



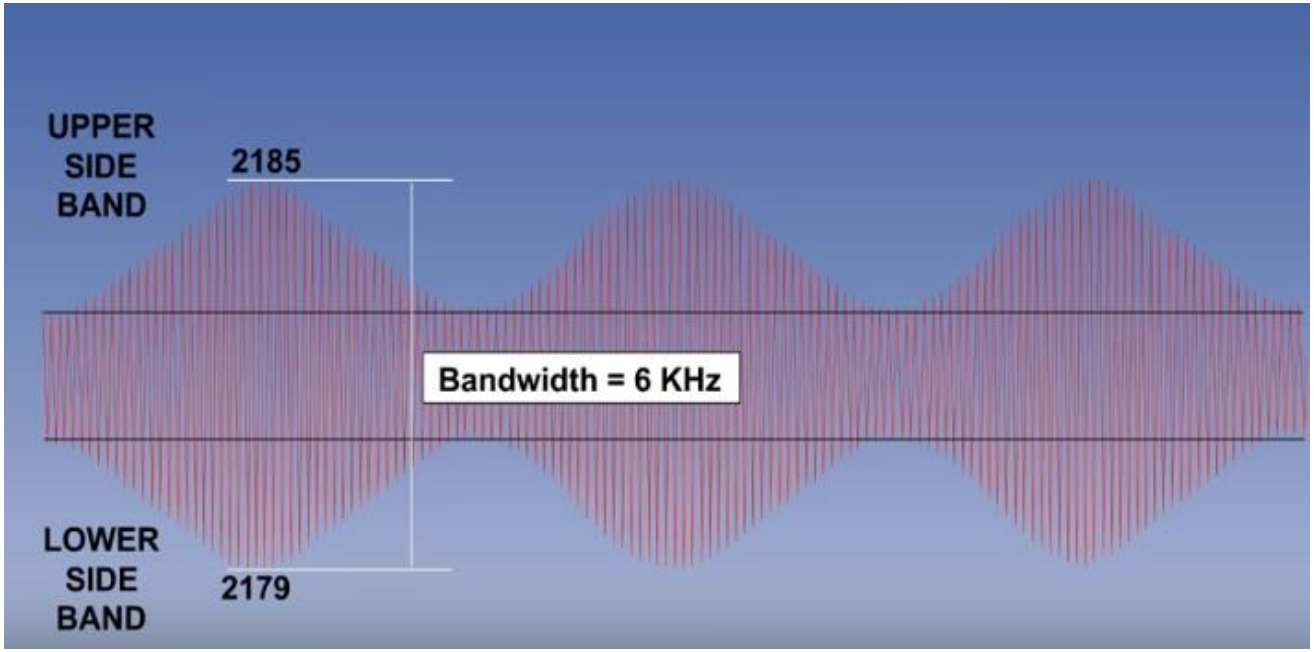
Propagation Theory-Modulation

For example; an audio frequency of 3 kilohertz and a low power of 50W is used to amplitude modulate a radio frequency of 2,182 KHz which has a high power of 100W. The radio frequency remains unchanged but the audio frequency is split into two side bands



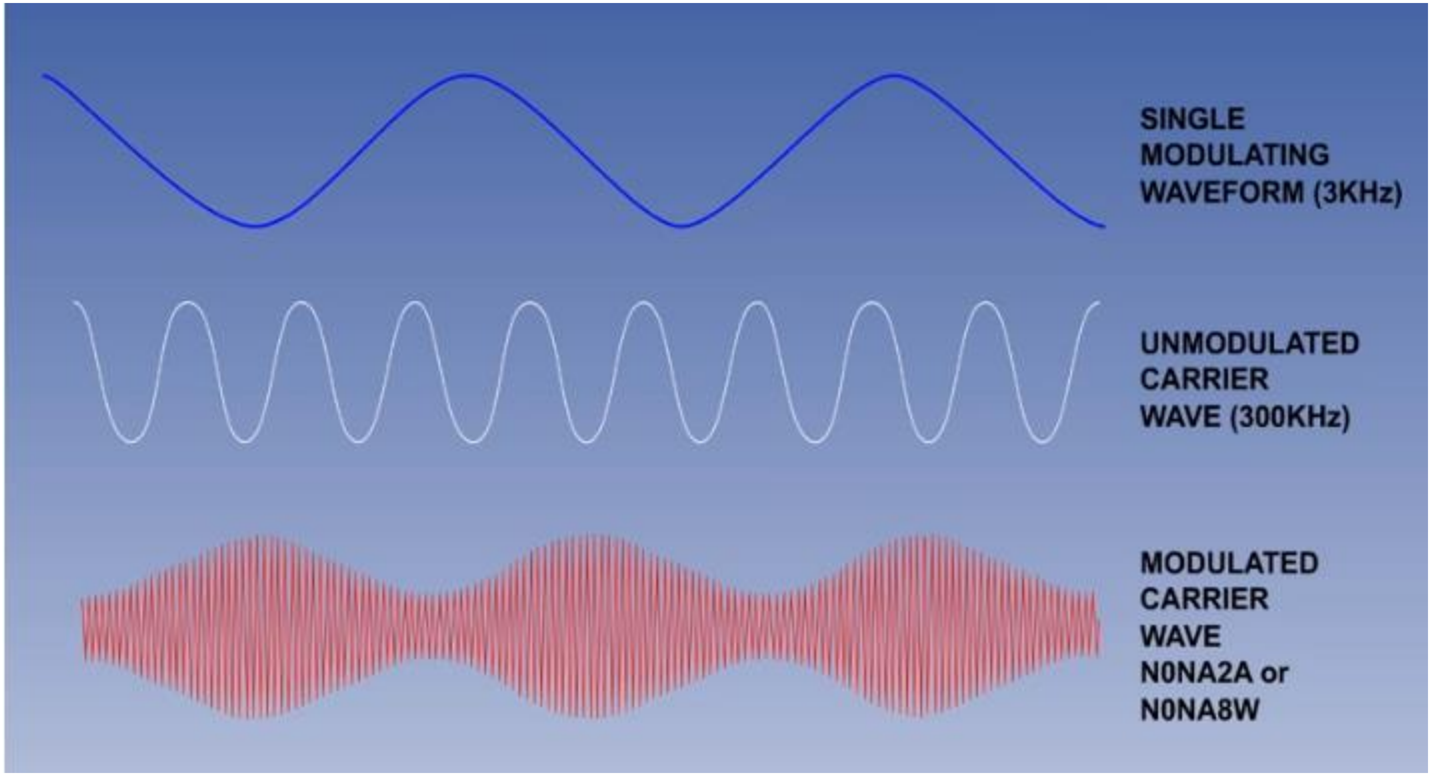
Propagation Theory-Modulation

One side band extends upwards from 2182.001 KHz to 2185 KHz (Upper Side Band). The other side band (Lower Side Band) extends downward from 2181.99 KHz to 2179 KHz. ~~The spread gives Bandwidth of 6 KHz which is double the audio frequency used.~~



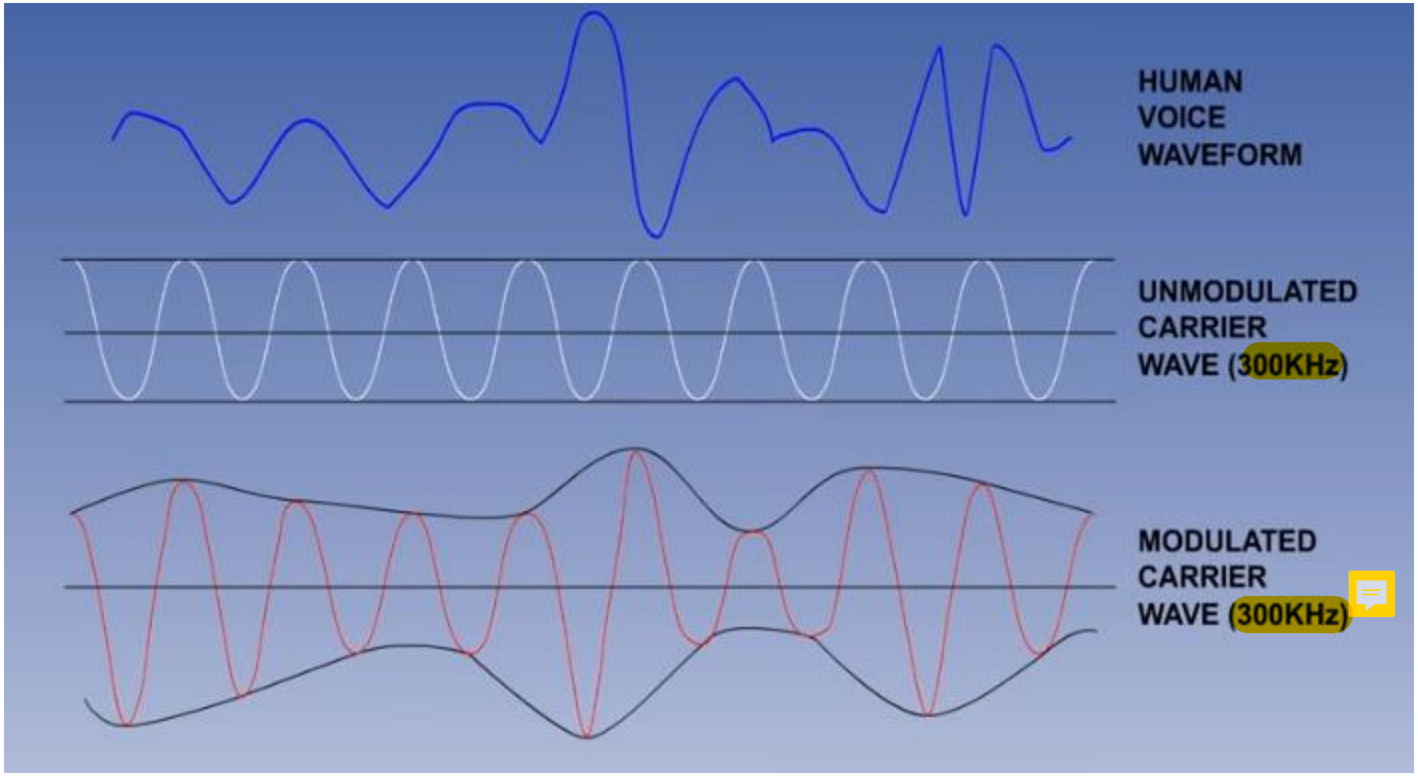
Propagation Theory-Modulation

Where the modulating waveform is constant in amplitude and frequency



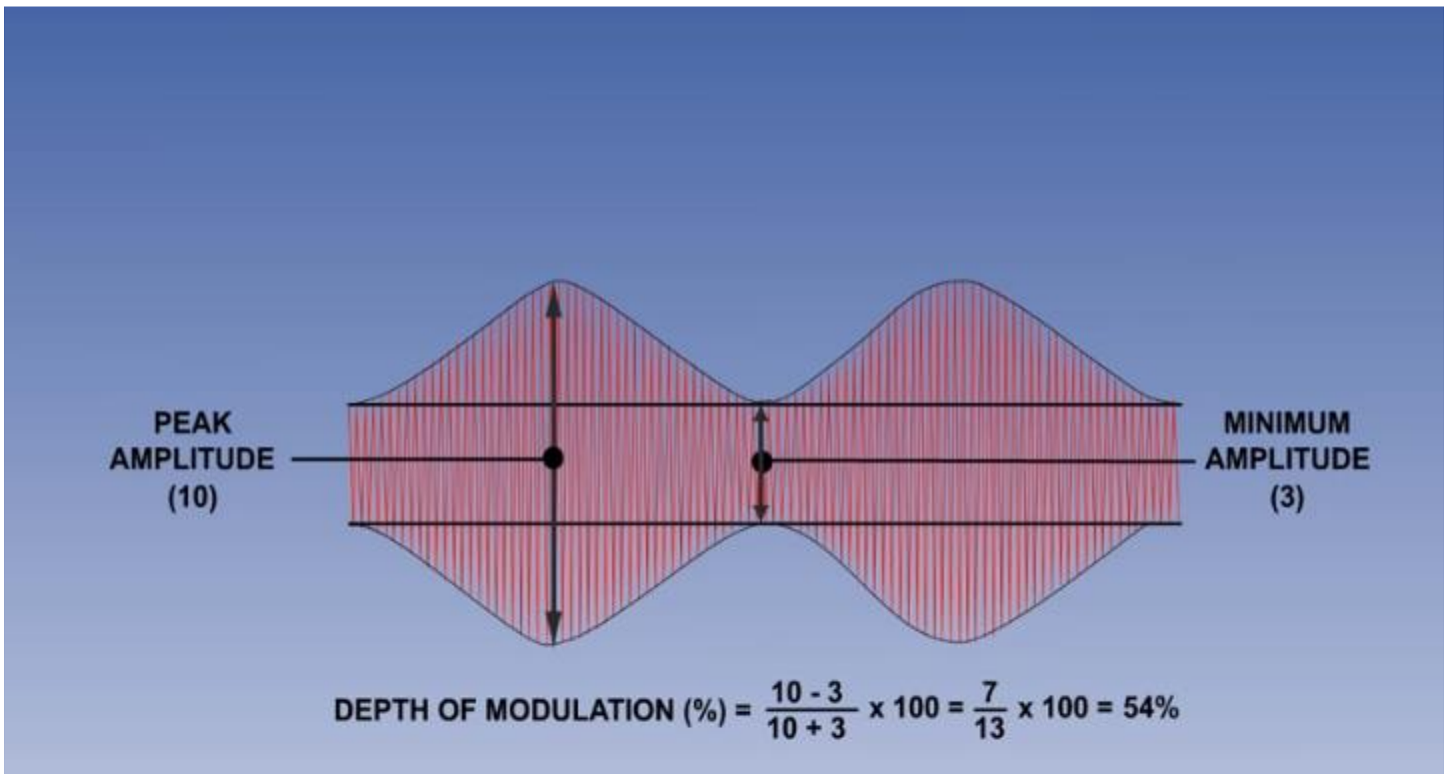
Propagation Theory-Modulation

Human voice however varies both in amplitude at its volume and frequency which is pitch , so the modulating waveform is complex and its effect on the carrier wave is shown here.



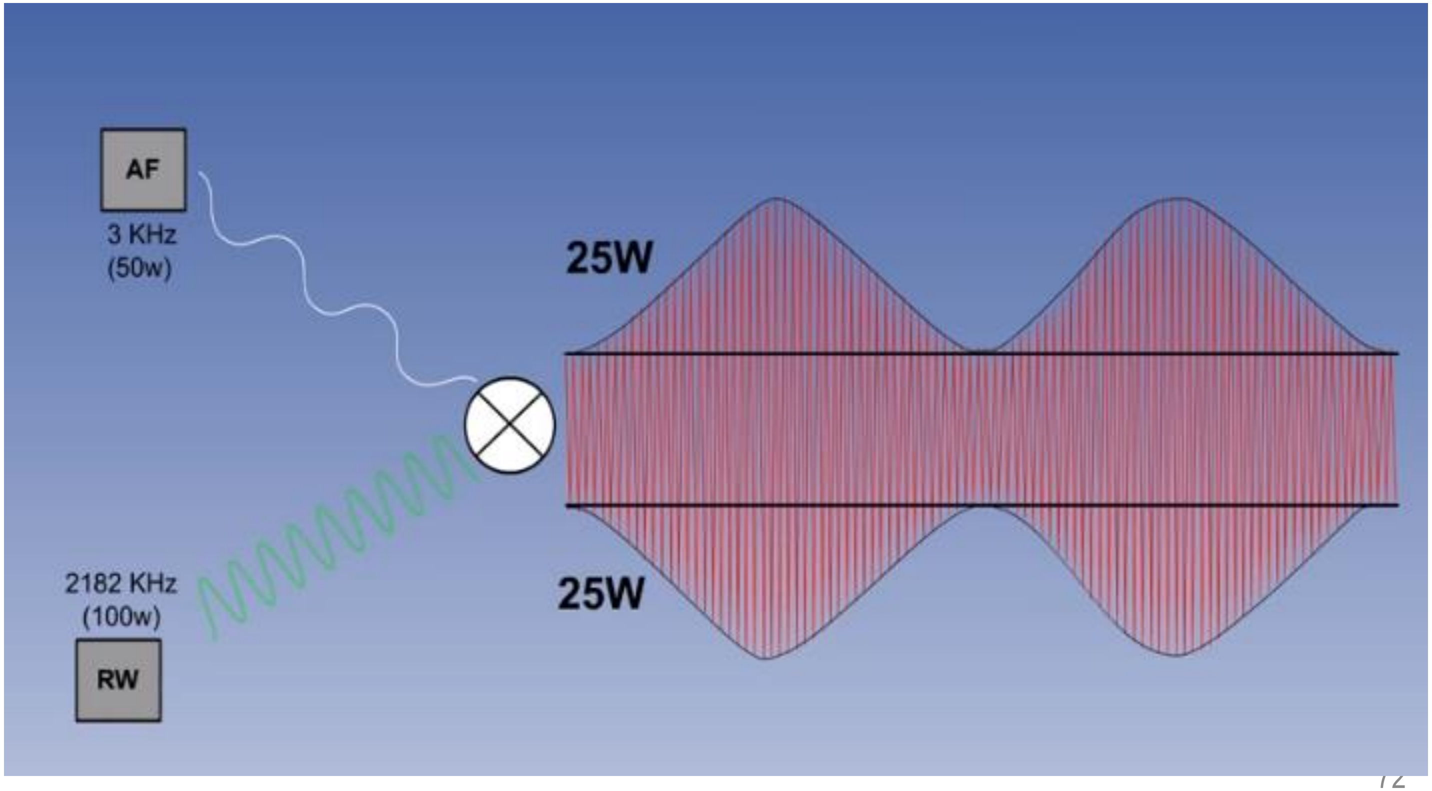
Propagation Theory-Modulation

The extent of modulation is given by



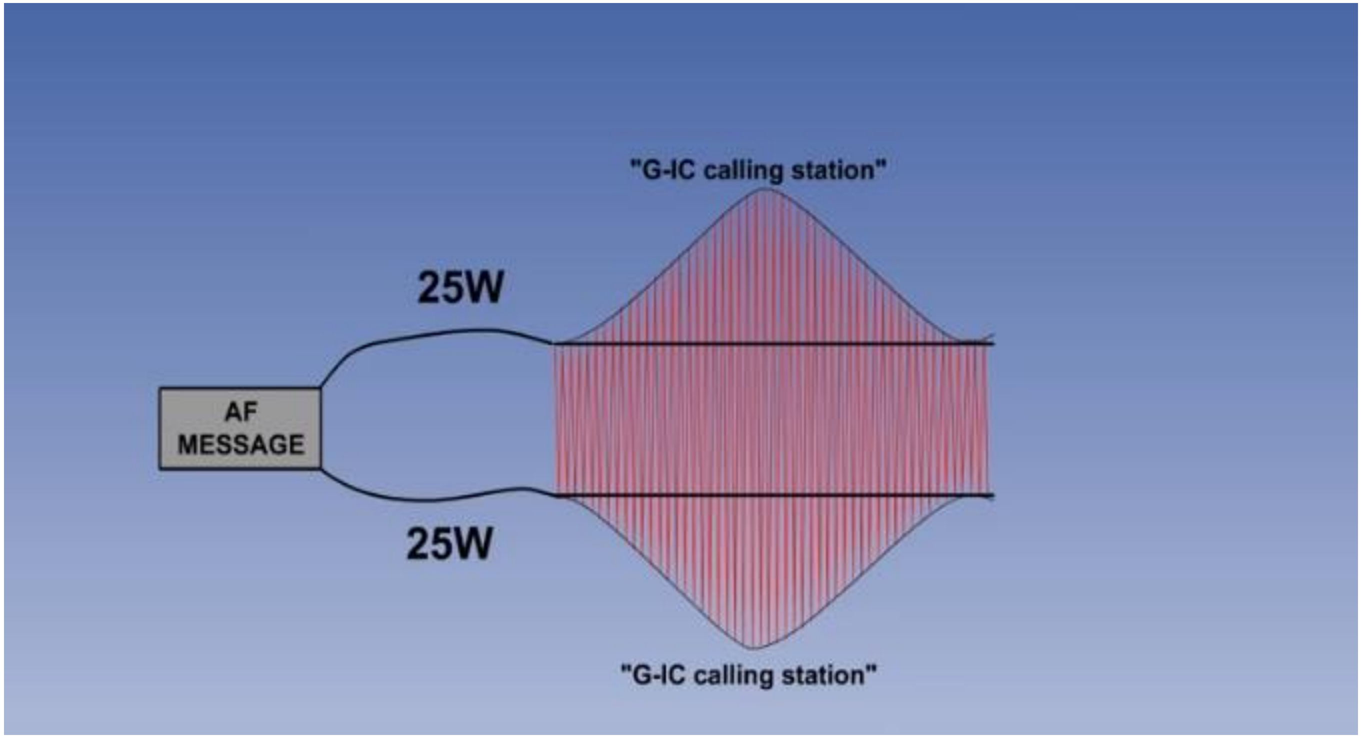
Propagation Theory-Modulation

If we look again at the way power of the audio wave from the power of the radio wave are distributed when they are mixed, we can see that the 50 watts of audio power is divided equally between the upper and lower side band. The power of the radio wave remains at 100 W



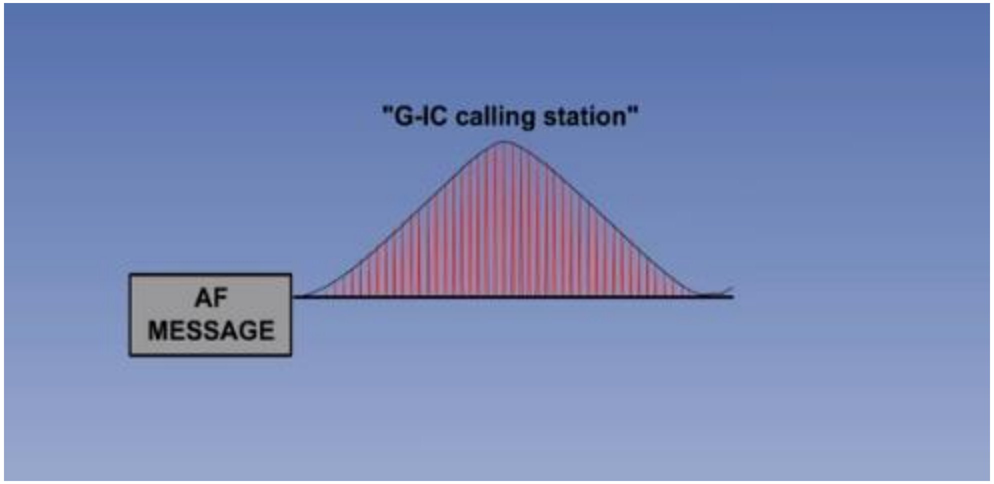
Propagation Theory-Modulation

The intelligence were laid on the modulating wave is the same in upper side band as it is in the lower side band therefore there is unwanted duplication.



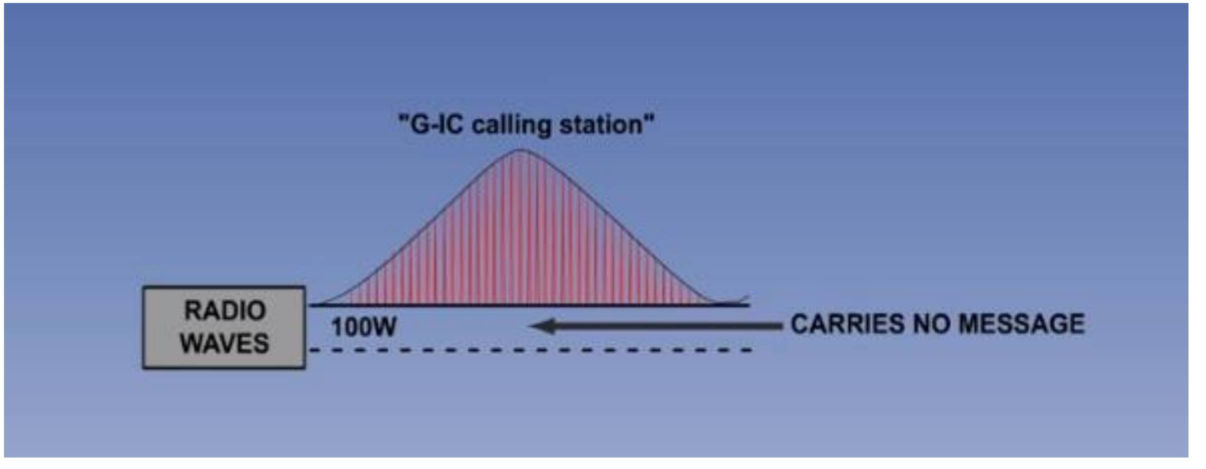
Propagation Theory-Modulation

It would be more energy efficient if one of these two sidebands could be deleted so that the energy were completely saved or applied to obtaining a greater range, it is usually the lower side band that is surpressed



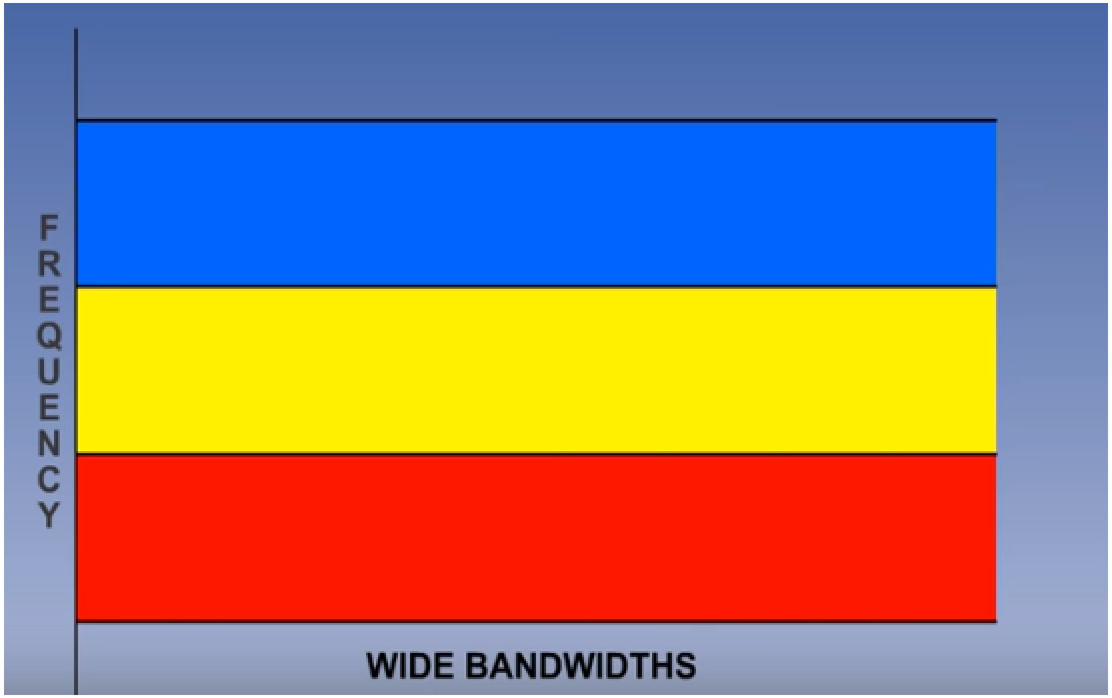
Propagation Theory-Modulation

Similarly, the radio wave having served the purpose to get the audio information into radio frequency is now redundant and should wither reduced or surpressed completely.



Propagation Theory-Modulation

In addition to the power saving, it is desirable to reduce the overall width of the transmission, because sky waves are liable to distortion in the ionosphere. The narrower the width, the lesser the distortion and the better the signal to noise ratio.



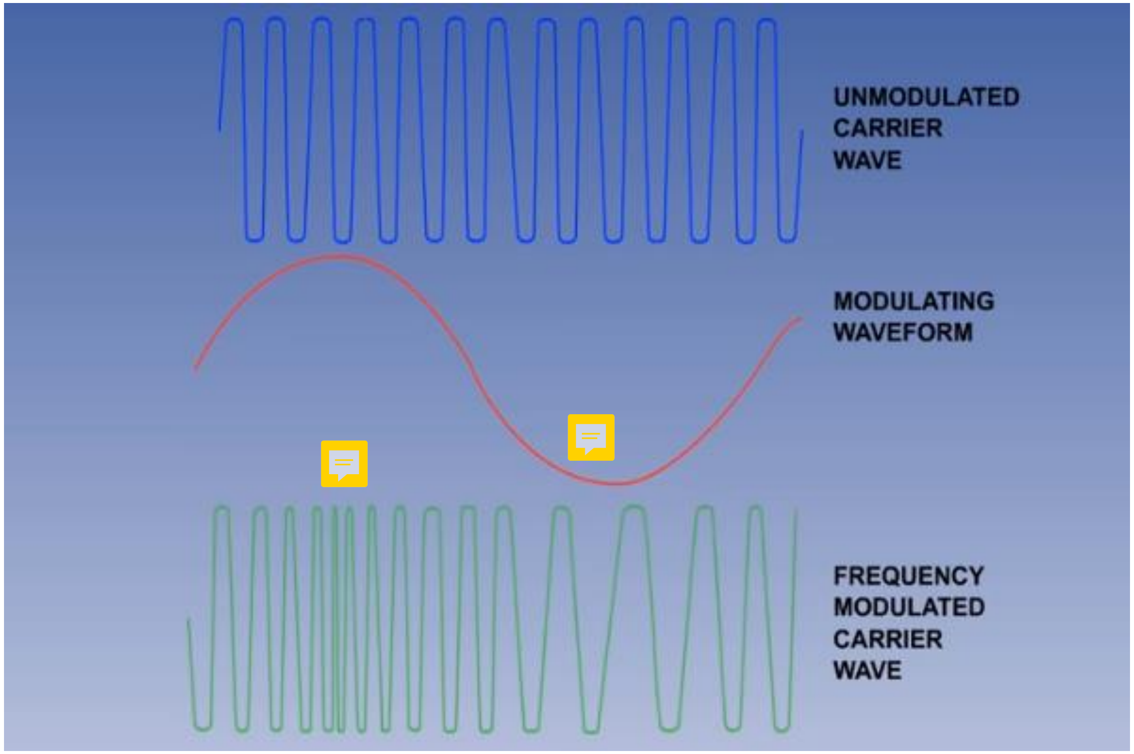
Propagation Theory-Modulation

When Pure FM techniques are employed the amplitude of the carrier wave remains constant.

This sine wave represents the information which is to be carried in other words the information to be modulated.

Propagation Theory-Modulation

This is achieved by making the frequency of the carrier wave vary in sympathy with the modulating waveform, so the peak of the modulating waveform is represented by an increased frequency of the carrier wave. The lower peak of the modulating waveform is represented by a low frequency of the carrier wave



Propagation Theory-Modulation

~~Advantages of FM~~

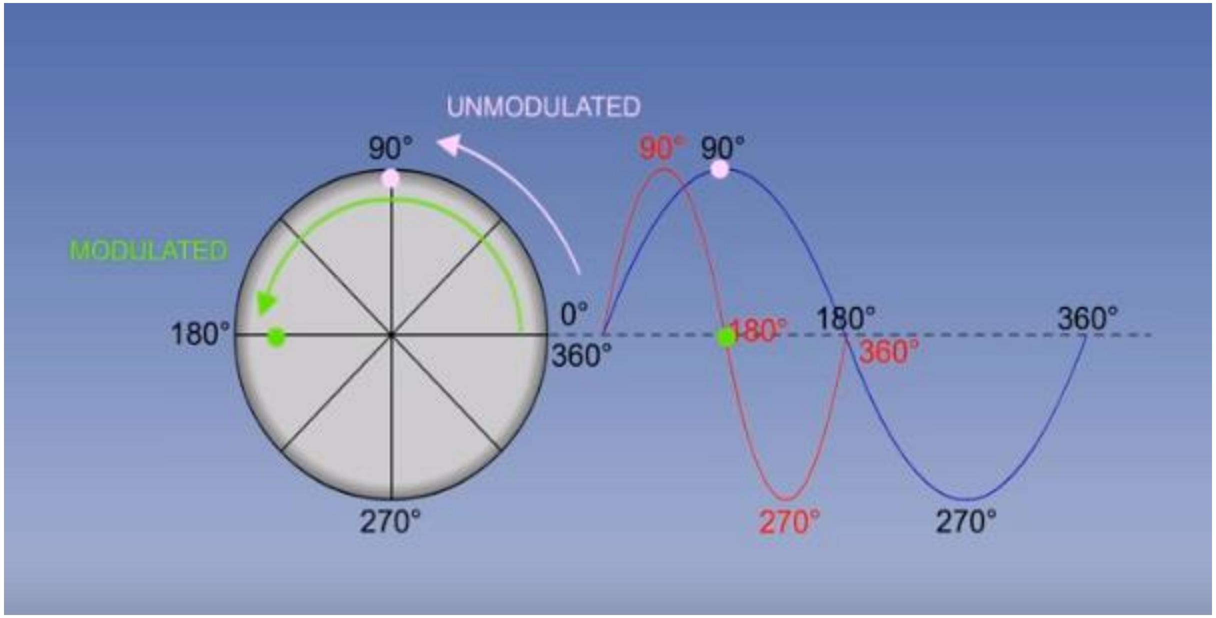
- ~~FM Transmitters are simpler than AM~~
- ~~The necessary modulating power is less than AM~~
- ~~FM reception is practically Static Free~~

~~Disadvantages of FM~~

- ~~FM receivers are more complex~~
- ~~A much wider bandwidth is required.~~

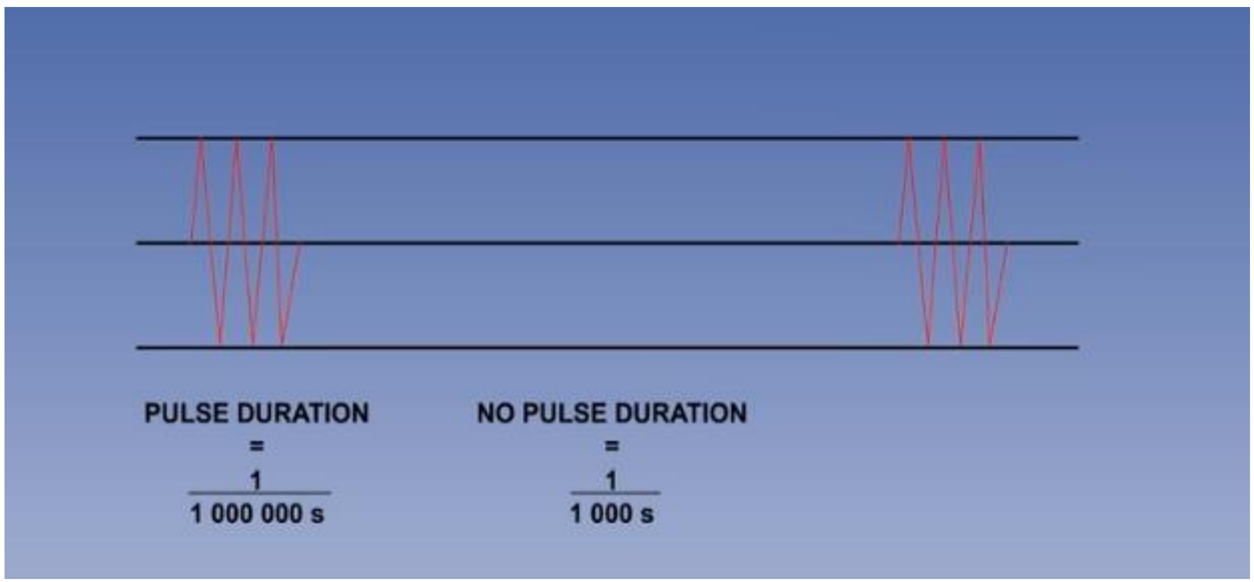
Propagation Theory-Modulation

Phase Modulation (Mainly used in MLS and GPS)



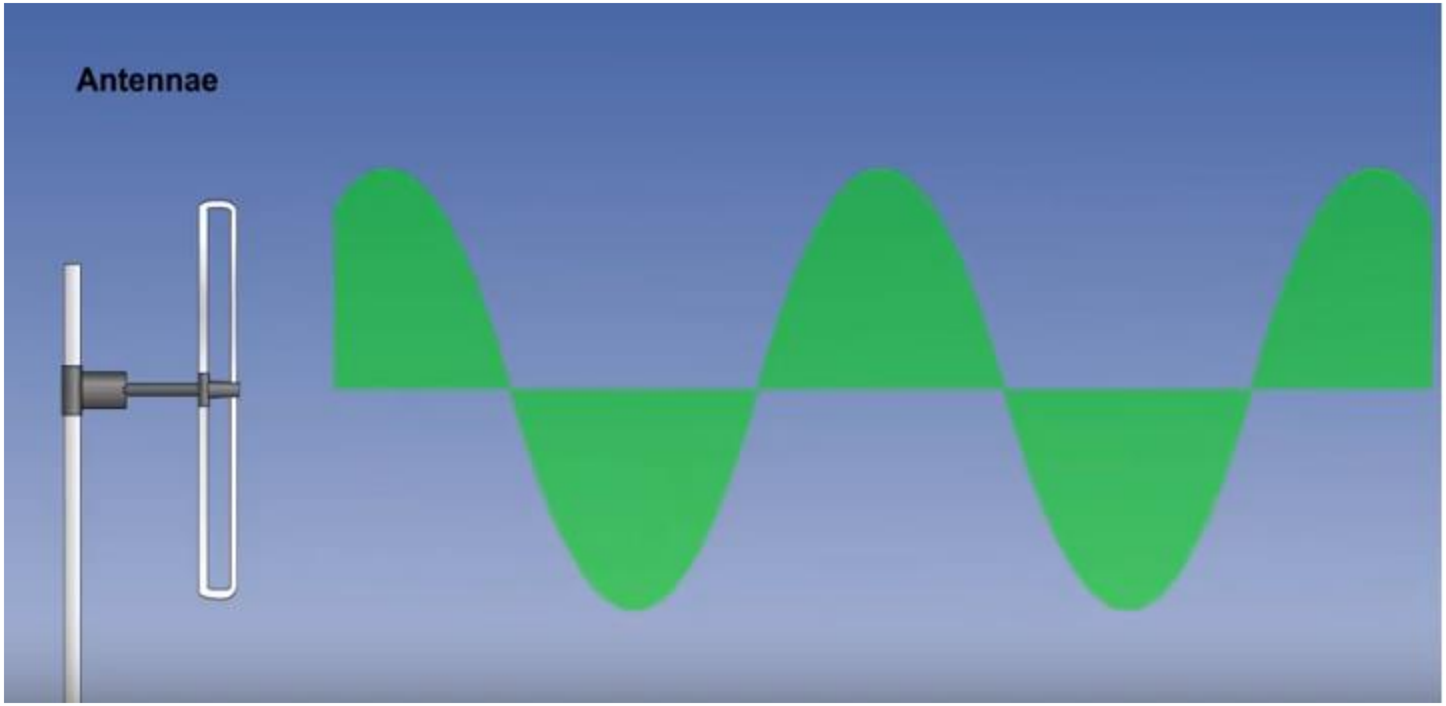
Propagation Theory-Modulation

Pulse Modulation (Radar and Data Link System)



Propagation Theory-Antennae

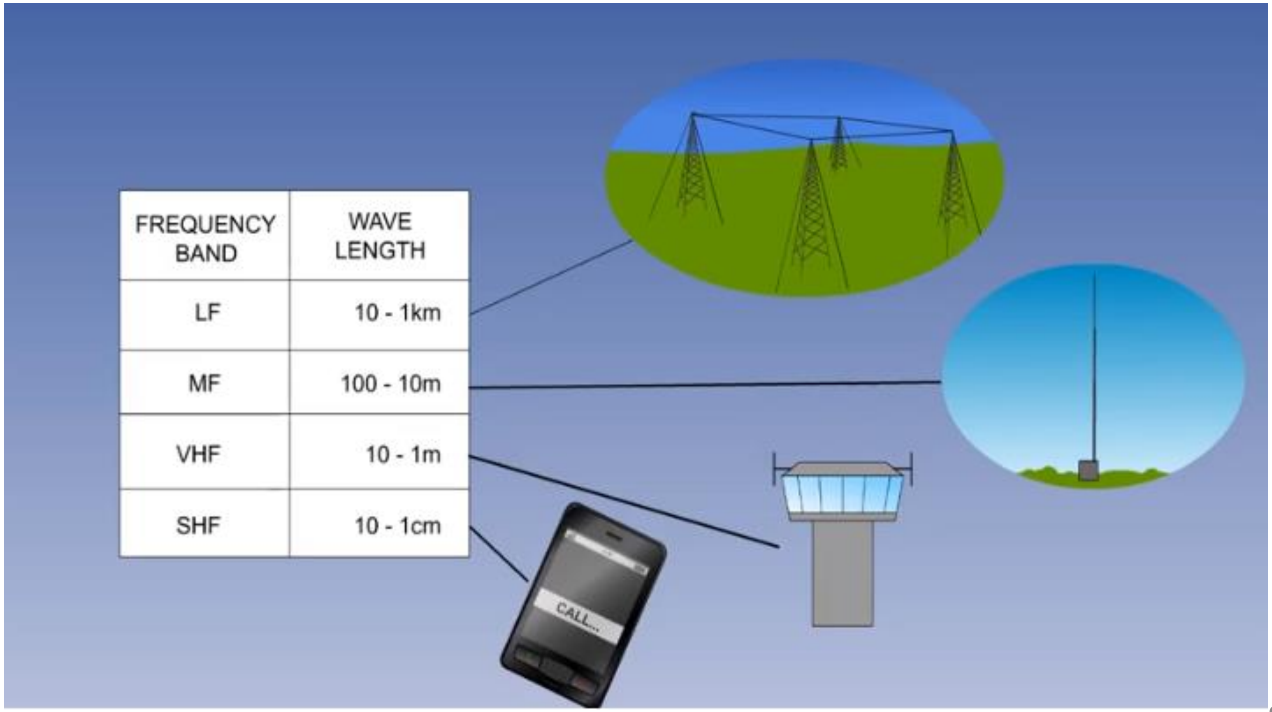
AC passed through a conductor produces EMW.



Propagation Theory-Antennae

Antenna Characteristics

- Size
- Shape
- Material

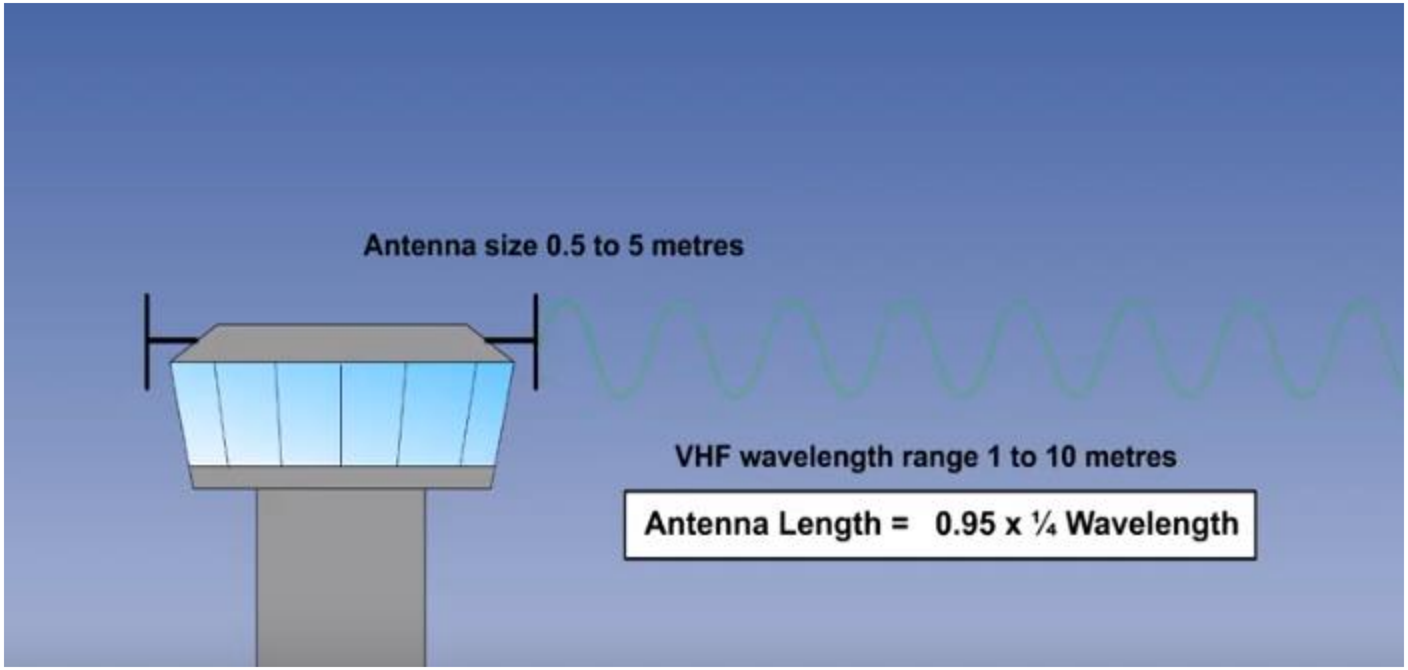


FREQUENCY BAND	WAVE LENGTH
LF	10 - 1km
MF	100 - 10m
VHF	10 - 1m
SHF	10 - 1cm

Propagation Theory-Antennae

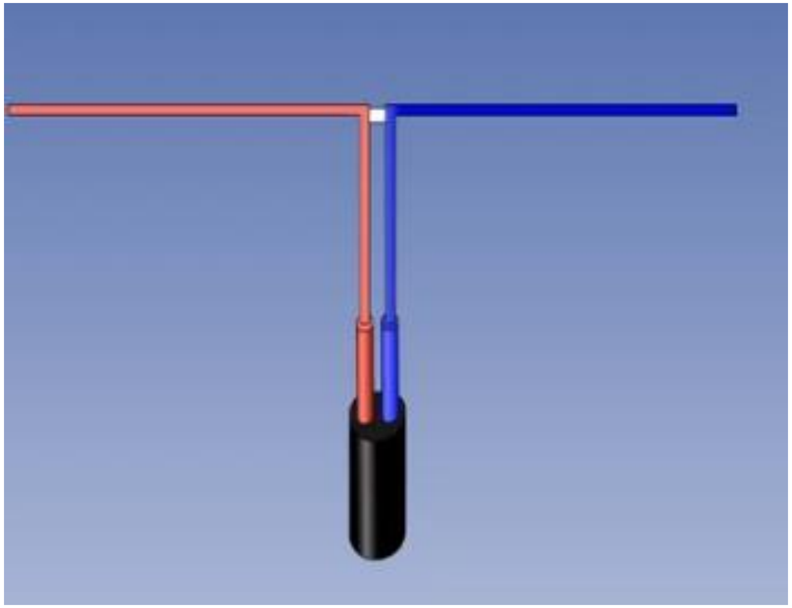
Antenna Characteristics

- Size
- Shape
- Material



Propagation Theory-Antennae

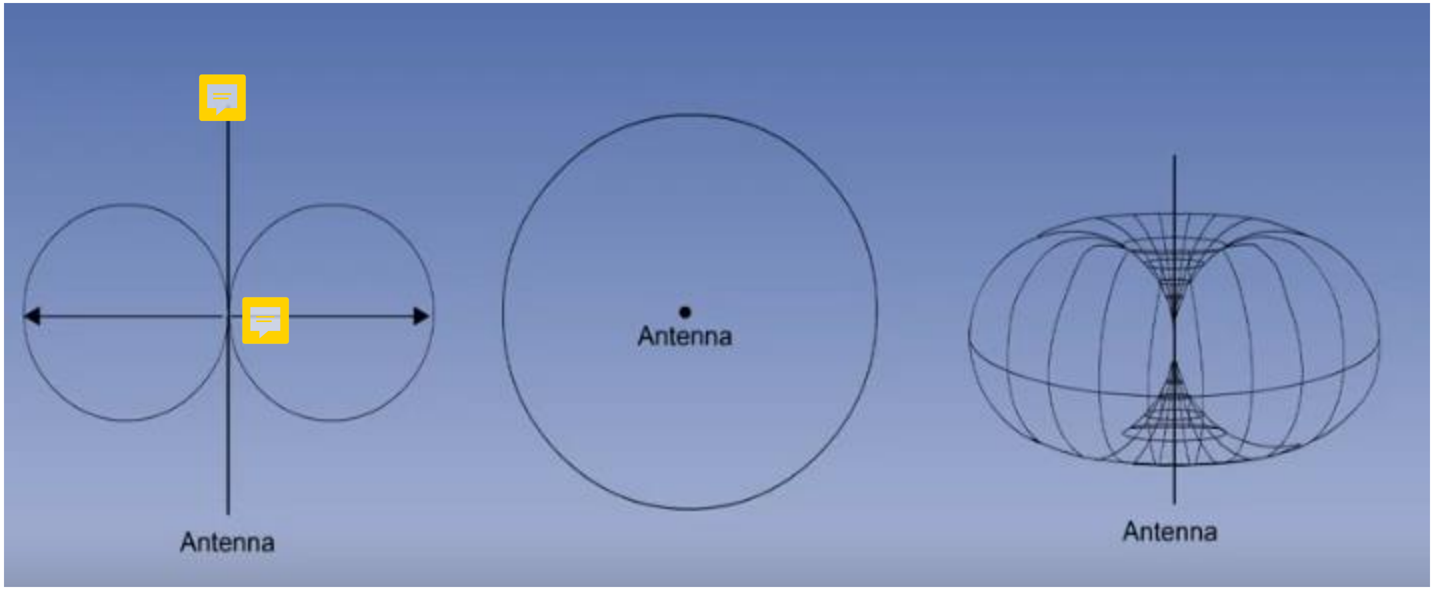
Half Wave Dipole (Ribbon Antenna)



Propagation Theory-Antennae

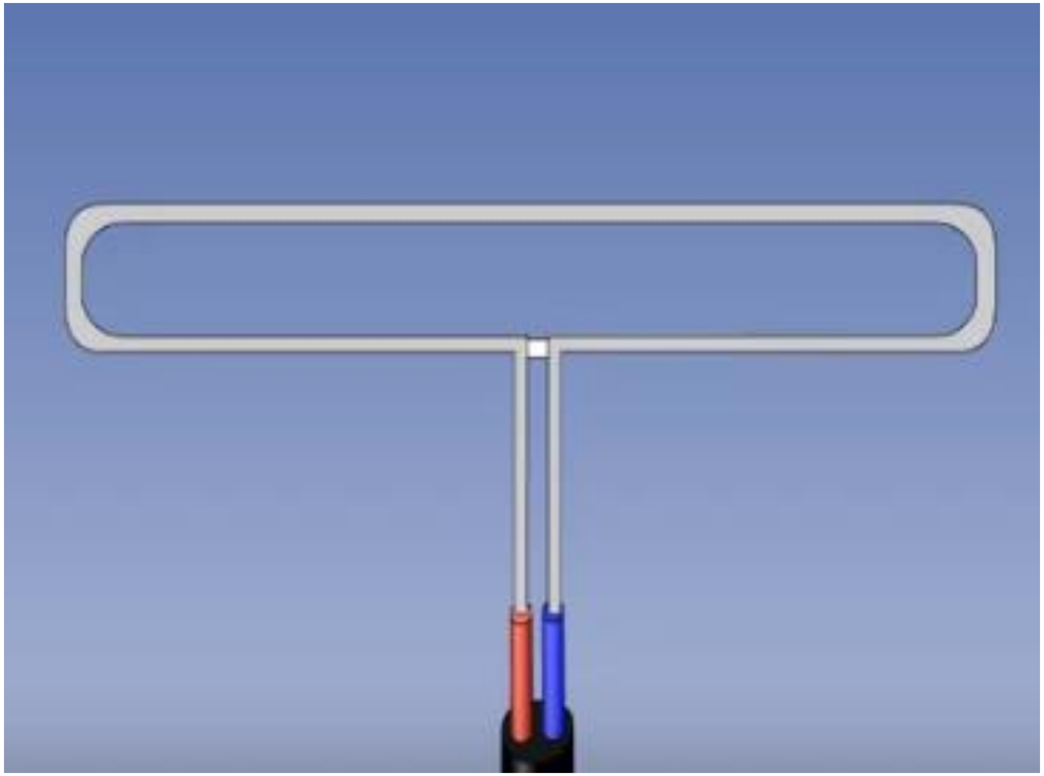
Half Wave Dipole Emission

- Greatest at right angles to center of the antenna and zero at the ends of the antenna
- The pattern or polar diagram is called toroidal



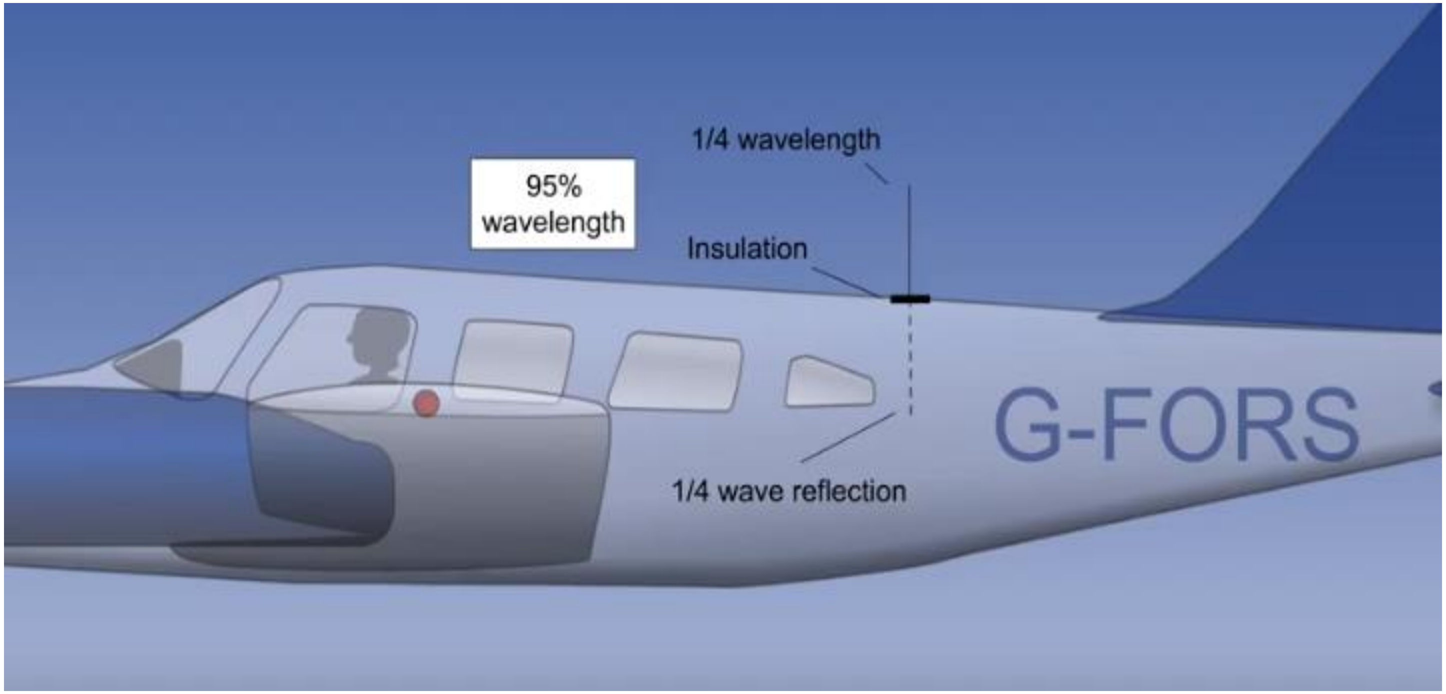
Propagation Theory-Antennae

Folded Half Wave Dipole Emission



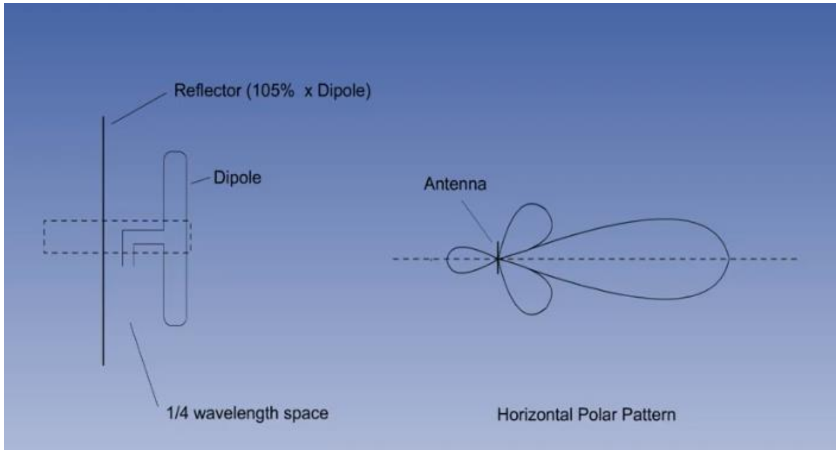
Propagation Theory-Antennae

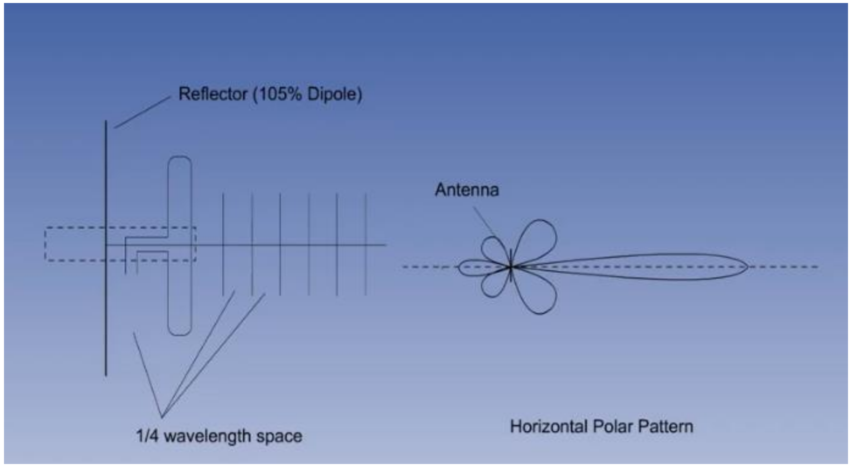
Marconi Antennae (Quarter Wave)



Propagation Theory-Antennae

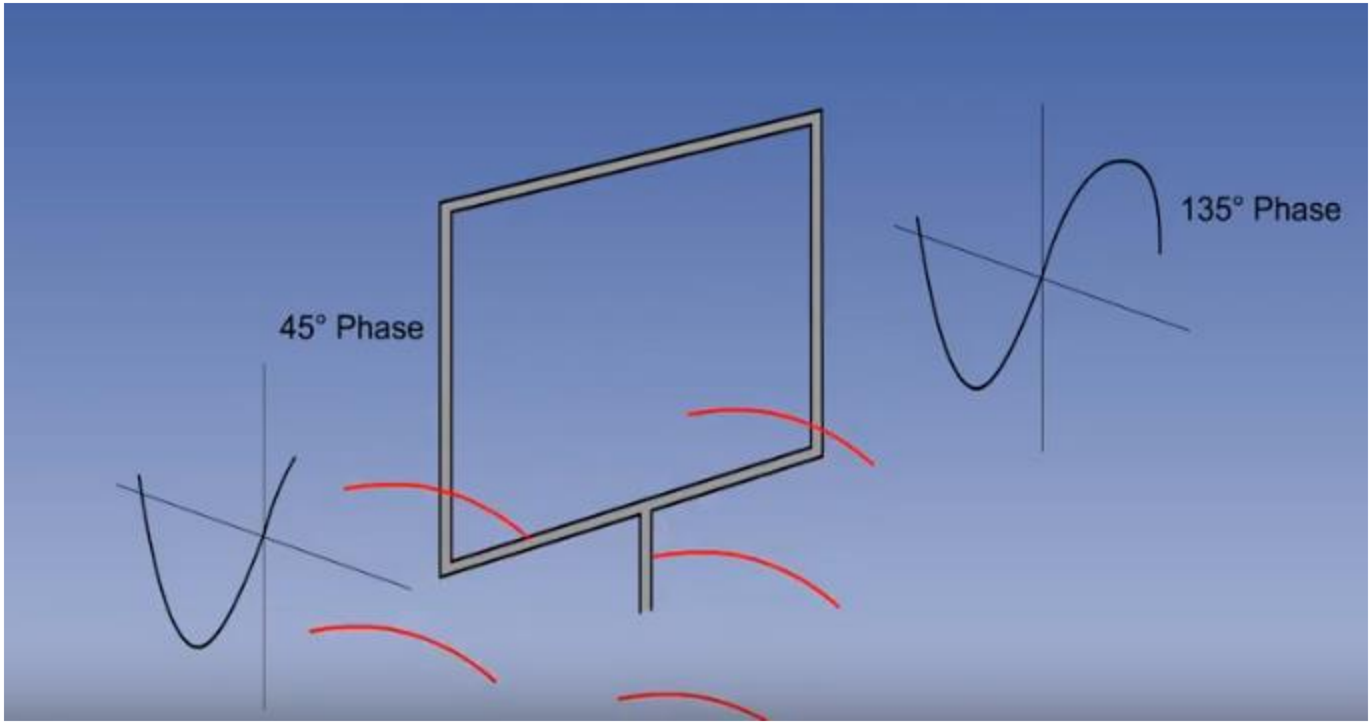
Reflector and Director (Mainly Used on ILS)





Propagation Theory-Antennae

Loop Antenna



Propagation Theory-Doppler

~~Self Read~~

VOR

A VOR system is made up of a ground component and an aircraft receiver component.

Aircraft Equipments Includes:

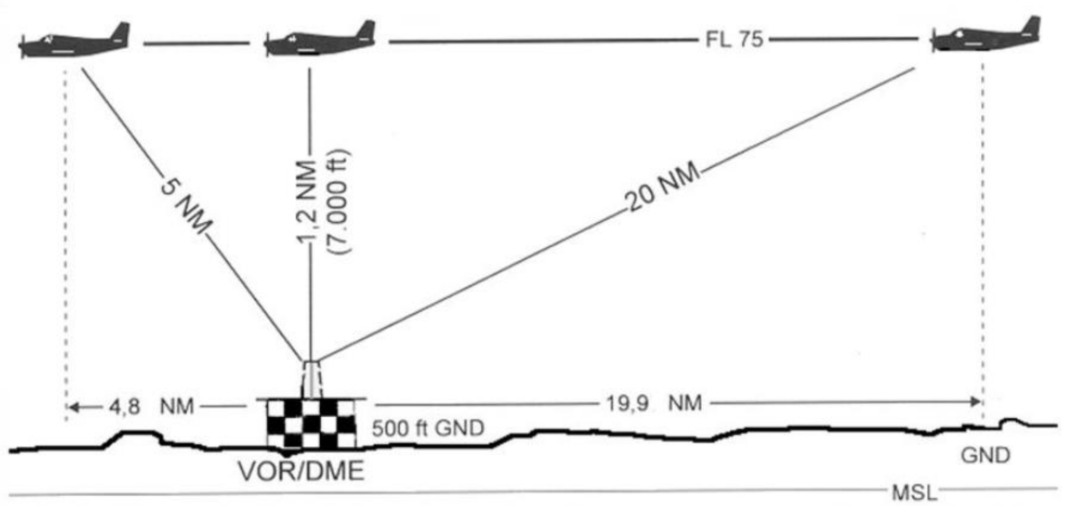
- VOR Antenna
- VOR Frequency Selector
- And Cockpit instruments

https://www.youtube.com/watch?v=1_JoKvaRf0g

https://www.youtube.com/watch?v=iCCk2ch-xL4

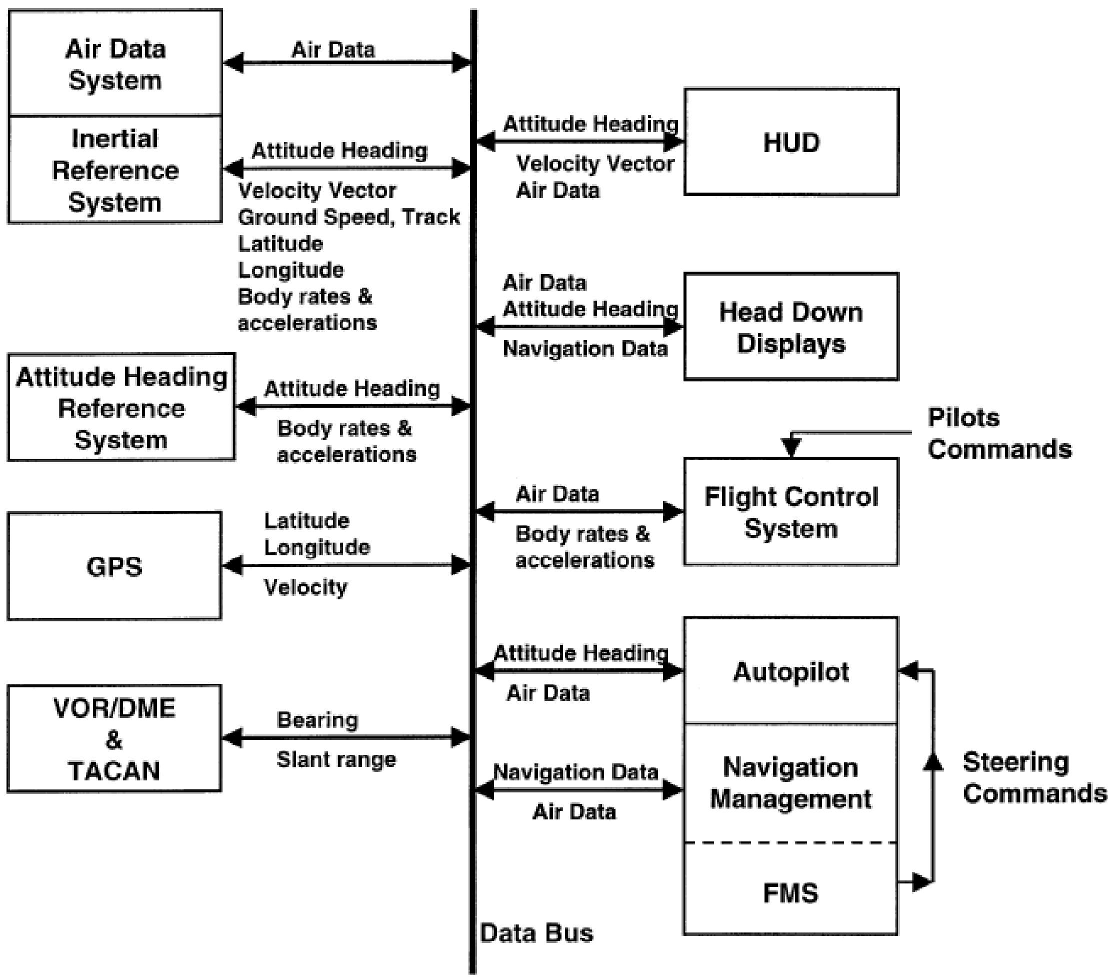
DME

- The aircraft receiver measure the time taken to transmit and receive the signal which is transmitted into distance.
- Beside that, the distance formula is also used by the DME receiver to calculate the distance from DME station in Nautical Miles.



http://slideplayer.com/slide/9749267/

1. Introduction



Navigation system information flow to user systems.

2. Inertial Navigation

- High accuracy.
- Self-contained.
- Autonomous – does not depend on other systems.
- Passive – does not radiate.
- Un-jamable.
- Does not require reference to the ground or outside world.
- Accurate velocity vector information together with an accurate vertical reference are essential for accurate weapon aiming and this has led to the INS being installed in military strike aircraft from the early 1960s onwards as a key element of the navigation/weapon aiming system.
- The self-contained characteristics of an inertial navigation system plus the ability to provide a very accurate attitude and heading reference led to the installation of IN systems in long range civil transport aircraft from the late 1960s.
- They are now very widely used in all types of civil aircraft.

3. Attitude Heading Reference Systems

- Modern Attitude Heading Reference Systems are strap-down systems exploiting solid state gyros and accelerometers and are basically similar to modern strap-down IN systems.
- The major differences are in the accuracy of the inertial sensors and their consequent cost. There is no significant difference in reliability between the two systems as both exploit solid state implementation.
- In the case of a Doppler velocity sensor, the Doppler and inertially derived velocities are compared along local NED (north east down) axes, as the Doppler is a key part of the navigation system.
- In the case of lower accuracy AHRS systems, the comparison of the air data and inertial velocity components is generally made along the aircraft body axes.

3. Attitude Heading Reference Systems

- The mechanization of an air data/inertial velocity mixing system to monitor the vertical reference of a strap-down AHRS is described below to show:
- The use of air data derived velocity as opposed to Doppler.
- The use of aircraft body axes as a reference frame of axes.
- The application to a lower accuracy AHRS with lower cost gyros in the few degrees/hour bias uncertainty performance bracket.