BSc in Computer Engineering
CMP4204
Wireless Technologies

Lecture 2

Antenna Principles

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1. Introduction

1.1 Magnetism

Magnetic dipoles or magnetic moments can often result on the atomic scale due to the movements of electrons. Each electron has magnetic moments that originate from two sources. The first is the orbital motion of the electron around the nucleus. In a sense this motion can be considered as a current loop, resulting in a magnetic moment along its axis of rotation. The second source of electronic magnetic moment is due to a quantum mechanical property called spin.

In an atom the orbital magnetic moments of some electron pairs cancel each other. The same is true for the spin magnetic moments. The overall magnetic moment of the atom is thus the sum of all of the magnetic moments of the individual electrons, accounting for moment cancellation between properly paired electrons. For the case of a completely filled electron shell or subshell, the magnetic moments completely cancel each other out. Thus only atoms with partially filled electron shells have a magnetic moment. The magnetic properties of materials are in large part determined by the nature and magnitude of the atomic magnetic moments. A magnet is a material or object that produces a magnetic field resulting of such atomic magnetic moments. This magnetic field is invisible but is responsible for a force that pulls on other ferromagnetic materials, such as iron, and attracts or repels other magnets.

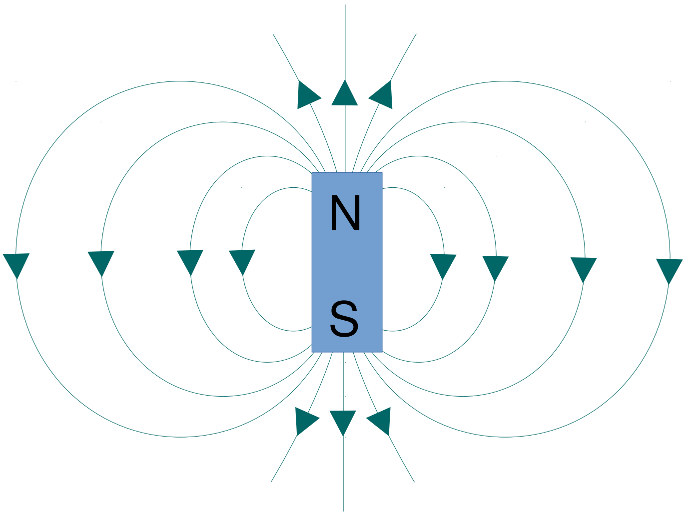


Illustration 1: Magnetic fields

1.1.1 Right-hand rule

Fleming's right-hand rule give the direction of a current induced in a wire when it is passed through a magnetic field.

Passing the wire through the magnetic field induces a current in the wire. The direction of current flow is given by Fleming's right-hand rule.

The right hand is held with the thumb, first finger and second finger at right angles to each other as shown in Illustration 2.

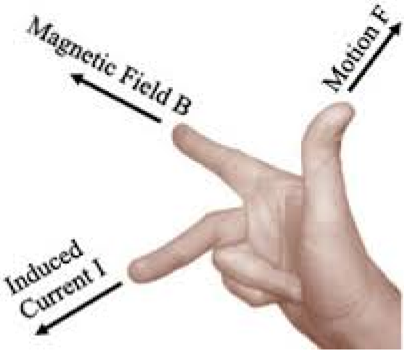


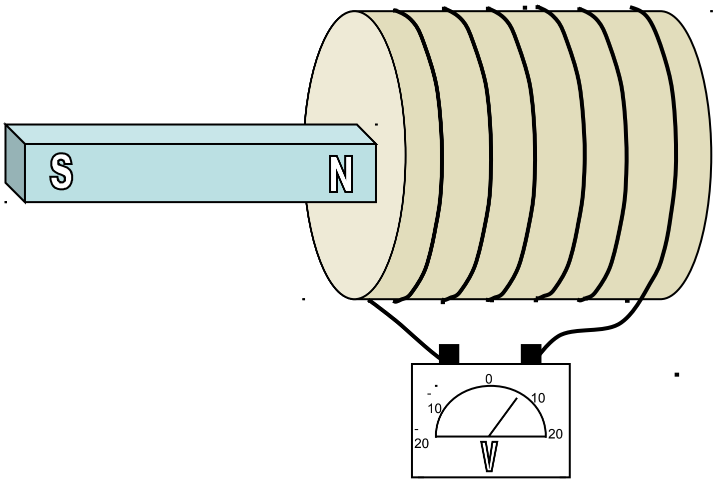
Illustration 2: Right hand rule

- thu**M**b → Motion
- **F**irst finger → Magnetic **F**ield
- Se**C**ond finger → **C**urrent

Thus it is easy to determine each element if two are known.

1.2 Magnetism and Electricity

A connection between electricity and magnetism was discovered accidentally by Hans Christian Ørsted in 1820, who noticed that a compass needle is deflected when brought into the vicinity of a current carrying wire. Thus, currents induce in their vicinity magnetic fields. 11 years later in 1831 Michael Faraday made his discovery of electromagnetic induction, his hypotheses that a changing magnetic field is necessary to induce a current in a nearby circuit. To test his hypothesis he made a coil by wrapping a paper cylinder with wire. He connected the coil to a galvanometer, and then moved a magnet back and forth inside the cylinder.



Drawing 1: Magnetism and electricity

When a magnet is moved back and forth, it can be noticed that the galvanometer needle moves, indicating that a current is induced in the coil. It can be noticed also that the needle immediately returns to zero when the magnet is not moving. Faraday confirmed that a moving magnetic field is necessary in order for electromagnetic induction to occur.

1.3 Theory of Antenna

An antenna or aerial, is an arrangement of conductors designed to radiate an electromagnetic field in response to an applied alternating Electro Motive Force (EMF) also known as alternating electrical current.

Alternatively, if an antenna is placed into an electromagnetic field, it will produce an alternating EMF in response to the field, see radio frequency induction.

In practice, an antenna can be simply a length of wire. By adding additional conducting rods, or elements, and varying their length, spacing and layout, an antenna can be made with different properties as required. Typically, antennas are designed to operate at a specific frequency and to either radiate or receive. The vast majority of antennas are simple vertical rods, which both radiate in and receive from all directions with equal power.

They have practical use for the transmission and reception of radio signals, which can pass through walls at the speed of light over great distances.

Since radio waves are electromagnetic, there are two basically different types of antennas: electric, and magnetic.

The typical electric antenna is a vertical conductive spike. The electric field goes up and down in the spike, and this causes waves that spread out in all directions from the spike. The spike will be more efficient if it resonates. In that way, a larger electric charge can be moved with relatively less input power. Another common trick is to make half of a vertical resonant spike, and then reflect the spike in a mirror, a *ground plane*. This reduces the height of the antenna by half.

Antennas vary in size and shape depending on their intended use. Low frequency radio waves resonate in large antennas. High frequency radio waves resonate in smaller antennas.

Another major concern of antenna theory is antenna gain. Antennas can be designed to amplify signals coming from some directions and reject them from others. The gain of an antenna expresses how much it amplifies a signal.

Directional antennas use reflectors. The simplest reflector is just a second undriven antenna one wave-length behind the first. At this point, the electric or magnetic component of the wave is again at full strength, and it will reflect from the second antenna element. TV antennas use many reflecting elements to make the antenna more directional.

2. Relationship between Frequency and Wavelength

2.1.1 Frequency

Frequency is a measurement of the number of occurrences of a repeated event in a given time. Frequency is the number of cycles and parts of cycles completed per second. $f=1/t$, where T is the length of one cycle in seconds.

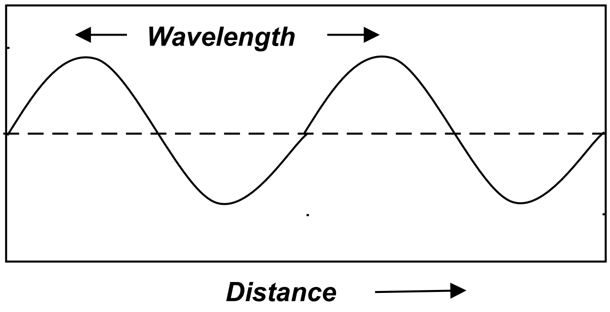
In statistics, the frequency can be the count of events during an entire experiment. The unit for frequency is Hertz Hz (named after German physicist Heinrich Rudolf Hertz), and is the inverse of seconds, the unit of time. This requires that the count of occurrences is divided by the time duration of the experiment or measurement.

In measuring the frequency of sound, electromagnetic waves (such as radio or light) or electrical signals, the frequency in Hz is the number of cycles of a repetitive waveform per second. Some old radio receivers had the dial labelled in Megacycles per second (Mc/s) rather than Mega-Hertz (MHz).

2.1.2 Wavelength

The wavelength is the distance between repeating units of a wave pattern. It is commonly designated by the greek letter lambda (λ).

In a sine wave, the wavelength is the distance between peaks:



Drawing 2: Sine wave

The x axis represents distance, and would be some varying quantity (for instance air pressure for a sound wave or strength of the electric or magnetic field for light), at a given point in time as a function of x.

Wavelength has an inverse relationship to the concept of frequency, the number of peaks to pass a point in a given time. The wavelength is equal to the speed of the wave divided by the frequency of the wave.

When dealing with electromagnetic radiation, this speed is usually the speed of light c (300,000,000 m/sec), so that the conversion becomes,

$$\lambda = c / f$$

For radio waves this relationship is easily handled with this formula: meters of wavelength = 300/frequency in MHz

2.1.3 Antenna Length

The length of an antenna is directly related to the wavelength as the antenna resonates at its resonant frequency or a sub multiple of the resonant frequency. A full wave antenna is thus calculated by the formula

$\lambda = c / f$ or $\lambda = 300 / f(Mhz)$

The ½ wave antenna is obviously as below and the sequence continues for ¼ wave etc..

$\lambda / 2 = c / f / 2$ or $\lambda / 2 = 300 / f(Mhz) / 2$

2.2 Spectrum properties

Different radio bands exhibit different properties. For example consider the lower and higher ends of the radio spectrum, the properties at the lower frequencies are deep penetration of solids and water but very low throughput can be achieved while at the higher end very large throughputs can be achieved but can propogate through air only.

2.2.1 Extremely Low Frequency (ELF)

This is the spectrum from 3 to 30 Hz. This therefore has wavelengths from 100,000 to 10,000 Km. ELF are typically only generated by lightning and natural disturbances in Earth's magnetic field. Because of the difficulty of building antennas that can radiate such long waves, ELF frequencies have been used in only a very few human-made communication systems. ELF waves can penetrate seawater, which makes them useful in communication with submarines. The USA, Russia, and India are the only nations known to have constructed ELF communication facilities. ELF waves can also penetrate significant distances into earth or rock, and "through-the-earth" underground mine communication systems use frequencies of 300 to 3000 Hz. The frequency of alternating current flowing in electric power grids, 50 or 60 Hz, also falls within the ELF band, making power grids an unintentional source of ELF radiation.

2.2.2 Very Low Frequency (VLF)

Illustration 3: Submarine, buoyant wire systems

This is the spectrum in the range from 3 kHz to 30 kHz and therefore has wavelengths from 10 to 100 kilometres. A property of this spectrum is limited bandwidth makes audio communications highly impractical, and therefore, only low data rate coded signals are used. The VLF band is used for a few radio navigation services, government time radio stations (broadcasting time signals to set radio clocks) and for secure military communication. Since VLF waves penetrate about 40m into saltwater, they are used for military communication with submarines. Submerged submarines use antenna systems connected to a buoy which can be reeled in or out allowing ELF/VLF communications via an extended and extremely long antenna. Because the frequency used is so low, (in some cases below the human voice range) the antenna can extend for miles.

Illustration 4: Satellite communications

2.2.3 Super High Frequency (SHF)

This band encompasses the range of frequencies from 3 GHz and 30 Giga-Hertz (GHz). A Ghz is 10^9 Hz. This band of frequencies is also known as the centimetre (cm) band as the wavelengths range from only 1 to 10 cm., or microwave band. Radio waves with these frequencies are called microwaves.

Satellite communications employ such a SHF and the receiving end employs the satellite dish shaped antenna to *catch* the transmitted signal. The signal is so small that the dish receives the transmitted signal and focuses the waves on the Low Noise Block (LNB) at the centre of the dish which contains a tiny antenna. The waves are so directional that strong winds on the dish can cause the angle to vary can loose the signal.

3. Types of Radiation

For the purposes of the antenna principles lecture it will concentrate on the High Frequency (HF) and Very High Frequency (VHF) bands, in a further lecture on Microwave communication the principles of that band will be covered in detail.

4. HF Communications

HF is the radio spectrum with frequencies between 1.6 and 30 MHz. Within this radio spectrum either Amplitude Modulation (AM) or a more efficient form, Single SideBand (SSB), is used. This, combined with the use of the ionosphere, a layer of ionisation gases that resides between 100 and 700km above the earth's surface, provides efficient, cost effective communications over short, medium and long distances, without the need for expensive re-transmission devices, such as the Very High Frequency (VHF) or Ultra High Frequency (UHF) repeaters or satellites, all of which have on going operational costs and a reliance on a physical infrastructure. In many remote areas , HF/SSB is the only form of communication possible.

4.1 HF propagation

When HF/SSB radio waves are generated by the transceiver there are usually two components:-

- Ground-wave, which travels directly from the transmitting antenna to the receiving antenna following the contours of the earth.
- Sky-wave, which travels upward and at an angle from the antenna, until is reaches the ionosphere (an ionised layer high above the earth's surface) and is refracted back down to earth, to the receiving antenna.

Generally speaking, ground-wave is used to communicate over shorter distances usually less than 70km. Because ground-wave follows the contours of the earth, it is affected by the type of terrain it passes over. Ground wave is rapidly reduced in level when it passes over heavily forested areas or mountainous terrain.

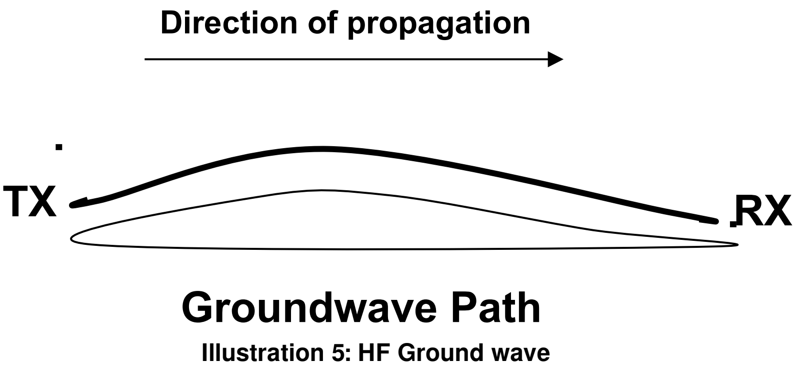


Illustration 5: HF Ground wave

Sky-wave is used to communicate reliably over medium to long distances up to 3,000km. Whilst the nature of sky-wave propagation means it is not affected by the type of terrain as in ground waves it is affected by factors involving the ionosphere.

4.2 Ionosphere Layers

The following diagram displays the layers of the earth's atmosphere and in particular the Ionosphere.

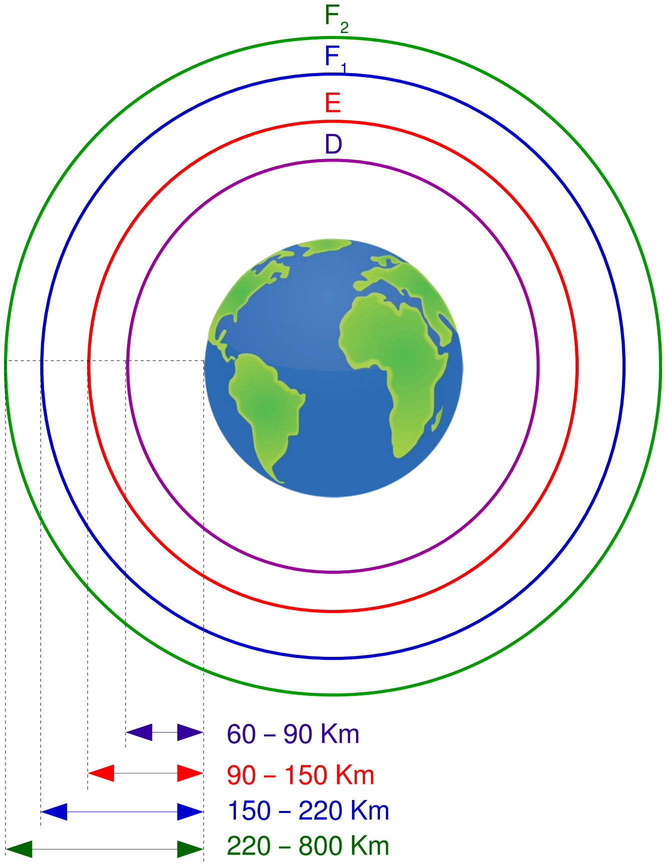


Illustration 6: The Ionosphere

Above the stratosphere is the mesosphere and above that is the ionosphere (or thermosphere), where many atoms are ionised (have gained or lost electrons so they have a net electrical charge). The ionosphere is very thin, but it is where aurora take place, and is also responsible for absorbing the most energetic photons from the Sun, and for reflecting radio waves, thereby making long-distance radio communication possible.

The structure of the ionosphere is strongly influenced by the charged particle wind from the Sun (solar wind), which is in turn governed by the level of Solar activity. One measure of the structure of the ionosphere is the free electron density, which is an indicator of the degree of ionisation.

The higher in the Ionosphere the greater the density of ions which cause the bending of the HF frequencies.

4.2.1 D Layer

Low number of ions and this layer has no effect on HF

4.2.2 E Layer

Greater refraction than the D Layer

4.2.3 F Layer

Large ion density and this layer is responsible for most HF communications.

The F_1 layer is the lower sector of the F layer and exists only during daylight hours. It is composed of a mixture of molecular ions O2+ and NO+, and atomic ions O+.

In the F_2 region, atomic oxygen becomes the dominant constituent because lighter O+ atomic ions tend this layer.

4.2.4 Skywave

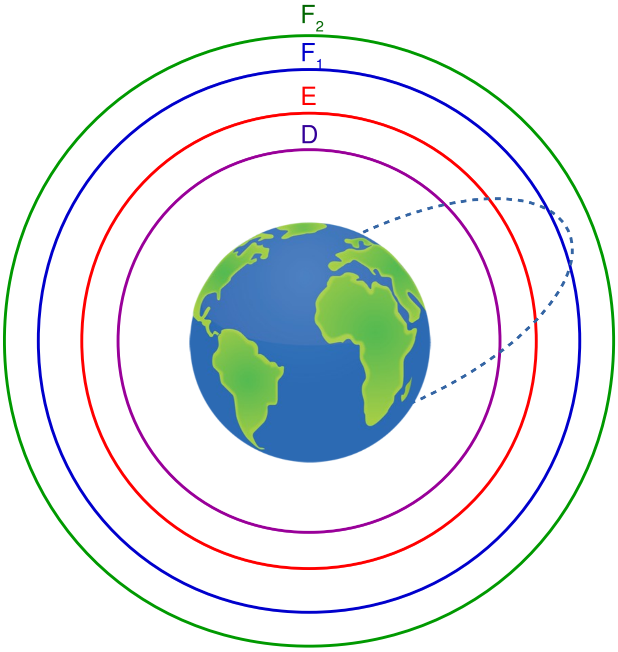


Illustration 7: Shywave propogation

4.3 Radio wave propagation illustrated

The following illustrations show the characteristics of ground-wave and sky-wave propagation during day and night time. In each illustration the height of the ionosphere above the ground is shown.

In both illustrations Station A communicates with Stations B, C and D. Propagation from Station A to B is by ground-wave. The diagrams illustrate that the ground wave is not affected by the time of day and the height of the ionosphere above the ground.

Propagation from Station A to C and D, however, is by sky-wave and as the diagrams illustrate the sky wave is significantly affected by the time of day and the height of the ionosphere above the ground.

Under each diagram there are recommended working frequencies listed. Please note that these will vary according to time of year and other factors. They are intended only as a guide and are subject to change.

4.3.1 Day

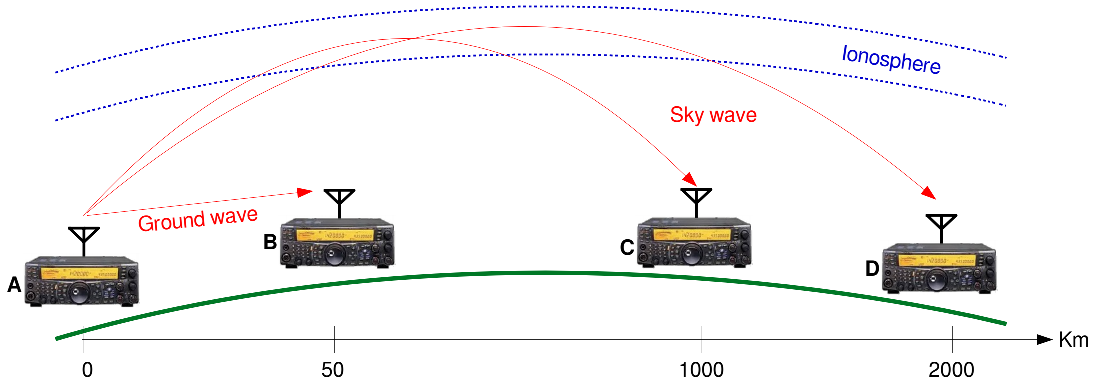


Illustration 8: HF propagation - Day

The sun is higher, the best frequency to use is higher

- A to B - Possible optimum working frequency is 3 MHz
- A to C - Possible optimum working frequency is between 7 - 9 MHz
- A to D - Possible optimum working frequency is between 13-16 MHz

4.3.2 Night

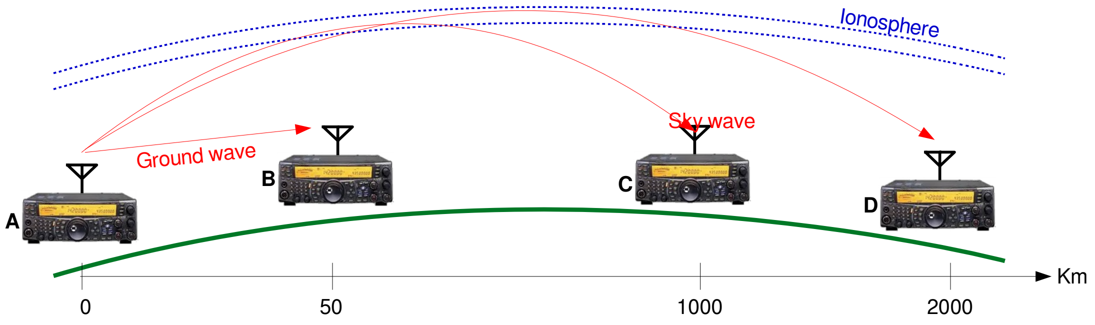


Illustration 9: HF Propodation - Night

The sun is lower, best frequency to use is lower

- A to B - Possible optimum working frequency is 3 MHz
- A to C - Possible optimum working frequency is between 5 - 7 MHz
- A to D - Possible optimum working frequency is between 9 -12 MHz

4.4 Factors which affect HF/SSB communications

There are a number of different factors which will affect the success of your communications via HF/SSB radio. These are outlined below:-

4.4.1 Frequency selection

Frequency selection is perhaps the most important factor that will determine the success of your HF/SSB communications. Generally speaking the greater the distance over which you want to communicate, the higher the frequency you should use.

4.4.2 Time of day

As a rule, the higher the sun, the higher the frequency that should be used. This means that you will generally use a low frequency to communicate early morning, late afternoon and evening, but you will use a higher frequency to cover the same distance during times when the sun is high in the sky (e.g. midday). You will need to observe the above rule carefully if your transceiver has a limited number of frequencies programmed into it, as you may only be able to communicate effectively at certain times of the day.

4.4.3 Weather Conditions

Certain weather conditions will also affect HF/SSB communications. Stormy conditions will increase the background noise as a result of 'static' caused by lightning. This background noise could rise to a level that will blank out the signals you are trying to receive.

4.4.4 Man-made electrical interference

Interference of an electrical nature can be caused by overhanging power lines, high power generators, air-conditioners, thermostats, refrigerators and vehicle engines, when in close proximity to your antenna. The result of such interference may cause a continuous or intermittent increase in the level of background noise.

4.4.5 System configuration and installation

The method in which your system is configured and installed will also affect the success of your HF/SSB communications. Your choice of antenna system and power supply is critical. Correct installation is also extremely important. An HF/SSB transceiver is generally installed using different rules to those used to install VHF or UHF transceivers. Failure to correctly install an HF/SSB system will greatly affect the communications quality you will obtain.

4.4.6 HF communications compared with VHF or UHF

Communications on any HF/SSB transceiver will sound different to that on a VHF (Very High Frequency) radio or UHF radio or telephone. This is because of the nature of HF propagation and the modulation methods used. On HF/SSB transceivers there will always be background noise evident behind the signal you are receiving and this will increase when there is electrical interference or thunderstorm activity in the area.

5. VHF/UHF Communications

VHF and UHF frequencies' propagation characteristics are ideal for short-distance terrestrial communication. Unlike HF frequencies, the ionosphere does not reflect VHF and UHF radio (except on rare occasions during solar flares) and thus transmissions are restricted to the local area (and can't interfere with transmissions thousands of kilometers away) It is also less affected by atmospheric noise and interference from electrical equipment than low frequencies. Whilst it is more easily blocked by land features than HF and lower frequencies, it is less bothered by buildings and other less substantial objects than higher frequencies. It was also easier to construct efficient transmitters, receivers, and antennas for it in the earlier days of radio. The VHF spectrum is used for broadcast audio and television, as well as two-way radios, and aircraft radios, the UHF spectrum is also used for terrestrial television and point to point microwave links.

Propagation in VHF is in the main the result of Space wave propagation. This means of propagation has two parts a direct ray which passes directly between the two antennas and a ground reflected ray which is a ray that is reflected of the ground and back up to the opposite antenna. Both rays combine to form the space wave. As a result of this means of propagation VHF is typically limited to line of sight applications.

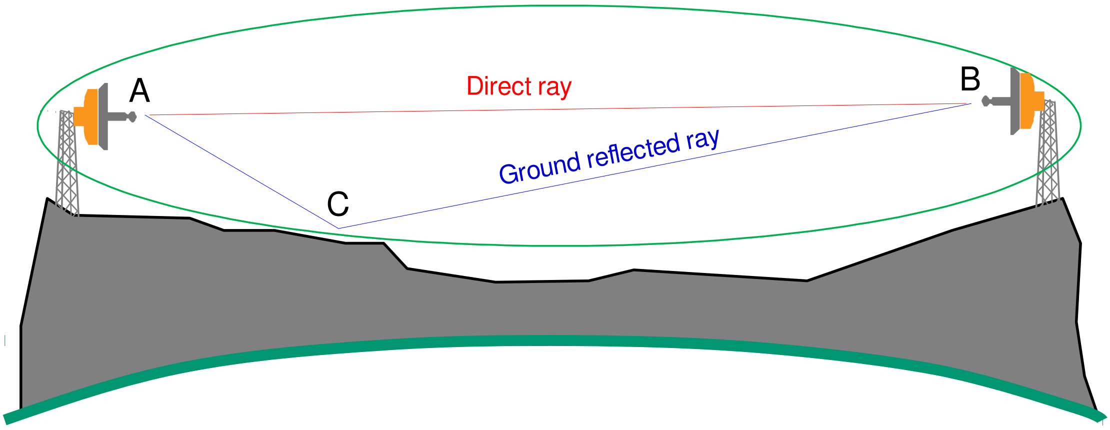


Illustration 10: UHF/VHF propagation

5.1.1 Tropospheric Propagation

Tropospheric Propagation is a propagation that occurs as a result of the Troposphere in the lower atmosphere. This layer can refract VHF radio waves though such refraction typically cannot be predicted with standard VHF radios.

6. HF and VHF Antenna

6.1 Dipole

The most basic form of antenna is called the Dipole. It is suitable for both HF and VHF applications

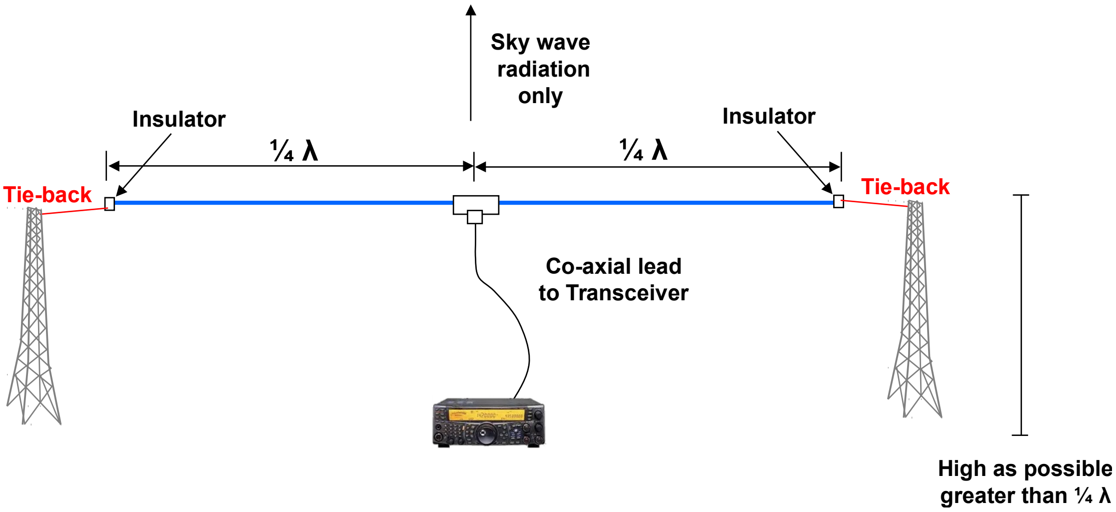


Illustration 11: Dipole antenna

A dipole antenna is a straight electrical conductor measuring 1/2 (½λ) wavelength from end to end and connected at the centre to a Radio Frequency (RF) feed line. This antenna, also called a doublet, is one of the simplest types of antenna, and constitutes the main RF radiating and receiving element in various sophisticated types of antennas. The dipole is inherently a balanced antenna, because it is bilaterally symmetrical.

Ideally, a dipole antenna is fed with a balanced, parallel-wire RF transmission line. However, this type of line is not common. An unbalanced feed line, such as coaxial cable, can be used, but to ensure optimum RF current distribution on the antenna element and in the feed line, an RF transformer called a balun (contraction of the words "balanced" and "unbalanced") should be inserted in the system at the point where the feed line joins the antenna. For best performance, a dipole antenna should be more than ½λ above the ground, the surface of a body of water, or other horizontal, conducting medium such as sheet metal roofing. The element should also be at least several wavelengths away from electrically conducting obstructions such as supporting towers, utility wires, guy wires, and other antennas.

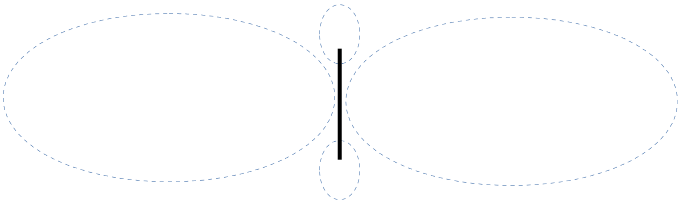


Illustration 12: Radiation pattern of a dipole antenna

Dipole antennas can be oriented horizontally, vertically, or at a slant. The polarisation of the Electro Magnetic field (EM) radiated by a dipole transmitting antenna corresponds to the orientation of the element. When the antenna is used to receive RF signals, it is most sensitive to EM fields whose polarisation is parallel to the orientation of the element. The RF current in a dipole is maximum at the centre (the point where the feed line joins the element), and is minimum at the ends of the element. The RF voltage is maximum at the ends and is minimum at the centre.

6.1.1 Antenna Gain

Antenna gain is used to indicate the increase in power of one antenna (when transmitting or receiving) as compared to another antenna. Gain is actually a ratio of power levels and is stated in decibels (dB). So how is this number used? Keep in mind that '*used to indicate the increase in power of one antenna as compared to another antenna'*. So, how much gain does the antenna have compared to say, an actual coat hanger? Probably a lot! We know that a coat hanger could not be much of an antenna. But when using dB gain to rate an antenna the reference antenna must be known!

Now, taking a vertical rod antenna with an omnidirectional radiation pattern compare it to the radiation pattern of a dipole antenna. If it was said to have'*6 dB over the reference antenna*, it would have meaning in terms of gain. Comparing the two radiation patterns at the same time, to see how one antenna is said to have gain gain.

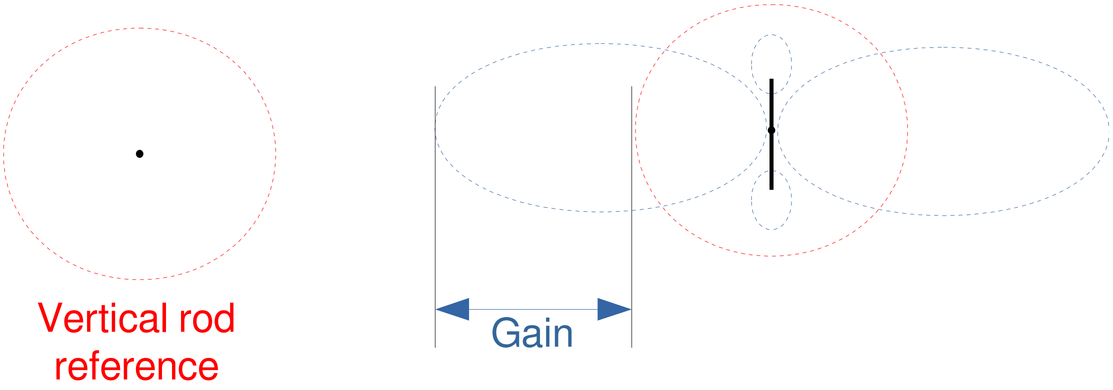


Illustration 13: Vertical rod pattern superimposed on Dipole to demonstrate gain

It can be seen that the dipole antenna concentrates it signal, making it stronger in two directions. The vertical on the other hand, spreads the signal out evenly, in an omnidirectional pattern, resulting in a weaker signal in some directions, but with a more evenly distributed coverage. The dipole uses energy off its sides and concentrates it in the two main lobes. You can see how gain translates into better signal range, by looking at the "increased range" marked on the diagram as Gain.

There is another antenna that is typically used to measure the gain of other antennas. It is known as the isotropic radiator, an antenna that exists theoretically only. Visualise the radiation pattern in 3 dimensions, like a sphere, radiating equally in every direction with the antenna as a point in the centre.

Obviously this antenna is not possible in reality due to the effect of the ground and other objects which alter the pattern of antennas. However it is a useful tool to use as a yardstick to measure real antennas by. Since it does not favour any particular direction, an isotropic radiator is said to have a gain of Zero (0 dB).

6.1.2 Antenna polarisation

A radio wave is actually made of up two fields, one electric and one magnetic. These two field are perpendicular to each other. The sum of the two fields is called the electro-magnetic field. Energy is transferring back and forth from one field to the other. This is what is known as '*oscillation*'.

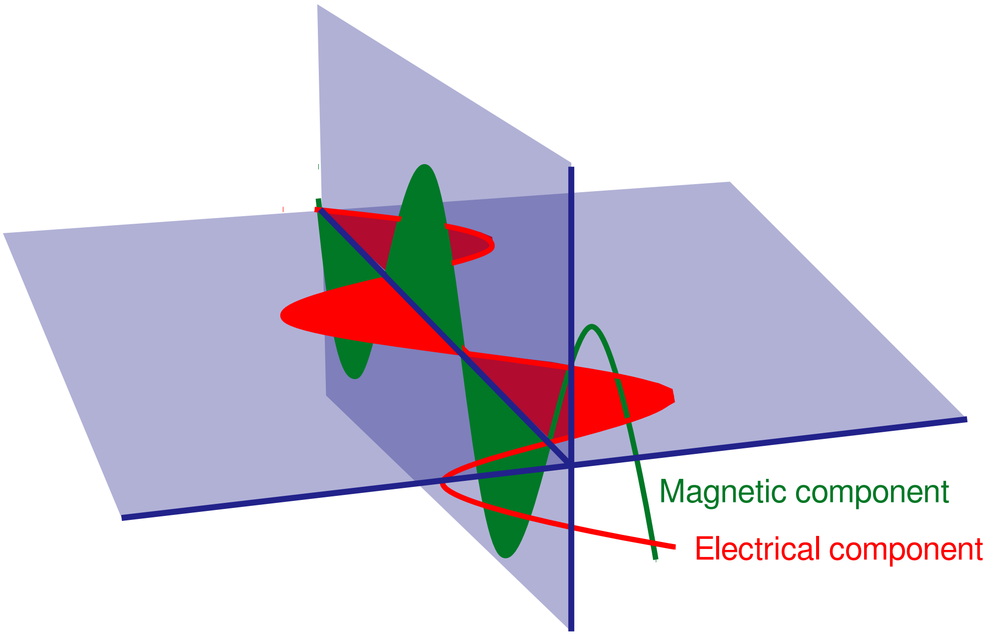


Illustration 14: Electro Magnetic field

From the radio perspective focus is primarily on one field, the electric field. Its position and direction with reference to the earth's surface (the ground) determines wave polarisation.

In general, the electric field is the same plane as the antenna's element (antenna element is that actually metal part of the antenna that is doing the radiating). So if the antenna is vertical, then the polarisation is vertical. The horizontal dipole is horizontally polarised. A vertical dipole's polarisation is consequently vertical. It is important to note that the ½ wave dipole in a vertical position has a different radiation pattern (and consequently different gain over an isotropic) than the ½ wave dipole in the horizontal position.

6.1.3 Standing Wave Ratio (SWR)

SWR is a ratio of how much power a radio is transmitting compared to how much power is reflected back by the antenna.

The lower the reflected component the better the transmission. This is an important factor in antenna tuning.

6.2 Omni-directional Antennas

"Omni-directional" is generic term for an antenna that radiates equally well in all directions. There are several antennas that are considered omni-directional.

6.2.1 1/2 Wavelength Vertical

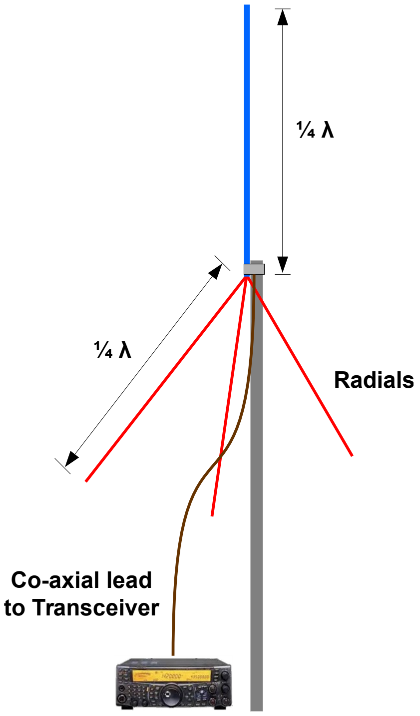


Illustration 15: Vertical antenna

Most engineers consider all vertical omni-directional antennas into the same category and call them "Ground Planes". A ground plane antenna is actually an antenna similar to the vertical dipole. Shown Illustration 15, it can be seen as hollow tubing brought out at a 45 degree angle and split into 3 sections. These rods are called *radials.* This type of antenna is really not a very high gain antenna but has a very event radiation pattern.

A much better type of antenna that has more gain is the 1/2 wavelength vertical as seen in Illustration 16.The impedance of the ½ dipole is known as 70 Ω and a standard co-axial cable like RG-58 has a n impedance of 50 Ω. It is therefore necessary to *match* these impedances with a matching device. Not matching the impedances would result in a very very high SWR.

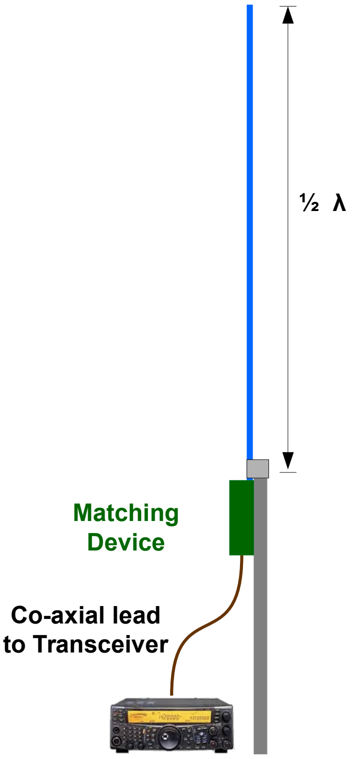


Illustration 16: 1/2 wave vertical antenna

6.2.2 VHF Discone antenna

The discone antenna as shown in Illustration 17is best suited for situations where a true omni-directional pattern is needed. The gain is several dB higher than competing omni-directional designs and construction relatively simpler because matching sections are not needed. The ideal situation for this antenna would be mounted on a tower or tall structure to provide access 360 °of coverage. The design is inherently stable both electrically and mechanically. The device is small for reduced wind-loading and impedance changes due to ice or rain on the antenna are minimal especially if enclosed in a shroud such as a 6 cm Poly Vinyl Chloride (PVC) pipe.

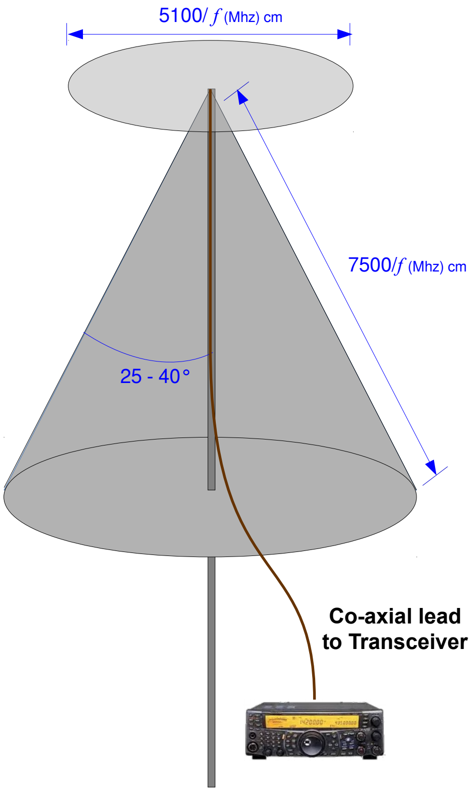


Illustration 17: Discone antenna

6.3 Directional Antennas

An antenna is known as "directional" if its pattern strongly favours a certain direction. A directional works by concentrating the signal in one direction at the expense of other directions. It is also commonly referred to as the "Beam" antenna.

6.3.1 The Yagi Beam

The yagi is very simple. The basic yagi consists of three elements, as shown in Illustration 18. The middle element is a 1/2 wave dipole antenna. This element is generically called the *driven element*. This is because it is the only element that is connected directly to the radio, it actually drives the whole antenna. The other two outer elements are generically called parasitic elements. One is called the *reflector* and the other is called the *director* element. The reflector reflects RF energy, the director directs RF energy. There is no magic circuitry located inside the elements, they are simply straight rods! The reflector element is typically 5% longer than the driven element and the director is typically 5% shorted than the driven element.

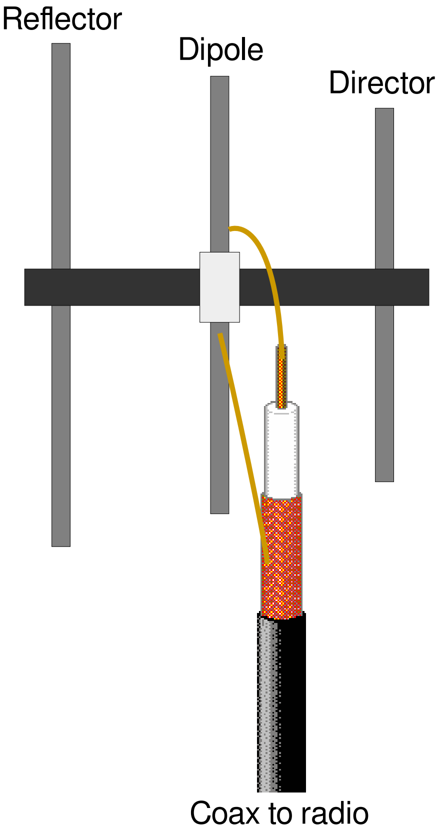


Illustration 18: Yagi beam

As a signal arrives it strikes all three elements hence generates a current on each element. Even though the current is very low, this current induced on the antenna actually re-radiates off the antenna again. The signals are re-radiated by the director and reflector and arrive at the driven element in-phase with one another (the two re-radiated signals and the original signal). These signals reinforce each other and make the incoming signal much stronger.

The radiation pattern is as shown in Illustration 19, very high gain in one direction.

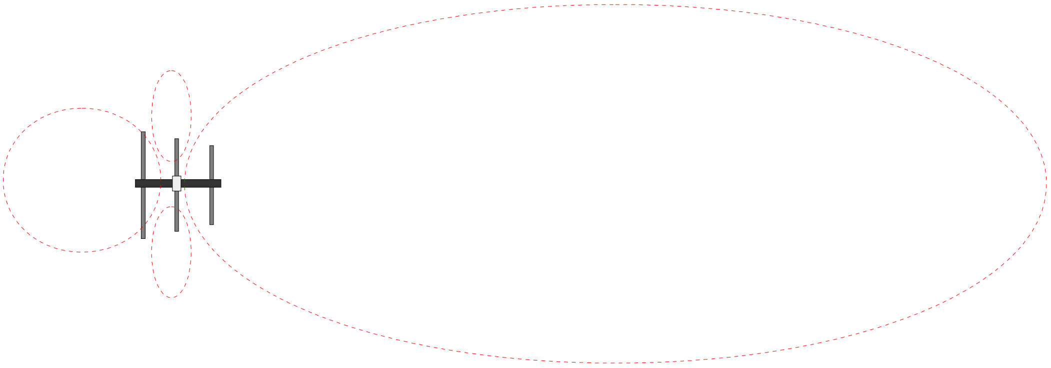


Illustration 19: Yagi radiation pattern

6.3.2 The Cubical Quad

The Cubical Quad is a. There really is not any new principles involved here, the quad works on the same principles as the Yagi. However, instead of using the dipole antenna for the driver, director and reflector elements, we are going to use the quad loop antenna. The quad loop was invented by an amateur radio operator by the name of Clarence Moore. He was working for a broadcast station in Quito, Ecuador.

It is called a quad loop because it is typically configured as a square (quad = 4, 4 sides to a square). The quad loop measures exactly 1/4 of a wavelength on each side. As you can see, this antenna actually is a Full wavelength antenna as compared to the 1/2 wavelength driven element of the Yagi. The loop is usually made from a 10 M piece of copper wire. The Quad loop alone has 2 dB of gain over the dipole antenna. So, using this as the driver element means it has at least 2 dB of gain over a yagi antenna with the same number of elements.

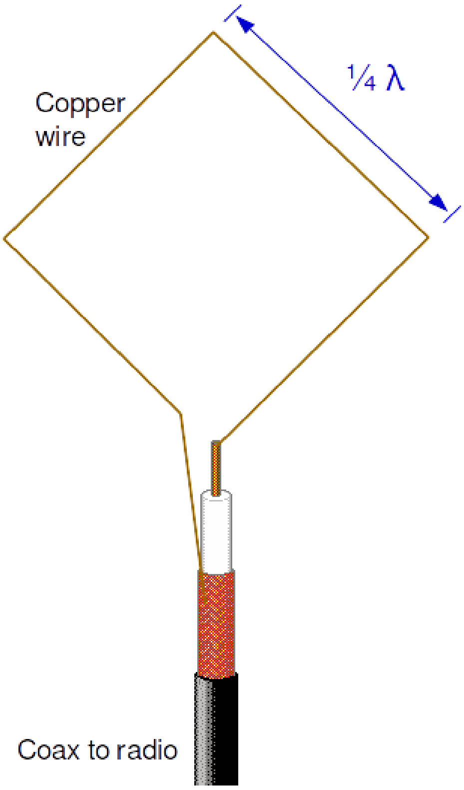


Illustration 20: Cubical quad

7. Transmission Lines

Most radios use coaxial (coax) cable to feed their antenna. Another name for the cable used to conenct the radio to the antenna is *feed line*. Feed line is a generic term for all types of cable including coax. Coax has been around for a long time and became very popular after World War II. Coax cable consists of two concentric wires, as shown in Illustration 21. It is important to note that coax cable is unbalanced, no current flows on the outside shield of the cable.

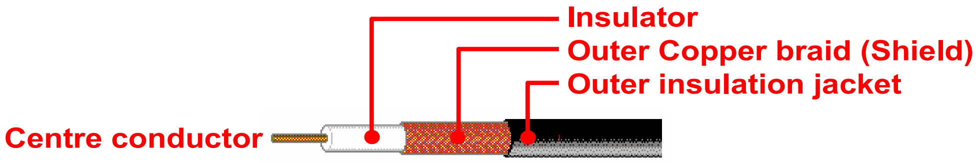


Illustration 21: Transmission line

Coax has several advantages over twin lead feed lines. Coax can be ran alongside metals and other transmission lines without interference. It is even possible to bury some types of Coax, if the outer jacket is suitable. Usually manufacturers rate their coax in decibels (dB) of attenuation per 30m lengths. So at a given frequency, exactly a 30m length would incur a loss of however many dB in the manufacture specifications.

Loss is primary dependent on the coax shield and dielectric. The shield is the outer wire braid that surrounds the inside of the cable. A thick, tight braid results in less loss. Also, the dielectric (usually white), the plastic type material that separates the inside wire from the outside braid has an effect on cable loss. Cables that use foam dielectric, that is where the insulation is mixed with an inert gas, have very low loss. It is important to use quality low loss cable. Connections at the coax ends are also essential to be correctly connected or higher losses will be generated.

7.1 Coax Impedance

Coax Impedance cannot be measured with a multi-meter for example. It is determined by the spacing (ratio) of the inner wire and outer braid. The two impedance's mainly used are 50Ω, used in radio and networking systems and 75 Ω typically associated with TV and video systems.

8. HF Antennas

8.1 Long Wire antenna

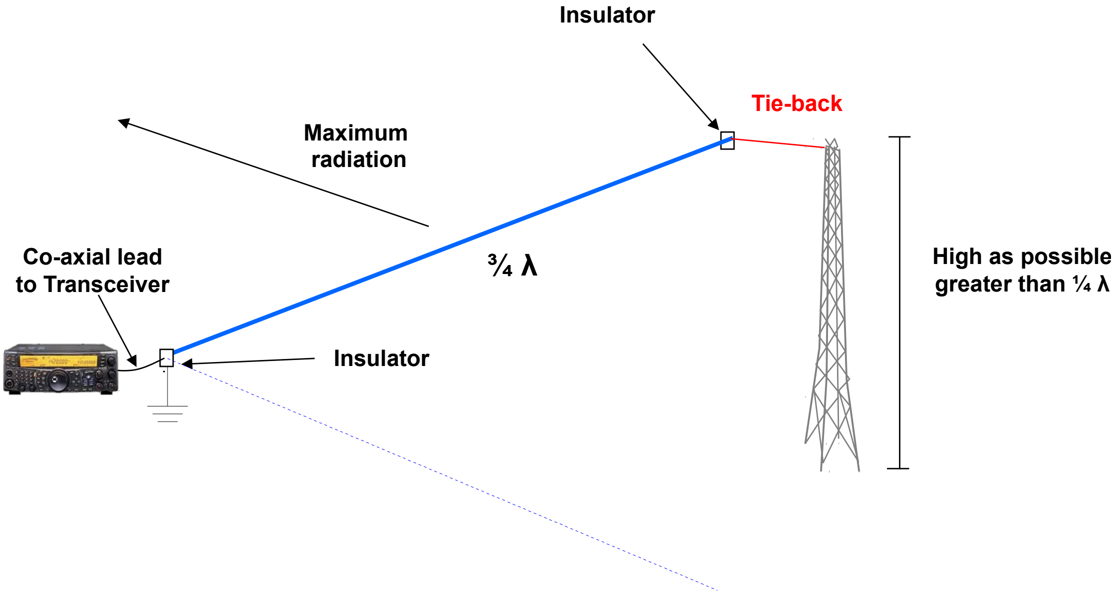
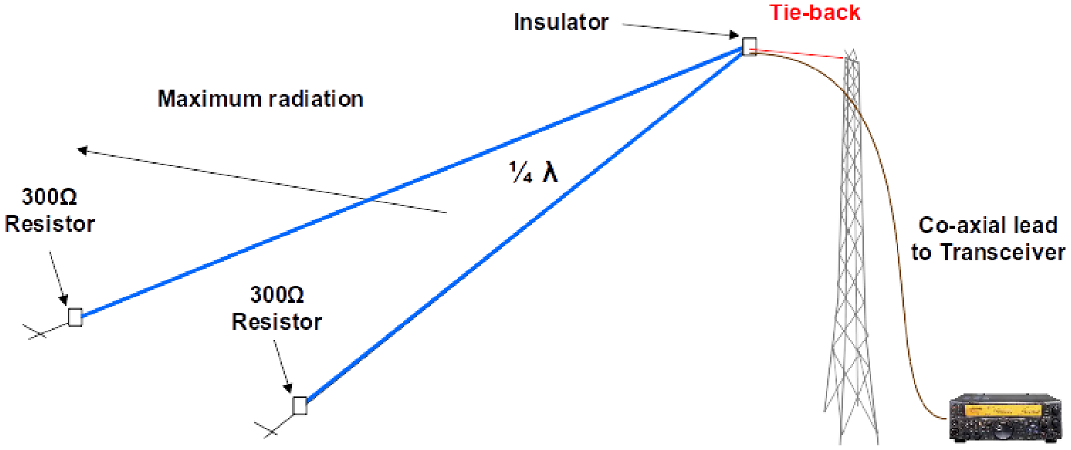


Illustration 22: Long wire antenna

8.2 Sloping 'V' antenna



300Ω Resistors prevent standing waves

Illustration 23: Sloping 'V' antenna

8.3 ¾ λ Inverted-L antenna

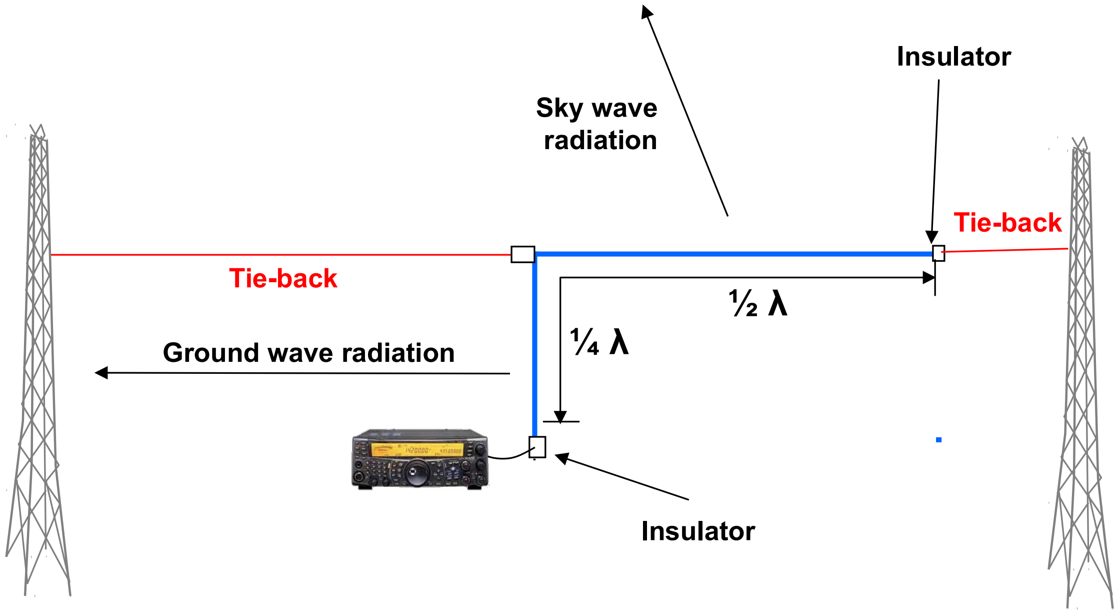
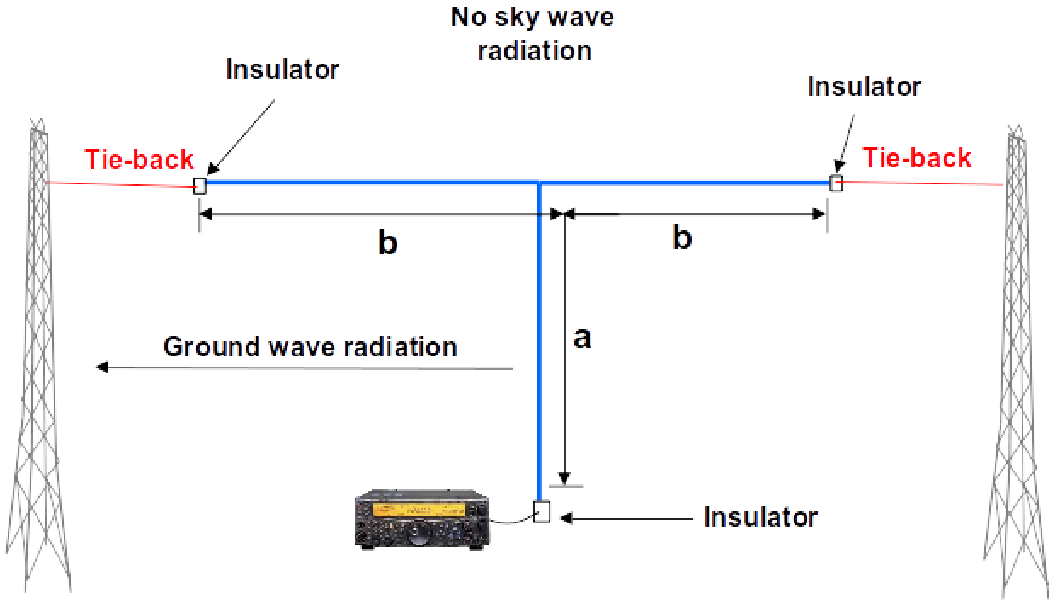


Illustration 24: ¾ λ Inverted-L antenna

8.4 T antenna



‘a’ + ‘b’ = ¼ λ with ‘a’ as long as possible

Illustration 25: T antenna

8.5 Vertical wire antenna

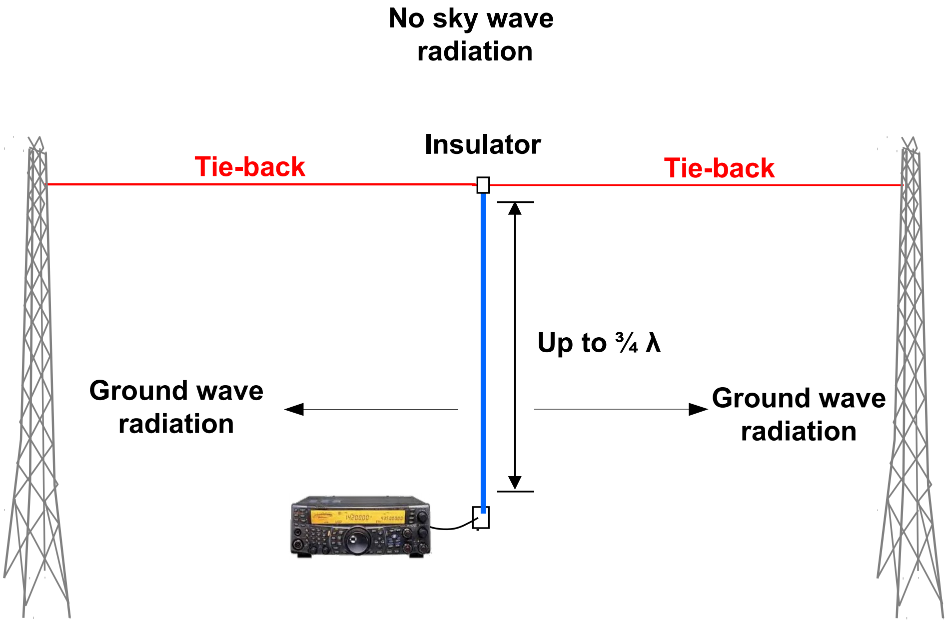


Illustration 26: Vertical wire antenna

9. Self-test Quiz

1. Describe the difference between ELF and VLF.
2. Contrast the difference between HF Skywave and HF Ground wave.
3. What is the importance of matching impedance between a transmission line and an antenna?.
4. List the dimensions of a Discone antenna designed for operation at 88 MHz.
5. What type of antenna would you consider for operation between two locations 1,000 Km apart and why ?

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