RADIO AMATEUR EXAM
GENERAL CLASS

By **4S7VJ**

CHAPTER-6

TRANSMISSION LINES AND ANTENNAS

6.1 Transmission line

There are three separate parts are involved in an antenna system;

1. The radiator (antenna)
2. Transmission line (Feed line)
3. Coupling arrangement (antenna tuner)

The place where RF power is generated is very frequently not the place where it is to be utilized. The antenna to radiate well, should be high above the ground and should be keep clear of trees and other obstacles that might absorb energy, but the transmitter itself is most conveniently installed indoor where it is readily accessible. The transmission line used to connect the antenna to the TX or Rx with a minimum of loss due to resistance or radiation. By the use of transmission lines or feeders, the power of the TX can be carried appreciable distance without much loss due to conductor resistance, insulator losses or radiation.

Types of Transmission line

There are three main types of transmission lines.

(1) The **single wire feed** arranged so that there is a true traveling wave on it.

(2) The **parallel wire line** with two conductors carrying equal but oppositely directed current and voltages, is balanced with respect to earth.

(3) The **coaxial** or concentric line in which the outer conductor enclosed the inner conductor.

6.1.1 Single wire feeder

Single wire feeders are inefficient and now seldom used since it is impossible to prevent them acting to some extent as radiators, and the return path which is via the ground, introduced further losses. The feeder wire itself also acting as the antenna.

6.1.2 **Parallel wire line**

This is called as a balanced line or open wire line. There are two types, two open parallel wires separated by insulating spreaders, and the other type is twin-lead, in which the wires are embedded in solid formed insulation. The field is confined to the immediate vicinity of the conductor and there is negligible radiation (losses), if proper precautions are taken. Line losses results from Ohmic resistance, radiation from the line and deficiencies in the insulation. Large conductors, closely spaced in terms of wavelength, and using a minimum of insulation, make the best balanced line. Balanced lines are best in straight runs. If bends are unavoidable, the angle should be as obtuse (between 90° and 180°) as possible. Care should be prevent one wire from coming closer to metal object than the other. Wire spacing should be less than 1/20 of wavelength.

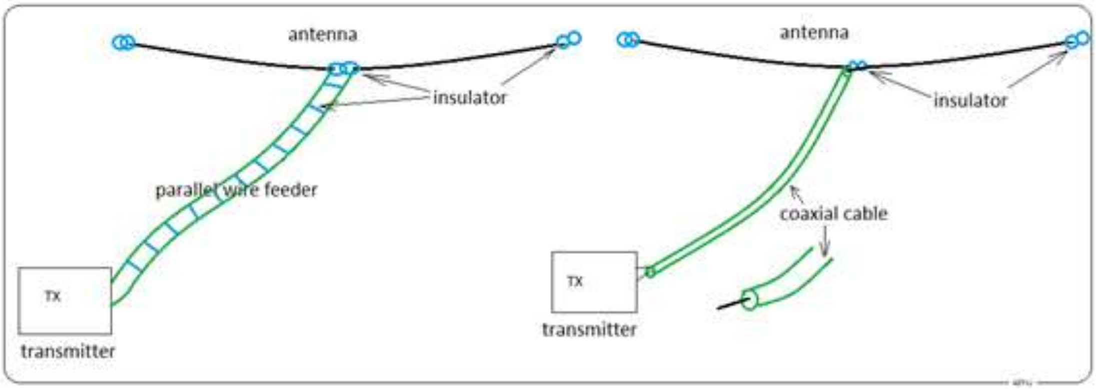

Fig-6.1

Properly build open-wire line can operate with very low loss in VHF and even UHF installations. A total line loss under 2dB per 100ft at 432MHz is readily obtained. A similar 144MHz setup (2 meter band) could have a line loss under 1dB per 100ft.

6.1.3 **Coaxial line**

Coaxial or concentric line made out of two cylindrical conductors having a common axis. The space between two conductors is filled with an insulating material; may be a solid or air. In the coaxial line the current passes along the center conductor and returns along the inside of the sheath or braid. Due to skin effect at high frequencies the current do not penetrate more than a few micro meters into the metal; hence with any practical thickness of the sheath there is no current on the outside. The fields are thus held inside the cable and cannot radiate.

6.1.4 Characteristic Impedance of a transmission line

If the transmission line were infinitely long and free from losses a signal applied to the input end would travel on for ever, energy being drawn away from the source of signal just as if a resistance had been connected instead of the infinite line. This resistance is known as the **Characteristic Impedance** of the line and usually denoted by the symbol "Zo". If we replace the line with pure resistance of Zo the generator will not be aware of any change. There is still no reflection, all the power applied to the input end of the line is absorbed in the terminating resistance, and the line is said to be matched.

A transmission line can be considered as a long ladder network of series inductances and shunt capacitances, corresponding to the inductance of the wires and the capacitance between them. It differs from conventional L-C circuits in that these properties are uniformly distributed along the line. If the inductance and capacitance for **any particular length** are L and C then the characteristic impedance Zo given by:

$$Zo = \sqrt{(L/C)} \quad \text{Ohms}$$

(If "L" in Henrys and "C" in Farads then "Zo" is in Ohms and also "L" in micro Henrys and "C" in micro Farads then "Zo" is in Ohms.)

N.B.:-
Almost every book says the value of "L" and "C" are the inductance and capacitance for a **unit length** of the coaxial cable but it is not true, any length is suitable, and also there is no difference between straight cable or coiled form according to my practical experience.

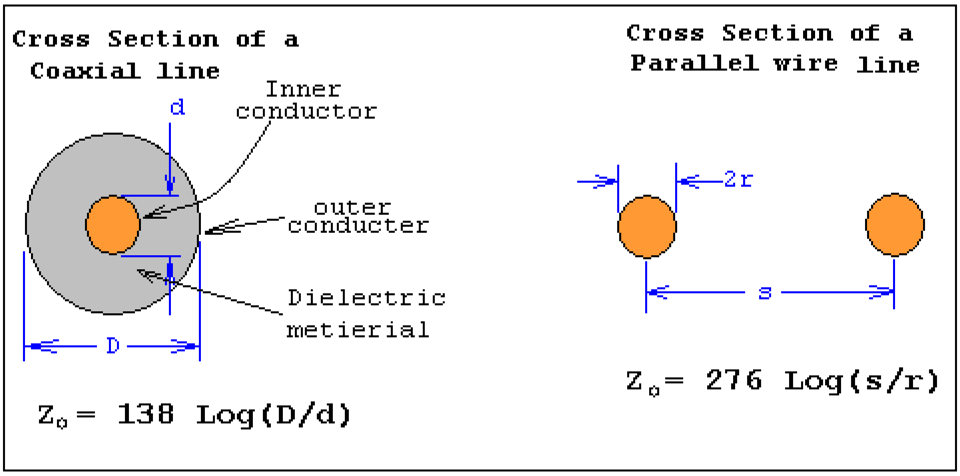

Fig 6.2

6.1.4.1 Characteristic impedance of a parallel wire line

Suppose the radius of the cross section of each wire is "r" and the distance between two axis's is "s" then the characteristic impedance:

$$Zo = 276 \log(s/r) \text{ Ohms}$$

6.1.4.2 Characteristic impedance of a coaxial line

Suppose the diameters of outer conductor and inner conductor respectively "D" and "d" then the characteristic impedance of an **air core** coaxial line:-

$$Zo = 138 \log(D/d) \text{ Ohms}$$

6.1.4.3 How to Measure the Characteristic Impedance

Capacitance "C"

First you take a coaxial cable having several meters long. Keep both ends open. Measure the capacitance between centre conductor and the braid with using a capacitance meter(digital multimeter) or DIP meter. (Fig. 6.3)

Inductance "L"

Then short circuit one end of the cable, and measure the inductance between the centre conductor and the braid of the other end by using an inductance meter (digital multimeter) or with a DIP-meter. (Fig. 6.3)

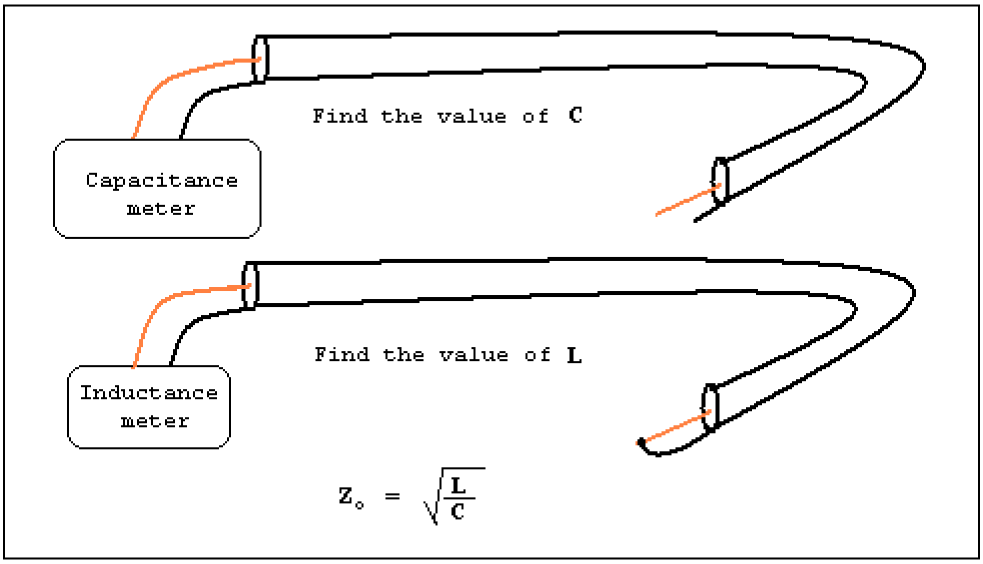

Fig 6.3

Now calculate Z_0 according to this formula, $Z_0 = \sqrt{(L/C)}$.

6.1.5 Velocity Factor

When the medium between the conductors of a transmission line is air, the traveling waves will propagate along it at the same speed as waves in free space. If a dielectric material is introduced between the conductors for insulation or support purposes, the waves will be slowed down.

The ratio of the **velocity of the waves on the line to the velocity in free space** is known as the velocity factor. It is approximately 0.66 for solid polythene cables. For open wire lines, it is between 0.8 and 0.95, while open wire lines with spacers at intervals may reach 0.98. It is important to make proper allowances for this factor in some feeder applications.

For example **if velocity factor is 2/3 (or 0.66) then quarter wave line would be physically 1/6 wavelength long. (2/3 x 1/4 = 1/6)**

Velocity factor for RG8A/U, RG58 and RG213/U coaxial cables is 0.66.

Example:-

Calculate the half wave lengths of 145.550MHz for following conditions.

1. in the free space
2. thin antenna wire
3. RG58 coaxial cable

solution:-

1. in the free space,

wave length = 300/frequency(MHz)
= 300/145.550
= 2.061m

half wave length = 2.061/2
= 1.0305m = **103.05cm**

2. For thin antenna wire,

velocity factor for thin wire is approximately 0.95
therefore half wave length = 0.95 x ½ x 300/145.55
= 0.979m = **97.9cm**

3. RG58 coaxial cable

velocity factor for RG58 cable is about 0.66
therefore half wave length = 0.66 x ½ x 300/145.55
= 0.6801m = **68.01cm**

6.1.5.1 Measuring of electrical length

We can measure the resonance frequency for ½ wave length or ¼ wave length by using a dip meter. According to the diagram in Fig 6.4 connect one turn of

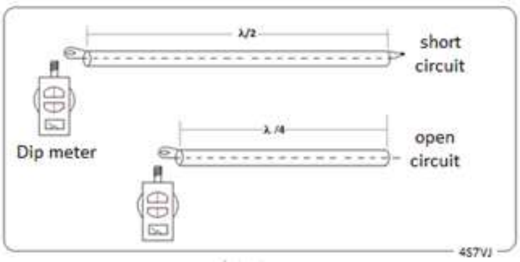

Fig-6.4

a coil to one end of the coaxial cable. If the other end is short circuit, the length is equal to the electrical ½ wave length for the resonance frequency.

If the other end is open circuit, the length is equal to the electrical ¼ wave length for the resonance frequency.

6.1.6 Standing waves

When a transmission line terminated by a resistance equal in value to its characteristics impedance, there is no reflection and the line carries a pure traveling wave. When the line is not correctly terminated, the voltage to current ratio is not the same for the load as for the line and the power fed along the line cannot all be absorbed to the load, some of it is reflected in the form of a secondary traveling wave, which must return along the line. These two waves, forward and reflected, interact all along the line to setup a **standing wave.**

6.1.7 Standing Wave Ratio – SWR

For get the maximum efficiency of a transmission line the characteristic impedance of the line (Zo) should be equal to the characteristic impedance of the antenna (Z).

Standing wave ratio or **SWR** is a figure which can be measure the amount of mismatch of the antenna system. This is always equal or greater than 1. **SWR = 1 for a perfectly matched antenna system.**

SWR = Zo/Z or **Z/Zo** (which ever is greater)

Example:

A transmission line having a characteristic impedance of 50 Ω and terminating to an antenna having 40Ω radiation resistance. What is the SWR of the antenna system?

Solution:

$$Z_0 = 50\Omega \quad \text{and } Z = 40\Omega$$

$$SWR = Z_0 / Z$$

$$= 50/40$$

$$= \underline{\mathbf{1.25}}$$

If the line is not perfectly match, there is a standing wave along the transmission line. Therefore the voltage and the current is varying according to the standing wave. Then the ratio between the maximum and minimum value of current or voltage is equal to the SWR. Refer the diagram (Fig.6.5)

SWR = Imax/Imin
= Vmax/Vmin

If the transmission line is perfectly matched to the antenna, the voltage or current through the line is constant and **SWR = 1**

Example:
The maximum and minimum voltages along a transmission line are 180 and 100 respectively. What is the SWR of the system.

Solution:
SWR = Vmax/Vmin , Vmax = 180v, Vmin = 100v
= 180/100 = **1.8**

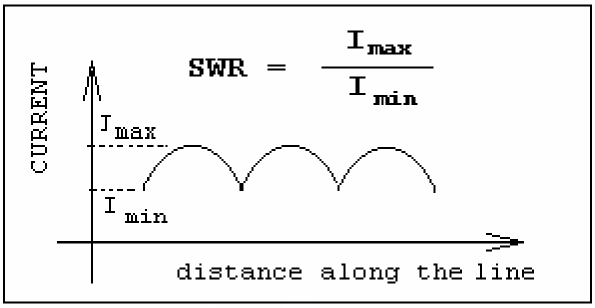

Fig 6.5

Measure the SWR according to the above explanation is not practicable because no way to measure these values.

6.1.7.1 SWR METER

This is a simple instrument use for measure SWR of a transmission line. Every shack should have one SWR meter. It can be the first indicator of antenna trouble. Fig 6.6 shows the circuit diagram for a simple SWR meter. (Refer paragraph 7.2.1 in the chapter-7 for calibration detail)

There is a special type of SWR meter use for visually handicaps. In this instrument generates an audio tone, the frequency of the tone is varying according to the SWR.

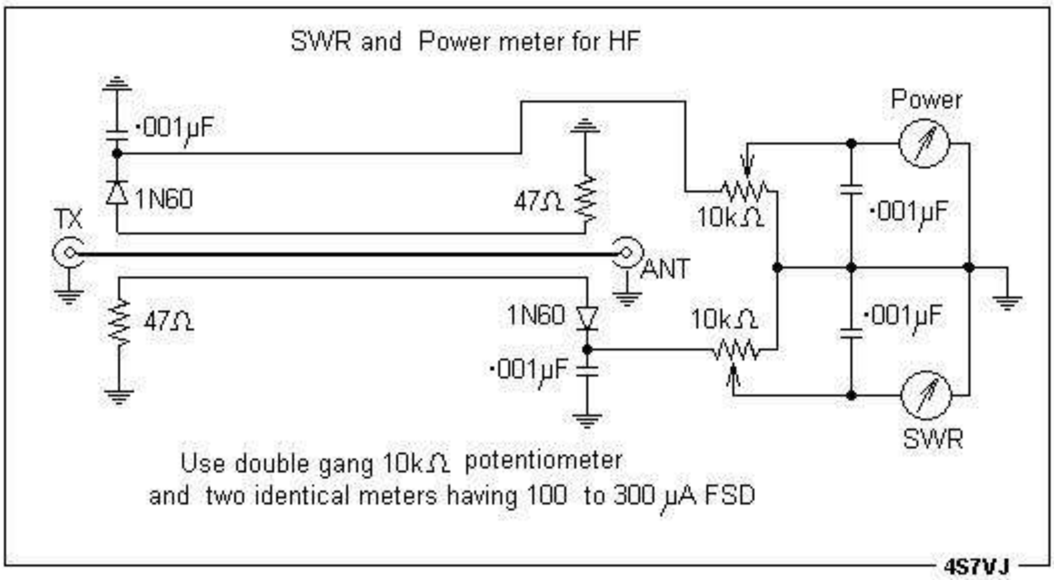

Fig-6.6

Fig-6.7

6.1.8 Reflection Coefficient

The ratio of the voltage in the reflected wave to the voltage in the incident wave (forward voltage) is defined as the **reflection Coefficient.** This coefficient is designated by the Greek letter rho **(ρ)**

$\rho = V_r / V_f$ V_r = reflected voltage
V_f = forward voltage

$\rho = \sqrt{(P_r / P_f)}$ P_r = reflected power
P_f = forward power

For perfectly matched transmission line,

$\rho = 0$ because $V_r = 0$ or $P_r = 0$

For completely mismatched transmission line,
$\rho = 1$ because $V_r = V_f$ or $P_r = P_f$

6.1.9 Relationship between SWR and reflection coefficient

$$SWR = \frac{1 + \rho}{1 - \rho}$$

$$\rho = \frac{SWR - 1}{SWR + 1}$$

6.1.10 Relationship between SWR and voltage

We can rearrange the above formula with the forward and reflected voltages as follows:

$$SWR = \frac{V_f + V_r}{V_f - V_r}$$

6.1.11 Relationship between SWR and power

If the forward power and reflected power are respectively P_f and P_r then we can rearrange the above formula as follows:

$$SWR = (\sqrt{P_f} + \sqrt{P_r})/(\sqrt{P_f} - \sqrt{P_r})$$

6.2 ANTENNAS (Aerials)

Introduction

The radio signal passes from one station to another station as a wave propagating in the atmosphere, but in order to achieve this it is necessary to have at the sending end something which will take the power from the transmitter and launch it as a wave, and at the other end extract energy from the wave to feed the receiver. This is an antenna (aerial) and, because the fundamental action of an antenna is reversible, similar antennas can be used at both ends. The antenna then is a means of converting power flowing in wires to energy flowing in a wave in space, or is simply considered as a coupling transformer between the wires and free space.

Dipole

The most simple and commonly used word in antenna work is **Dipole** or **simple dipole.** Basically a dipole is simply which has two poles or terminals into which radiation-producing current flow. Dipole is used as a reference antenna for antenna experiments.

6.2.1 Properties of Antennas

There are some important properties of antennas as follows:

1. Resonant
2. Radiation
3. polarization
4. Directivity
5. Gain
6. Radiation resistance

6.2.1.1 Resonance of an Antenna

When the SWR of an antenna is 1 (or 1:1) then the antenna is perfectly matched, in other word the total RF power out put is converts to electro magnetic wave or we can say the antenna is resonating for the particular frequency. Normally this is happens for the multiple of half wave lengths of the antenna.

6.2.1.2 Radiation

Whenever a wire carries an alternating current the electromagnetic wave travel away into the space with the velocity of light. It is called the radiation of the electromagnetic energy or RF (radio frequency) energy. We normally use the antenna as the radiator or radiating element. The amount of radiation is proportional to the current flowing into the antenna.

6.2.1.3 Polarization

There are two inseparable fields associated with the transmitted signal,

1. An electric field due to voltage changes,
2. A magnetic field due to the current changes,

and these always remain at right angles to one another and to the direction of propagation as the wave proceeds. The lines of forces in the electric field run in the plane of the transmitting antenna. By convention the **direction of the lines of forces of the electric field defines as the direction of polarization** or the plane of polarization of the radio wave.

Thus **horizontal antennas propagate horizontal polarized waves and vertical antennas propagate vertical polarized waves.**

For the maximum performance RX antenna also should be in the same polarization plane. When the TX antenna is horizontal, RX antenna also should be in the horizontal plane.

Circular Polarization

For long distance propagation through ionospheric layers, due to reflection, refraction and diffraction a degree of cross polarization may be introduced which results in signals arriving at the receiving antenna with both horizontal and vertical components presents. This signal called as **circularly polarized**. Varying of the plane of the receiving antenna is not giving any deference for circular polarized signal.

6.2.1.4 Directivity

The radiation field which surrounds the antenna is not uniformly strong in all directions. It is strongest in directions at right angles to the current flow in the antenna element and falls in intensity to zero along the axis of the element; in other words its exhibits directivity in its radiation pattern, the energy being concentrated in some directions at the expense of others. Later it will be explained how directivity may be increased by using number of elements. These are called beam antennas.

6.2.1.5 Antenna Gain

If one antenna system can be made to concentrate more radiation in a certain direction than another antenna (reference antenna), for the same total power supplied, then it is said to exhibit **gain** over the second antenna in that direction. In other words, more power would have to be supplied to the reference antenna to give the same radiated signal in the direction under the consideration.

Gain can be expressed either as a ratio of the power required to be supplied to each antenna to give equal signals at a distant point, or as the ratio of the signals received at that point from the two antennas when they are driven with the same power input. Gain is usually expressed in **decibels**, according to the following formula.

Antenna gain

$$\mathbf{dB = 10\ Log\ (P_2/P_1)}$$

where P_1 = input power to the directional antenna

P_2 = input power to the reference antenna **to** exhibit same performance

6.2.1.6 Effective Radiated Power ERP

ERP is the effective radiated power of an antenna system with respect to a standard radiator or antenna. Measured antenna performance is usually compared to a dipole.

For an example:- A transmitter having 15 W out put power is connected to an antenna system of 6dB gain. What is the ERP?

Let the ERP = P, therefore 6dB = 10 Log (P/15)
therefore 0.6 = Log (P/15)
but antilog of 0.6 = 4
therefore Log 4 = Log (P/15)
4 = P/15, P = 60
therefore ERP = 60 watts

6.2.1.7 Radiation resistance or antenna impedance

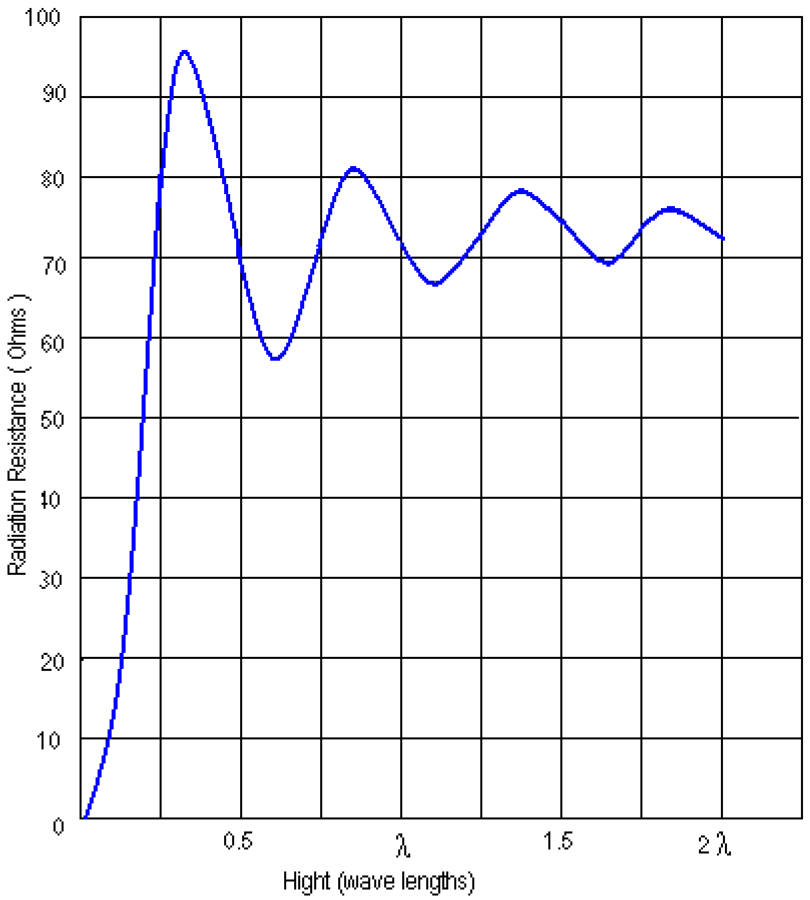

Fig 6.8

When power is delivered from the transmitter into the antenna, some small part will be lost as heat, since the material of which the antenna is made will have a finite resistance, albeit small, and a current flowing in it will dissipate some power. The bulk of the power will usually be radiated and, since power can only be consumed by a resistance, it is convenient to consider the radiated power as dissipated in an imaginary resistance which is called the ***radiation resistance*** of the antenna.

Using ordinary relationships of circuits, if the current flow is ***I*** into the radiation resistance ***R*** then the power of $I^2 \times R$ watts is being radiated. ($W = I^2R$)

The radiation resistance of an antenna is varying with the height above the ground. Fig 6.8 shows the pattern of variation for simple dipole. It is approaching to 72 Ohms.

6.2.1.8 Free Space Wave Length

The relation between the wave length and frequency is very simple. The product of wave length and frequency is equal to the speed of electro magnetic wave (radio signal).

$$v = f \times \lambda$$

Where, v = speed, f = frequency, λ = wave length, speed ajnd wave length are depend on the medium which the wave is traveling. We can assume that the wave is traveling through air (atmosphere) and free space. Speed of radio waves (same as speed of light) in the free space and the air are almost same. It is 299,792,458 m/s (299.792458 Mm/s) in free space. If we take the frequency in MHz and wave length in meters, then speed is in Mega meters, so we can write the above formula as

$$\mathbf{299.792458}\ (\text{Mm/s}) = \mathbf{f}\ (\text{MHz}) \times \boldsymbol{\lambda}\ (\text{m})$$

or

$$\text{MHz} \times \text{meter} = 299.792458$$

Approximately we can consider this as

$$\textbf{MHz} \times \textbf{meter} = \textbf{300}$$

6.2.1.9 Field Strength

The RF energy generated by the TX is radiated to the space by the antenna. This energy density (field strength) gradually gets reduced because it's spread into space. We can calculate the field strength according to the following formula.

$$E = \frac{\sqrt{30\,P}}{d}$$

Hear E = field strength (V/m)

P = Effective radiated power (ERP) in watts (W)

d = the distance from the antenna (m)

Example :-
A vhf transmitter having 3W output power is connected to an antenna having 20dB gain. Find the field strength at a point 100m away from the antenna.

Find the ERP first. According to the formula

$$dB = 10 \log(P_{out} / P_{in})$$

therefore $20 = 10 \log(ERP/3)$
therefore $2 = \log(ERP/3)$
but we know that $2 = \log 100$
therefore $\log 100 = \log(ERP/3)$
therefore $ERP/3 = 100$
$ERP = 300$ Watts

Now apply the formula $E = (\sqrt{30P})/d$, P=300, d=100

Therefore $E = (\sqrt{30 \times 300})/100$
$= \sqrt{9000} / 100$
$= 94.8/100$
$= 0.948$ V/m
= **948 mV/m**

6.2.2 Types of Antennas

There are various types of antennas for using with HF, VHF, UHF, and other bands and also with receivers and transmitters. The following list included several types.

1. Vertical antenna
2. Long wire (harmonic)
3. Dipole
4. Whip
5. Loop
6. Quad
7. Yagi
8. Quagi
9. Parabolic
10. Rhombic antenna
11. Receiving antenna

All types of above, can be divided into three categories as

1. Omni directional antenna
2. By directional
3. Directional or unidirectional antenna

And also for another three categories as

1. Horizontal polarization
2. Vertical polarization
3. Circular polarization

6.2.2.1 Vertical Antenna

Vertically polarized RF wave propagating from vertical antenna. Radiating element is in vertical, for most of vertical antennas. Fig 6.9 shows various types of vertical antennas. Fig 6.9(a) shows Marconi antenna; quarter wave vertical radiator installed on ground with insulation and it is connected to the center conductor of the coaxial feeder and braid is connected to the ground.

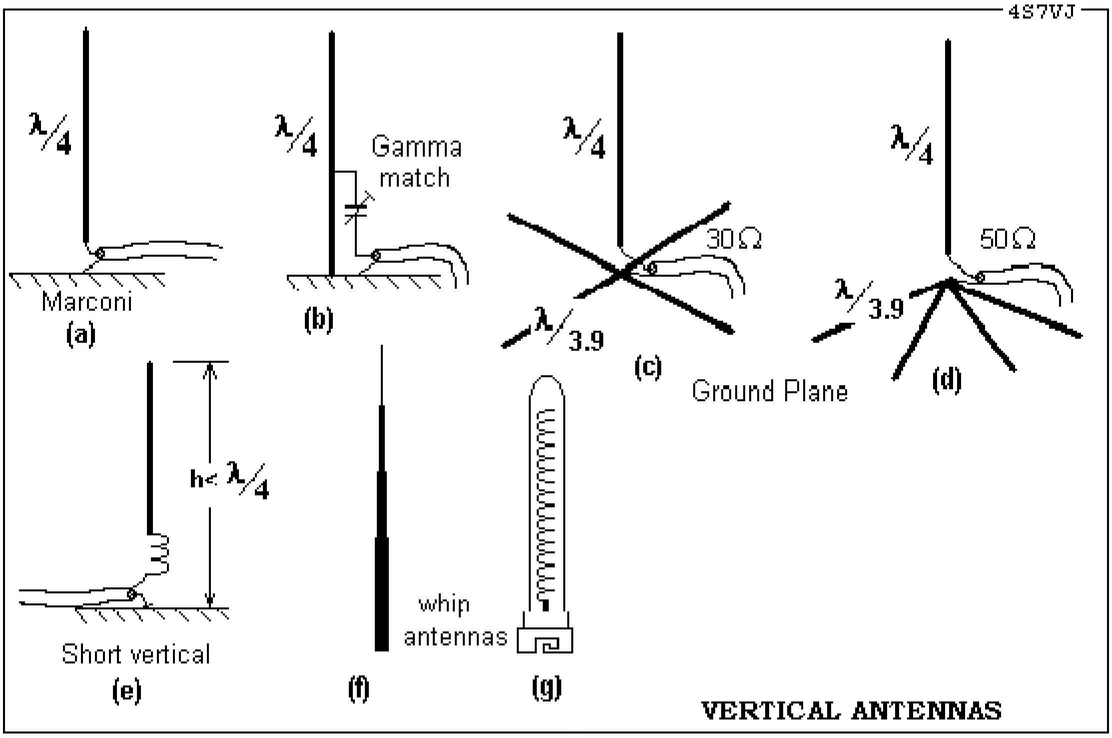

Fig. 6.9

Fig6.9(b) shows grounded quarter wave radiator connected to the coaxial feeder with Gamma match. It is very much protection against lighting because the whole antenna system is grounded. (d.c. ground antenna)

For the Gamma match system, the braid is connected to the ground and center cable connected to some point in the radiator element through a trimmer condenser and adjust the trimmer for the lowest SWR; and also adjust position of the connecting point on the radiator element.

(c)and (d) show λ/4 **Ground plane** antenna having four radials slightly longer than the radiator **(λ/3.9)**. When they are horizontal, feed point impedance is approximately 30Ω. If those radials slanted 45° to the horizontal the feed point impedance increase up to 50Ω. Instead of being actually grounded, a quarter wave antenna can work against a simulated ground (four radials) called a **ground plane**.

Fig 6.9(e) shows a **short vertical** antenna. The radiator is connected to an inductor (loading coil) at the bottom. This is very useful for low frequency bands (40m or 80m); and also for mobile operations.

Fig 6.9(f) and (g) are **Whip antennas**. Fig 6.9(f) is a telescopic type it is normally use for receivers (radio & TV). Fig 6.9(g) is a **rubber flex whip antenna**; normally use with hand held vhf TRX. The coiled antenna element is covered by a insulated rubber cover.

6.2.2.2 Bi-Directional antenna

If any antenna radiates equally on opposite directions, it is called as Bi-directional antenna. Following antennas are Bi-directional

1. Long wire antenna
2. Dipole antenna
3. Loop antenna

6.2.2.2.1 Long wire Antenna (harmonic antenna)

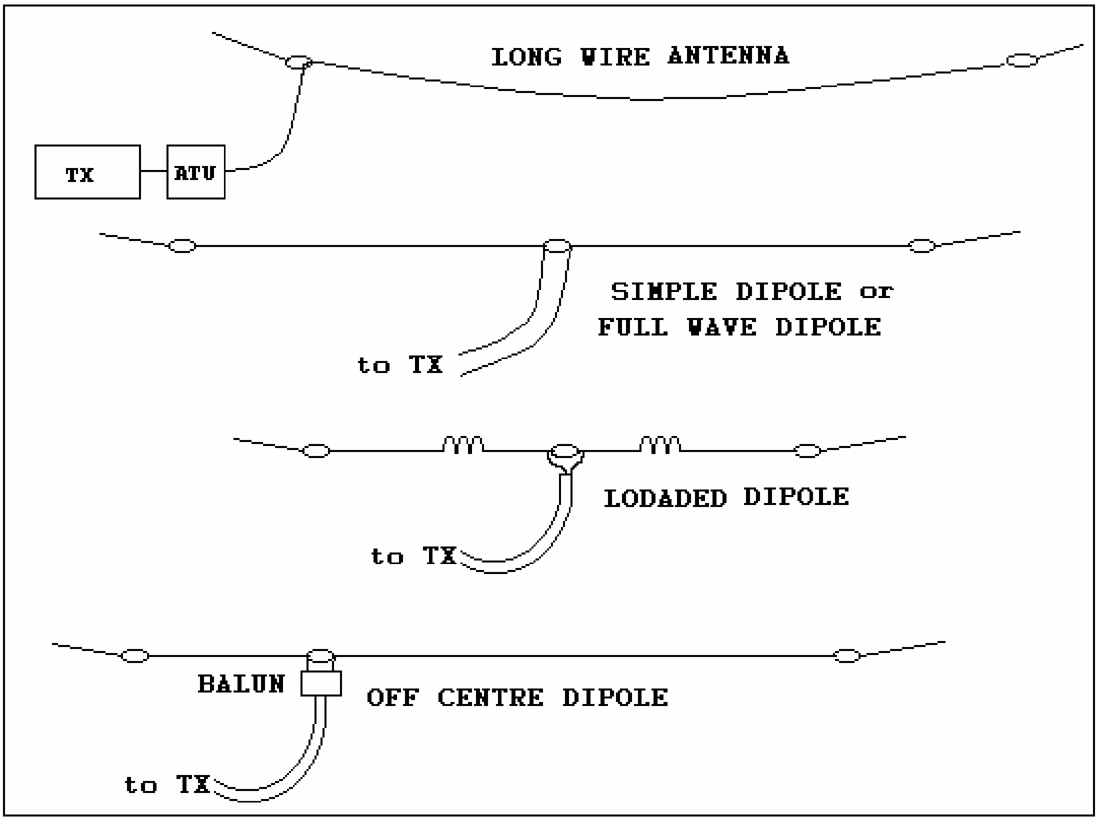

Fig 6.10

An antenna will be resonant so long as its length is some integral multiple of a half wave-length. When the length of the antenna is more than one wave-length it is called a long-wire antenna, or a harmonic antenna.

This is not a good type of antenna because there are considerable losses and antenna gain is low and SWR is high. But very easy to install. Normally this type is using with an ATU (antenna tuning unit) for reduce the SWR, otherwise the final stage of the TX will be damage by overheating. The efficiency of this antenna is very low.

6.2.2.2.2 Dipole antenna

As mentioned earlier the dipole is the most simple useful antenna which has two poles. The length of the dipole is depend on the operating frequency or resonance frequency of the dipole. There are several types of dipoles as follows:

1. Simple dipole
2. Full wave dipole
3. Short dipole (loaded dipole)
4. Off center dipole

6.2.2.2.3 Simple dipole

If the length is equal to the electrical half-wave length it is called as **simple dipole** or **half wave dipole** and it is normally use as a reference antenna for antenna experiments.

Approximate electrical ½ wave length **= 0.95 x ½ x 300/f**
= 142/f meters

(f = frequency in MHz)

Theoretical Length = **λ/2,** (150/f meters). this is the half wave length in free space for the particular frequency. The actual length is shorter than the half wave length. (due to velocity factor) It is depend on the diameter of the wire, shorter length for higher diameters.

6.2.2.2.4 Full-wave dipole

The length of this is a full wave length **(λ)** or double the size of the simple dipole.

6.2.2.2.5 Short dipole or Loaded Dipole

A short dipole is less than half the wave length. It needs to be tuned to resonance by adding inductance because of mismatch. It should be tuned for the lowest SWR. This type is very much useful for a location having limited space. The only disadvantage is the narrow bandwidth. ^to download click here)
www.qsl.net/4s7vj/download/Dipole.exe

6.2.2.2.6 Inverted-V antenna

The diagram in Fig-6.11 is called as inverted-V antenna. The centre insulator should be attached to a vertical pole or hung on a tree. The angle between two arms is approximately 90^0. The total length is about 5% longer than half wave dipole. It is about 149/f(MHz) meters. This is a Bi-directional antenna.

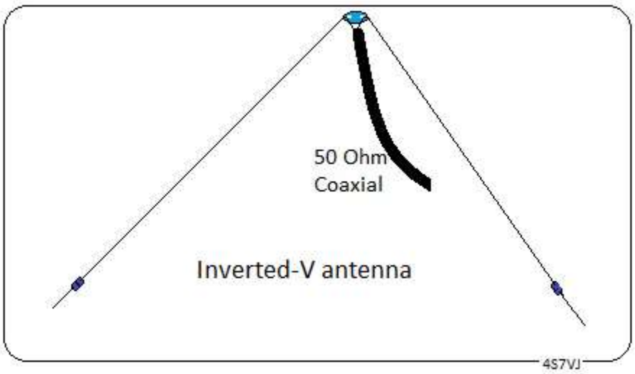

Fig-6.11

6.2.2.2.7 λ/4 half sloper antenna

This is like one half of the inverted-V antenna and is a sloper wire starting from the top of a mast through an insulator. Feeder cable should be connected to the sloper wire and the mast at the top. The slope of the antenna wire is about 45^0 to the vertical. The wave is a vertically polarized signal. SWR is about 1.5

We can construct a multiband antenna using a number of ¼ wave wires connected together at the top end.

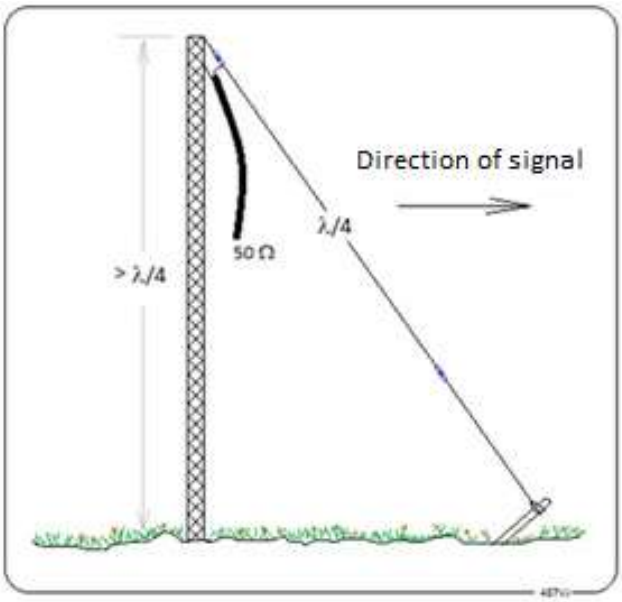

Fig-6.12

6.2.2.3 Loop Antenna

There are few types of loop antennas as follows

1. Circular loop
2. Quad loop
3. Delta loop
4. Magnetic loop

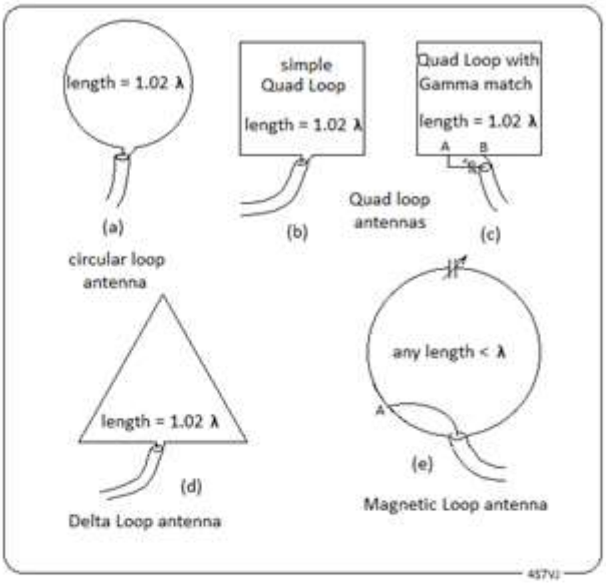

Fig 6.13

6.2.2.3.1 Circular Loop Antenna

This is the most simple loop-antenna. A conductor (tube) having a full wave length bend as a circle and two ends connected to the feeder wire. Due to practical difficulties this is suitable only, for vhf and uhf. (Fig6.13-a)

6.2.2.3.2 Quad Loop

A conductor having a full wave length, bend as a square and two ends connected to the feeder wire. (Fig 6.13-b) The total length of this antenna is 1.02λ

If it is attach with a gamma match system and adjusted properly (SWR=1) it will be very much efficient broad band antenna. (Fig 6.13-c)

6.2.2.3.3 Delta Loop

If the same Quad loop antenna bent as a triangle it is called **Delta-Loop** antenna.(Fig 6.13-d)

6.2.2.3.4 Magnetic Loop antenna

The construction of this is appearing in the diagram (Fig 6.13-e). An open loop constructed by a copper wire or a copper tube, and both open ends at the top are connected to a variable capacitor "C". Inner conductor of the coaxial cable connected at the point "A"; braid is connected at the mid-point of the conductor at the bottom. Position "A" is the deciding factor for the characteristic impedance of the feeder.

The ideal small transmitting antenna would have performance equal to a large antenna. This small loop-antenna can approach that performance except for a reduction in band-width. This is very narrow band, but that effect can be overcome by re-tuning the capacitor

"C" for resonance. High voltage develop at the capacitor (few kV). At the resonance SWR = 1. About one meter diameter loop antenna can be use for whole HF band with varying the capacitor. This capacitor is a high quality high voltage type.

For more practical details click here www.qsl.net/4s7vj/download/LoopAnt.exe

6.2.2.4 Directional or unidirectional antenna

It is possible to construct an antenna to radiate more energy to one direction. It is called directional or unidirectional antenna. Few directional antennas as follows.

1. Cubical Quad antenna
2. Yagi antenna
3. Quagi antenna
4. Parabolic antenna

6.2.2.4.1 Quad or Cubical-Quad antenna

This is a directional antenna with a high gain, made with two or more number of Quad-Loop elements, arrange with a specific dimension.

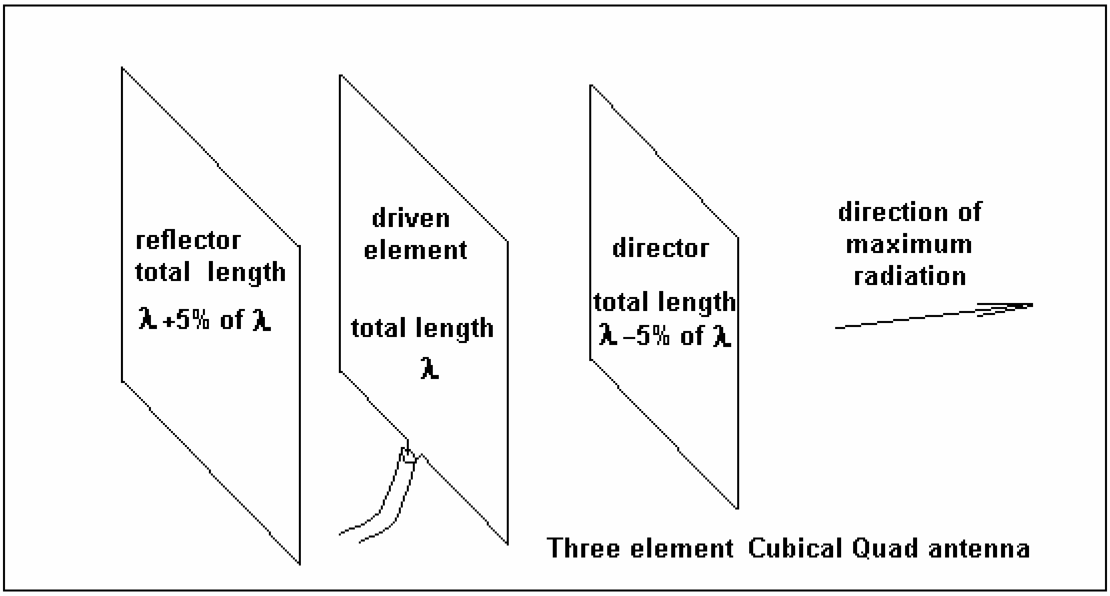

Fig 6.14

Quads have been popular with amateurs during the past few decades because of their light weight, relatively high gain and small turning radius ,and their unique ability to provide good DX performance even when mounted close to the ground. Fig 6.14 shows **three element quad.**

The total length of the driven element is slightly more than full wave length. Reflector is 5% greater than the driven element and director is 5% smaller. All three elements can be mount on an aluminum pipe called boom. If the feeder wire connected through the Gamma-match system, the performance is improving (SWR=1). The gain of a three element Cubical Quad is about 9dB.
You can get full practical details from
http://www.qsl.net/4s7vj/download/My publication/Antenna Book.pdf

6.2.2.4.2 Yagi Antenna

This is a popular type of directional antenna. The simplest Yagi antenna is one with just two elements as indicated in Fig 6.15. Fig 6.15(a) has a reflector and a driven element. The Fig-6.15(b) has a driven element and a director. Fig 6.15(c) is a three element Yagi antenna with a driven element (λ/2 long) a reflector (5% longer than the driven element) and a director (5% shorter than the driven element). The feeder line is connected to the driven element. To improve the performance we must install an impedance matching system in between the driven element and the feeder wire. Fig 6.15(d) is a five element Yagi antenna. If we increase the number of elements according to the proper dimensions the directional property gets increased. It means the antenna gain for that particular direction gets increased.

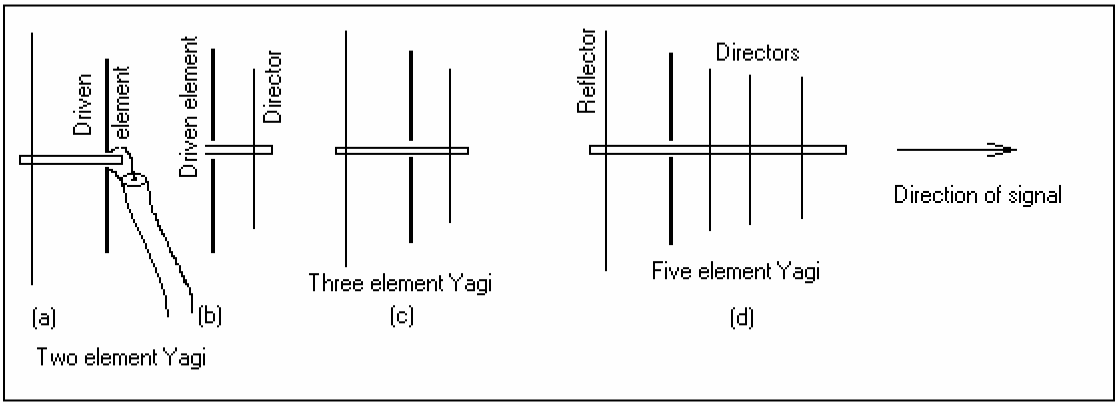

Fig. 6.15

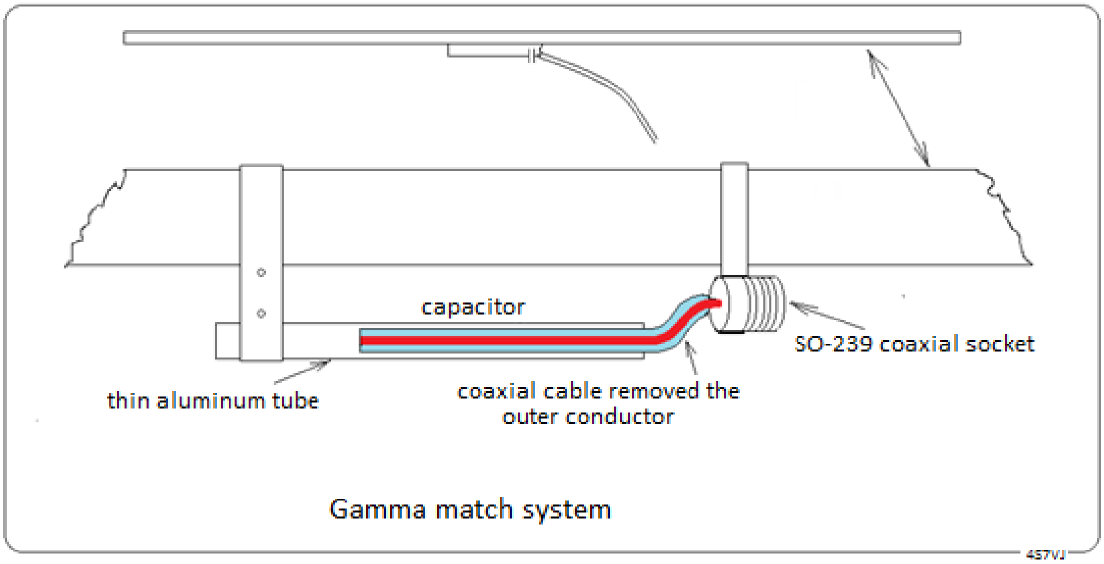

Fig-6.16

We can use this gamma match system for any antenna made out of aluminum tubes. The gamma capacitor made out of a thin aluminum tube and insulated wire inserted into the tube. For vary the capacitance we must vary the length of wire inserted into the tube.

6.2.2.4.2.1 Properties of Yagi antenna

All elements except radiating element (or driven element) are called parasitic elements. The effect from other elements to the driven element is called as **parasitic excitation.**

Increase the number of elements is decreasing the radiation resistance (feed point impedance)

There are three important factors in a Yagi antenna when increases the spacing between elements.

1. Increase the radiation resistance.
2. Increase the antenna gain.
3. Decrease the front to back ratio (F/B)

6.2.2.4.3 Quagi Antenna

This is a combination of a Quad and a Yagi. Normally reflector and driven element are like a Cubical Quad and all directors like Yagi.

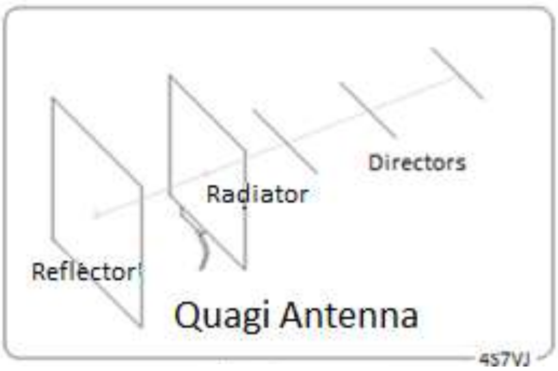

Fig-6.17

6.2.2.4.4 Parabolic Antenna

This is a dipole antenna installed at the focal point of a parabolic reflector. It is highly directional and very high gain along the axis of the parabolic reflector. This type called as micro wave antenna because this type use only for frequencies higher than UHF. (micro wave)

6.2.2.4.5 Receiving Antennas

Any type of antenna is possible to use with a receiver; but if it is mismatch with the receiver, the only problem is the strength of the input signal to the RX become weak; there will be no damage or power loss like transmitters. Most popular receiving antennas are

1. Ferrite rod antenna
2. Telescopic antenna
3. Loop antenna
4. Long wire antenna

6.2.2.5 Multi band Antennas

All antennas explained earlier work with a good performance for one frequency. It is called the resonance frequency. Some antennas work to a satisfactory level for odd multiples of frequency. For Example 40m dipole can be used for 15m.

6.2.2.5.1 Multi-band Dipole Antenna

The multi-band antenna is constructed to work with a good performance for several bands. When several dipole antennas are connected to a single feeder wire, it is called a multi-band dipole antenna system.

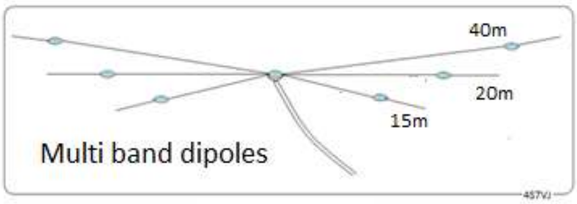

Fig-6.18

6.2.2.5.2 OFF CENTRE DIPOLE

The feed point of this antenna is not the centre. (Fig-6.10). It is calculated according to a special calculation. This is a multiband antenna. The feed point impedance is more than 50 Ohms. To reduce this value to 50 Ohm, we must use a BALUN. BALUN is the abbreviation for "balance to unbalance transformer". The characteristic impedance of a normal coaxial cable is 50 Ohms.

6.2.2.5.3 Trap Dipole Antenna

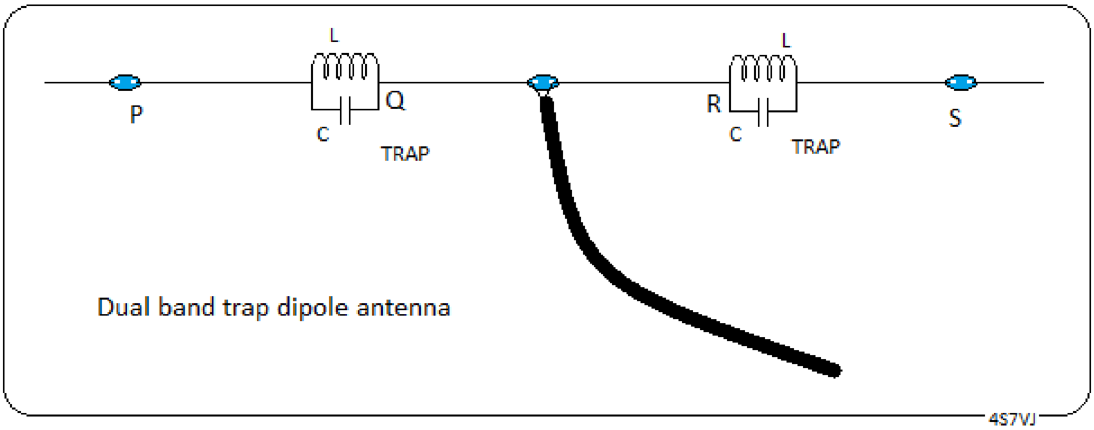

Fig-6.19

Trap is a kind of RF filter constructed as a parallel resonance circuit. Fig-6.19 has shown a two band trap dipole antenna. If it is constructed for 14MHz and 7MHz bands, traps should be tuned for 14MHz band. The 14MHz signal is not passing through traps because the impedance is maximum for 14MHz. Only QR portion is acting as 14MHz antenna.
The total length is acting as 7MHz half wave dipole antenna, because 7MHz signal is passing through traps. The total length is little bit less than the 7MHz half wave dipole because the wire length of the trap-coil also to be counted.
We can construct a multi-band antenna for any number of frequency bands.

6.2.2.5.4 Multi band Directional antenna

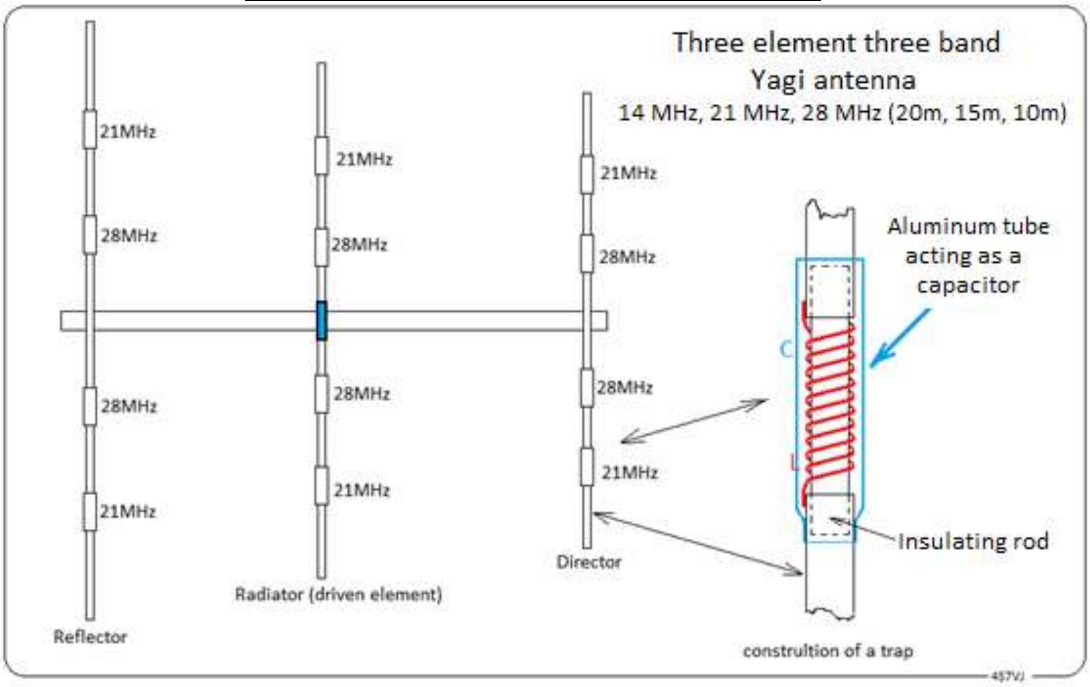

Fig-6.20

Fig-6.20 shows the most popular antenna among amateur radio operators. It is a three element three band Yagi constructed for 10m, 15m and 20m. There are 12 traps connected as shown in the diagram. The trap is a parallel LRC resonance circuit. There is no physical capacitor in this trap. One side of the capacitor (C) is the external aluminum tube and the other side is the coil (L).

6.2.2.6 Isotropic antenna

A simple way to appreciate the meaning of antenna gain is to imagine the radiator to be totally enclosed in a hollow sphere. If the radiation is distributed uniformly over the interior surface of this sphere, the radiator is said to be **isotropic radiator** or **isotropic antenna.**
An antenna which causes radiation to be concentrated into any particular area of the surface of the sphere, produces a greater intensity than that produced by an isotropic antenna fed with equal power, is said to exhibit a gain relative to an isotropic antenna.

The gain of an antenna is usually expressed as a power ratio, either as a multiple of so many times or in Decibel (dB) units. For example twice the power gain could be represented as 3 dB. (3 = 10 Log2)

The gain of a simple half wave dipole is 2.15dB (or 2.15dBi) relative to an isotropic radiator. The expression dBi is used to define the gain of an antenna system relative to an isotropic radiator.

6.3 POLAR DIAGRAM

Around any antenna, the field strength varies according to the direction and the distance. We can get the field strength at a constant distance from the antenna and rotate the antenna to change the direction.

If we use a directional antenna, the maximum field strength or the gain is on the axis of the antenna. We can take a set of readings and plot a graph.

Two variables are degrees and the field strength (or gain) This is called polar diagram. Fig 6.12 shows a part of a polar diagram from 0^0 to 90^0 only. We can get readings for 0^0 to 360^0 and get a complete diagram.

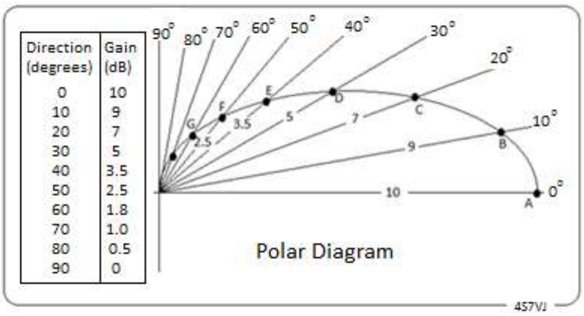

Fig-6.12

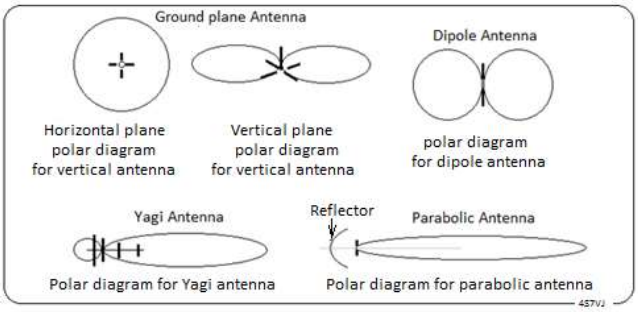

Fig 6.13 shows complete polar diagrams for few antennas.

Fig-6.13

6.4 WAVE PROAGATION

Radio wave is one portion of Electro Magnetic Waves. Other portions are light waves, infra-red, ultra violet, x-ray, gamma-ray etc. Straight line propagation is a common property for all of these waves. Apart of that refraction, reflection, diffraction and absorption also exhibits. There are some properties varying with the frequency. All types of electromagnetic waves are travel with a constant speed. That is 300,000 km/s or $3x10^8$ m/s in free space. In the air this is reduced very slightly but it is negligible.

6.4.1 IONOSPHERIC PROPAGATION

Properties of the ionosphere

Regarding radio wave propagation through the atmosphere and the ionosphere, there are three main properties.

1. Absorption
2. Refraction
3. Reflection

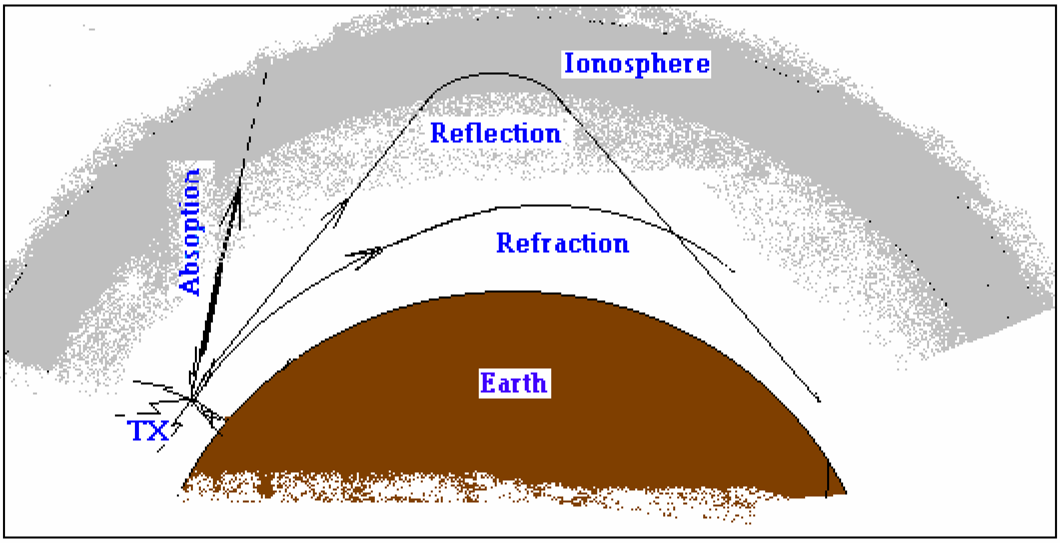

Fig-6.14

6.4.1.1 ABSORPTION

In traveling through the ionosphere the wave gives up some of its energy by setting the ionized particles into motion. That means some percentage of the energy belonging to the radio wave is lost or absorbed by the ionosphere. This absorption is greater at lower frequencies. It also increases with the intensity of ionization, and with the density of the atmosphere in the ionized region.

6.4.1.2 REFRACTION

When radio waves travel through the atmosphere, they are bent slightly, due to variation of the density of air layers and degree of ionization in the ionosphere. Thus low-frequency waves are more readily bent than those of high frequency. For this reason the lower frequencies, 3.5 and 7 MHz are more reliable than the higher frequencies. (14 to 28 MHz.) When the degree of ionization is low value, the waves of the higher frequencies are not bent enough to return to earth.

6.4.1.3. REFLECTION

When radio waves bend more and return to earth, it is call reflection. This reflection happens from upper layer of the ionosphere. These layers are named D, E, and F (F1, F2). (Fig-6.15)

Actually, it is not a reflection. It is continually refraction and turn back to the earth.

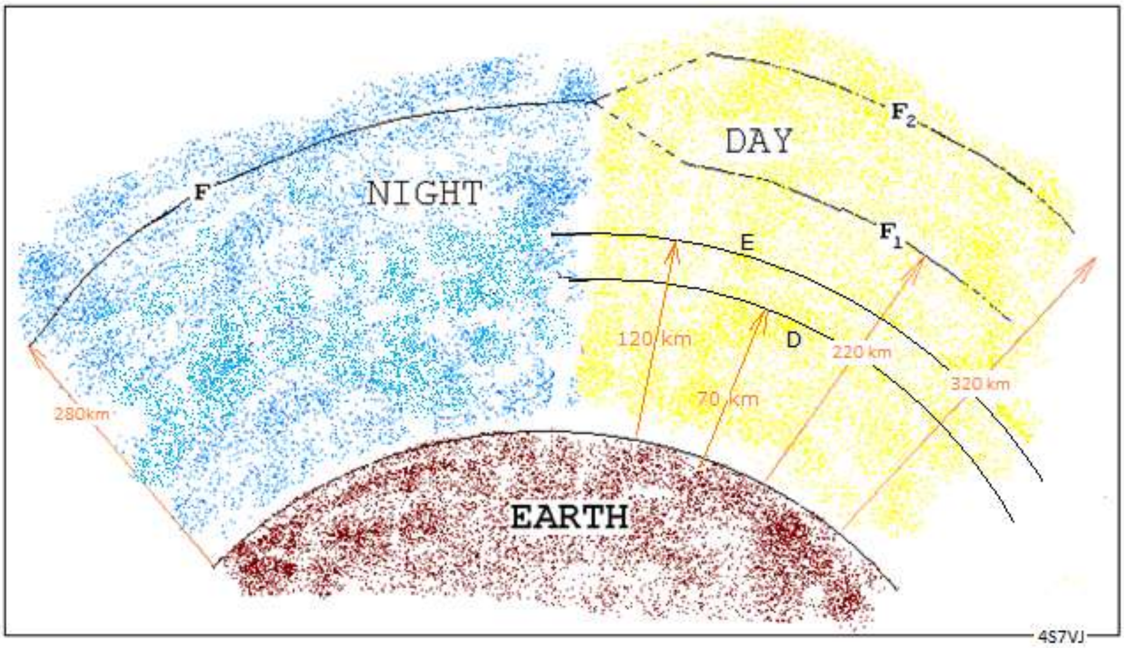

Fig-6.15

Classification and Definitions of the Ionosphere

6.4.1.3.1 D-LAYER

In the daytime there is a still lower ionized area, the D region. D region ionization is proportional to the angle of elevation of the Sun and is greatest at noon. The lower frequencies (1.8 and 3.5 MHz) are almost completely absorbed by this layer, and only the high-angle radiation penetrates and is reflected by the E layer.

6.4.1.3.2 E-LAYER

This is the lowest useful ionized layer, and the average height is about 120km. The E- layer normally disappears after Sunset.

6.4.1.3.3 F-LAYER

This is the most important layer, which has a height of about 280km at night. In the daytime the F layer splits into two parts, the **F1 and F2 layers,**(Fig-6.15) with average virtual heights of 220km and 320km respectively. These layers merge again at sunset into the F layer. (280km)

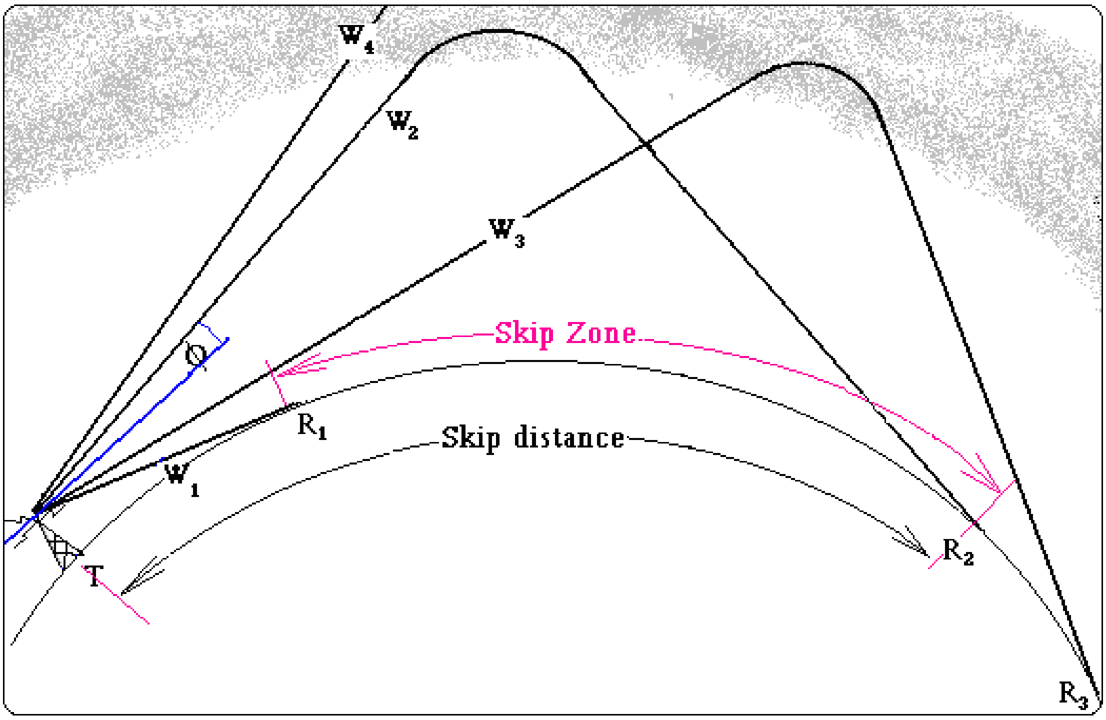

Fig-6.16

6.4.2 ANGLE OF RADIATION

The angle between the direction of the wave and the horizon or tangent of the earth is called the wave angle or angle of radiation. This is denoted by Ø in the diagram of Fig-6.16

6.4.3 GROUND WAVE

The horizontal waves from the TX antenna (W_1 in the Fig 1.10)travels a line of sight distance or little more, parallel to the ground. This is called ground wave.

6.4.4 CRITICAL ANGLE

The wave at a somewhat lower angle is just capable of being returned by the ionosphere. (W_2 in the Fig 1.10) This radiation angle is called the critical angle.(Ø in the Fig-6.16)

Radiation at angles more than the critical angle do not return to Earth, because it is only slightly bent in the ionosphere and to pass through it. **This is called sky wave.**The radiation at angles smaller than the critical angle return to the Earth at a long distance. (W_3 in Fig-6.16)

6.4.5 SKIP DISTANCE and SKIP ZONE

When the wave angle is **equal to the critical angle** for a particular **frequency** and for a particular **time** for the day, it is reflect and return to the Earth at a certain distance. (at R_2 in Fig 1.10) For lower angle of radiation signals are reach beyond that point.(at R_3 in Fig 1.10)

This is illustrated in Fig-1.10, where Ø and smaller radiation angles give useful signals while waves sent at higher angles penetrate the layer and are not returned. The distance between T and R_2 is therefore the shortest possible distance at the particular frequency, and for a particular time for the day, over which communicate by ionospheric reflection can be accomplished. This distance is called **skip distance.**

The area between the end of the useful ground wave and the beginning of the ionospheric wave reception is called the **skip zone.**

The extent of the skip zone depends upon the frequency and the state of the ionosphere, and also upon the height of the layer in which the reflection takes place.

6.4.6 CRITICAL FREQUENCY

If the frequency is low enough, a wave sent vertically to the ionosphere will be reflected back down to the transmitting point. (Eg: 80 m-band with horizontal Quad loop). If the frequency is then gradually increased, eventually a frequency will be reached where this vertical reflection just fails to occur. This is the **critical frequency for the layer** under consideration. When the operating frequency is **below the critical frequency, there is no SKIP ZONE.** The critical frequency is a useful index to the highest frequency that can be used to transmit over a specified distance.

6.4.7 MAXIMUM USABLE FREQUENCY (MUF)

If a radio wave leaving the transmitting point 'T' and receive at the point 'R', for example, at a frequency 14 MHz., and if a higher frequency would skip over the receiving point, then 14 MHz. is the m.u.f. for the distance between T and R. The greatest possible distance is covered when the wave leaves along the tangent to the earth, that means horizontal. (Zero wave angle) Under average conditions, this distance is about 4000 km., for the F2 layer, and 2000 km., for the E layer. This distance varies depending on the height of the layer. **Frequencies above the m.u.f. do not return to earth at any distance.** The 4000km m.u.f. for the F2 layer is approximately three times the critical frequency for that layer. For the E layer the 2000 km m.u.f. is about 5 times the critical frequency.

6.4.8 LOWEST USABLE FREQUENCY (LUF)

There is a lower limit to the band of frequencies which can be selected for a particular application. This is set by the **lowest usable frequency**, below which the circuit becomes either unworkable or uneconomical because of the effects of absorption and the level of radio noise.

6.5 SUN-SPOT CYCLE

The propagation of the HF radio wave depends on the 11 year Sunspot cycle Activity. The maximum sunspot season is the best for HF Communication. (Eg:- 1980 & 1991, next 2002) The critical frequencies are highest During sunspot maximum period. During the period of minimum sunspot activity, the lower frequencies (40m & 80m) are the only usable bands at night. When the sunspot number increased, the ionization will be increased.

6.5.1 PROPAGATION IN THE HF BANDS

6.5.1.1 160m-band (1.8-2.0 MHz)

160m band offers reliable working over range up to 40 km during daytime. On winter nights ranges up to several thousand km.

6.5.1.2 80m-band (3.5-3.8 MHz)

During the day time 80m-band covers upto about 300 km. This band is more useful during the night because the range is several thousand miles. Transoceanic contacts are regularly made during the winter months. During the summer the static level is high.

6.5.1.3 40m-band (7.0-7.1 MHz)

40m-band has many of the characteristics as 80m-band except that the distance, that can be covered during the day and night hours are increased. Day-light distance upto about thousand miles and during winter nights it is possible to work stations as far as the other side of the world. The signals following the darkness path. Summer static is much less of a problem than on 80m.

6.5.1.4 30m-band (10.1 - 10.15 MHz)

This is a WARC band introduced in 1980, permitted only for CW operation . This band is usable during 24 hours of the day. This is usable for 1500 to 2000km during the day time and throughout the world during night.

6.5.1.5 20m-band (14.0-14.35 MHz)

This is the best amateur band for DX work. During the high portion of the sunspot cycle it is open to most part of the world practically throughout the 24 hours, while during a sunspot minimum it is generally useful only during twilight hours and the dawn and dusk periods. There is practically always a skip zone on the band.

6.5.1.6 17m-band (18.068 – 18.168 MHz)

This is a WARC band introduced in 1980. Most of the properties of this band are like the 15m band. It is more reliable during day-time and early evenings. Normally this band gets weaker and weaker after sunset. During minimum sunspot period, this band is fairly active only around noon even though it is only for equatorial regions.

6.5.1.7 15m-band (21.0-21.45 MHz)

15m-band shows highly variable characteristics depending on the sunspot cycle. During sunspot maximum it is useful for long distance work during a large part of the 24 hours, but in years of low sunspot activity it is almost wholly a daytime band, and sometimes unusable even in daytime. However, it is often possible to use it for distances up to 1500 miles or more.

6.5.1.8 12m-band (24.890-24.990 MHz)

This is a WARC band introduced in 1980. This band has combined properties of 10m and 15m bands. This is limited to day time during sunspots minimum and average seasons. This is a good DX band after sunset during sunspot maximum periods.

6.5.1.9 10m-band (28.0-29.7 MHz)

10m-band is generally considered to be a DX-band during the daylight hours (except in summer) and good for local work during the hours of darkness, for about half the sunspot cycle. At the sunspot minimum the band is usually dead.

6.5.1.10 6m-band (50.0-50.4 MHz)

This is the lowest frequency band in vhf range. For this band noise and interference are minimum. Normally this 6m-band is suitable for short distance communication up to about 150 km, but occasionally having ionospheric reflection. This is suitable for DXing due to the reflection by F_2 layer during sunspot maximum season.

6.5.1.11 WARC bands

International Amateur Radio Union (IARU) is the international organization of the amateur radio service. International Telecommunication Union (ITU) is the international organization for all communication systems in the world. In 1979 there was a conference of the above organizations called WARC (World Administrative Radio Conference). At this conference it was decided to give another three new bands for the amateur radio service called WARC-bands.

They are as follows:

30m - 10.100 - 10.150 MHz (CW only)
17m - 18.068 - 18.168 MHz
12m - 24.890 - 24.990 MHz

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Last edited on 3rd March 2025