# CMP4204
# Wireless Technologies

# Lecture 2

# Antenna Principles

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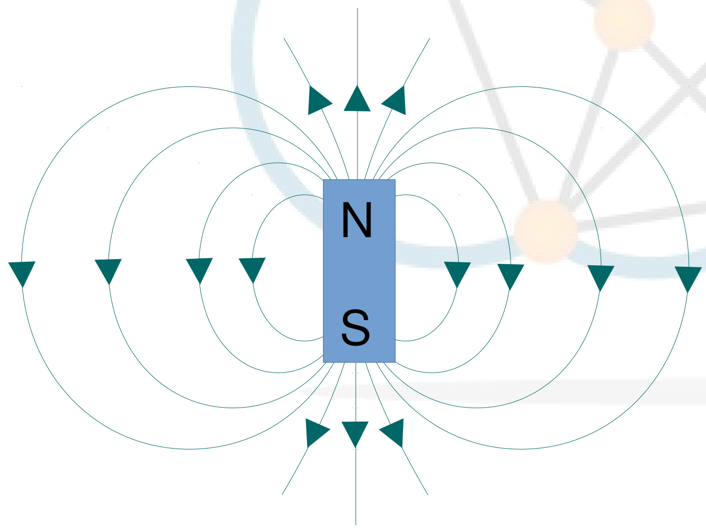
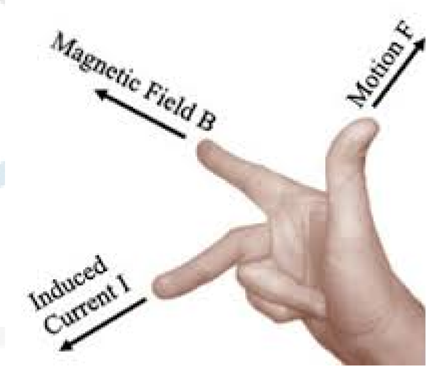
# Magnetism

- Magnetism is a phenomenon by which materials exert an attractive or repulsive force on other materials.
- Some well known materials that exhibit magnetic properties are iron, some steels, and the naturally occurring mineral lodestone.
- In reality all materials are influenced to one degree or another by the presence of a magnetic field, although in some cases the influence is too small to detect without special equipment.

# Magnetism

- For the case of electric current moving through a wire, the resulting field is directed according to Fleming's "right hand rule".
  - thu**M**b → Motion
  - **F**irst finger → Magnetic **F**ield
  - Se**C**ond finger → **C**urrent



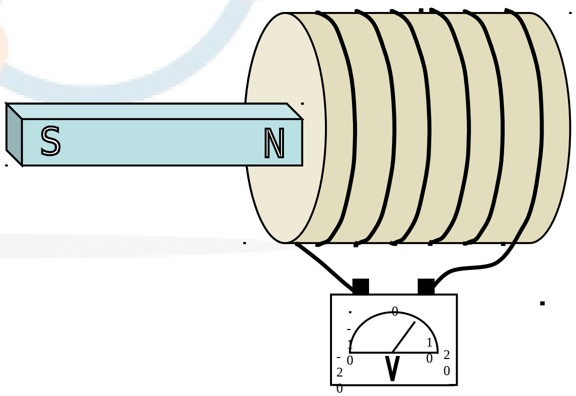



# Magnetism

- Hans Christian Ørsted in 1820 noticed that a compass needle is deflected when brought into the vicinity of a current carrying wire.
- Therefore currents induce in their vicinity magnetic fields.
- In 1831 Michael Faraday made his discovery of electromagnetic induction.

# Magnetism

- 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.
- Faraday confirmed that a moving magnetic field is necessary in order for electromagnetic induction to occur.



# Theory of Antenna

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# Theory of Antenna

- An antenna in electronics, sometimes called an "aerial," is an arrangement of conductors designed to radiate an electromagnetic field in response to an applied alternating electromotive force (EMF) also known as alternating electrical current.
- Antennas are designed to operate at a specific frequency and to either radiate or receive.

# Theory of Antenna

- 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.

# Theory of Antenna

- 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.
- 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.

# Relationship between Frequency and Wavelength

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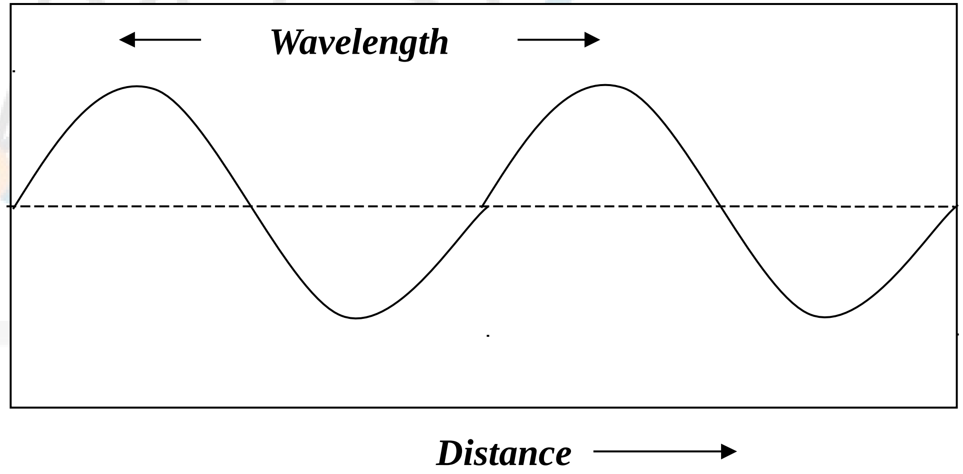
# Frequency

- 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 (Hertz).

# Wavelength

- The wavelength is the distance between repeating units of a wave pattern.
- It is commonly designated by the greek letter lambda ($\lambda$).
- In a sine wave, the wavelength is the distance between peaks:



# Wavelength

- Wavelength has an inverse relationship to frequency, the number of peaks to pass a point in a given time.
- Speed of light c (300,000,000 m/sec), so that:
  - $\lambda = c / f$
  - $\lambda = 300 / f\ (Mhz)$

# 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 and the sequence continues for ¼ wave etc..
  - $\lambda / 2 = c / f / 2$ or $\lambda / 2 = 300 / f(Mhz) / 2$

# Calculating Wavelength

- Calculating wavelength
  - $\lambda = c / f$
    - $\lambda$ = Wavelength (Metres)
    - $c$ = Speed of light (300, 000, 000 M/sec)
    - $f$ = Frequency (Hz)

Example : Wavelength at 5 MHz

*λ = 300, 000, 000 / 5, 000, 000 = 60 M*
*½ λ = 30 M*
*¼ λ = 15 M*

# Calculating Wavelength

- Calculating wavelength maybe thus simplified as:
  - $\lambda = 300 / f(MHz)$

Example : Wavelength at 5 MHz

$\lambda = 300 / 5 = 60\ M$
$\frac{1}{2}\lambda = 30\ M$
$\frac{1}{4}\lambda = 15\ M$

# Properties of radio bands

- **Extremely Low Frequency (ELF)**
  - 3 to 30 Hz.
  - Wavelengths: 100,000 to 10,000 Km.
  - Penetrate significant distances into earth or rock.
  - Massive antenna systems, cover whole mountains.
- **Very Low Frequency (VLF)**
  - 3 kHz to 30 kHz
  - Wavelengths: 10 to 100 kilometres.
  - Used for a few radio navigation services, government time radio stations and for secure military communication.
  - VLF waves penetrate about 40m into saltwater, they are used for military communication with submarines.
- **Super High Frequency (SHF)**
  - 3 GHz and 30 Giga-Hertz (GHz) ( x $10^9$ Hz).
- Wavelengths: 1 to 10 cm.
  - Centimetre (cm) band or microwave band with radio waves called microwaves.
  - Satellite communications employ such a SHF and the receiving end employs the satellite dish shaped antenna to catch the transmitted signal.
  - Low Noise Block (LNB) at the centre of the dish which contains a tiny antenna.

Buoyant VLF systems

Satellite systems

# Calculating Wavelength - Exercise

- Exercise
  - Calculate the following wavelengths
    - ¾ λ at 6 MHz
    - ¼ λ at 15 MHz
    - ¼ λ at 60 MHz
    - λ at 400 MHz
  - What do you notice ?

# Types of Radiation

# High Frequency (HF)

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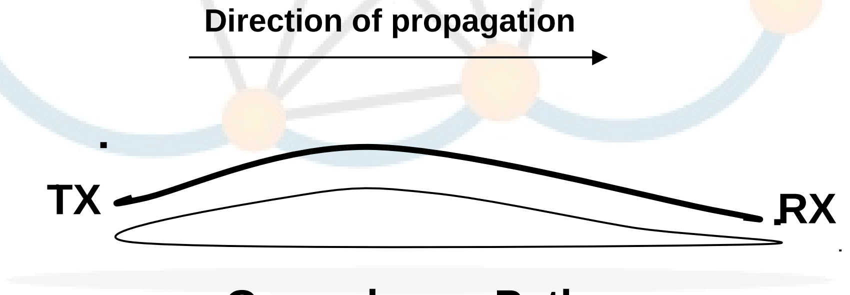
# HF Communications and propagation

- HF (High Frequency) is the radio spectrum with frequencies between 1.6 and 30MHz.
  - Amplitude Modulation (AM)
  - Single Side Band (SSB)
- Ground wave, along earth surface - 70Km
- Skywave, off Ionosphere – Thousands Km
  - layer of ionisation gases that resides between 100 and 700km above the earth.

# HF propagation - Groundwave

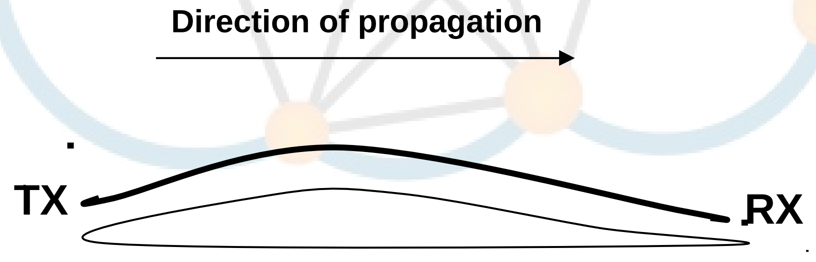
- Groundwave Stations.
- The proper positioning of a vertical antenna for Groundwave stations is important because it has a marked effect upon the range of the set.
- They are greatly influenced by objects close to the antenna.




Groundwave Path

# HF propagation - Groundwave

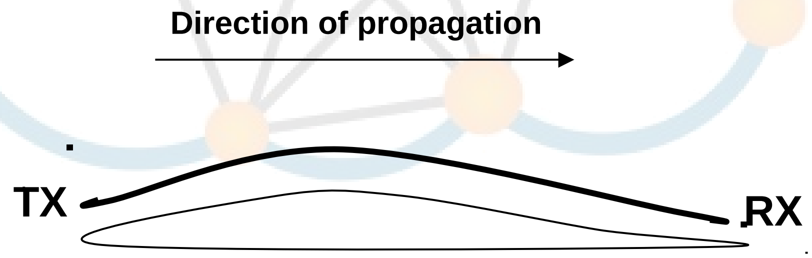
- Groundwave Stations aim at:
  - Open space around the antenna, particularly in the direction of the distant station.
  - High ground in preference to low ground.
  - Forward slope of a hill in preference to reverse slope.




Groundwave Path

# HF propagation - Groundwave

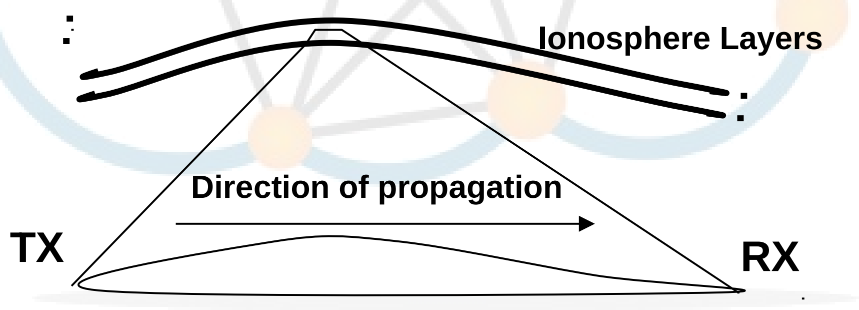
- Groundwave stations avoid:
  - Electrical power lines, telephone lines and any large object which is a good conductor of electricity such as metal bridges, water tanks or steel framed buildings.
  - Places where vehicles may be expected.




**Groundwave Path**

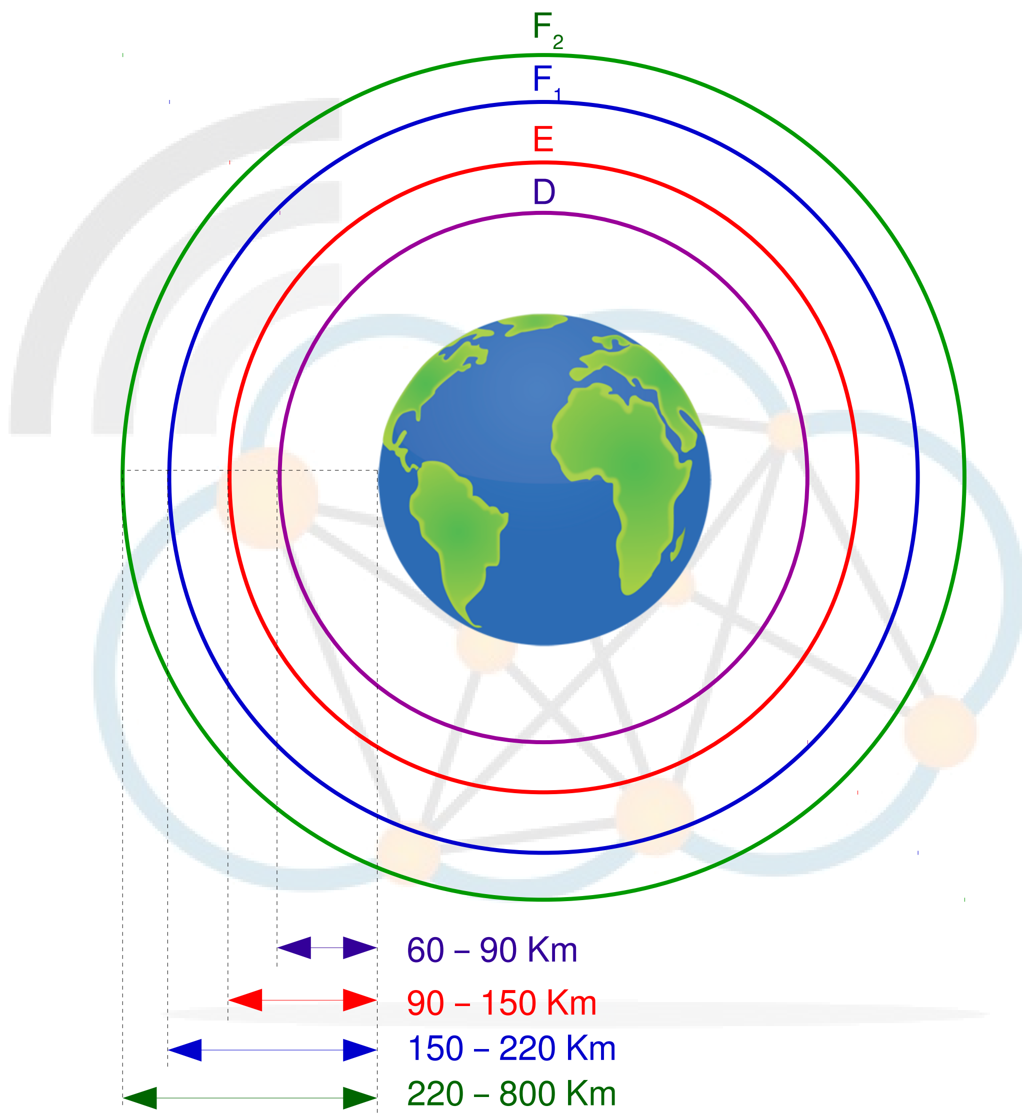
# HF propagation - Skywave

- Skywave Stations
  - Positioning of Skywave antenna is not as critical as that of Groundwave.
  - The horizontal part of the antenna should be open to the sky, avoid trees or buildings in front of antenna.




Skywave Path

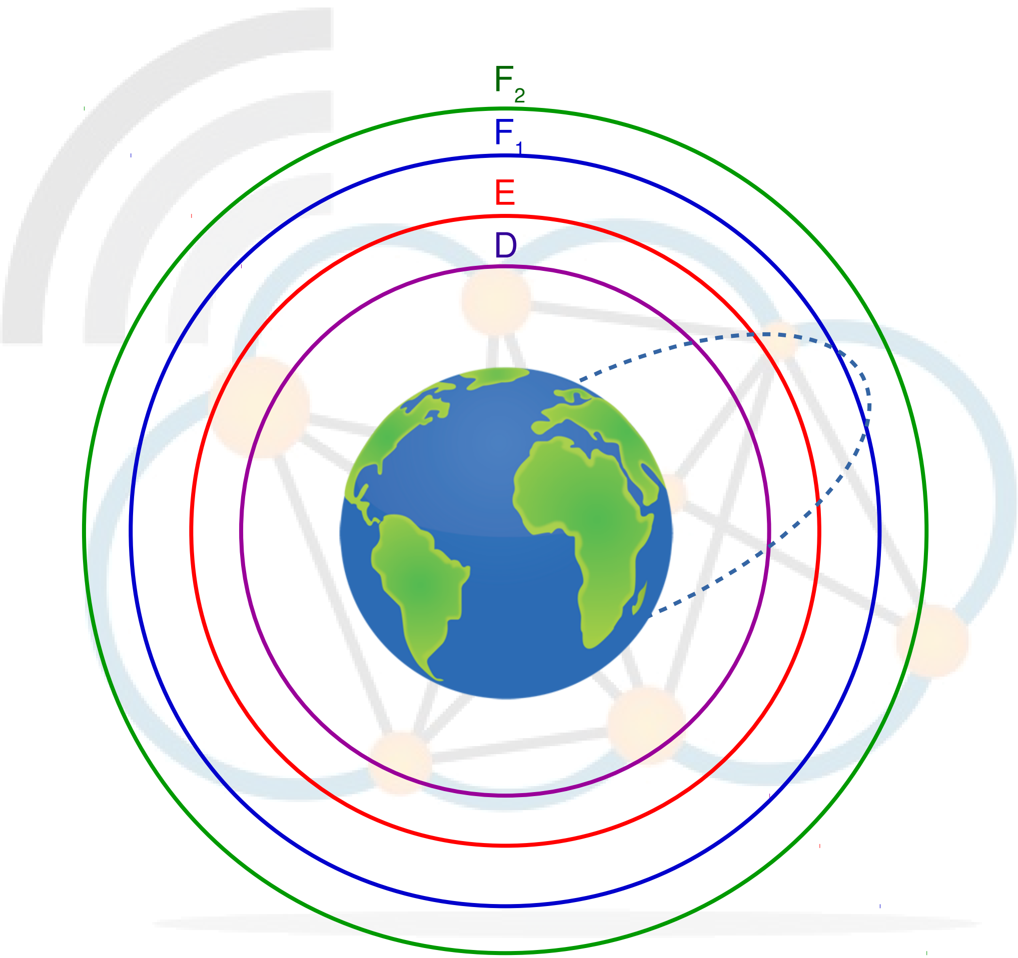
# The Ionosphere



# The Ionosphere

- Above the surface of the earth.
- During the day the sun keeps this area ionised and higher frequencies (above 5 MHz) are best.
- At night time the $F_1$ and $F_2$ layers combine due to non-ionisation and it is better to use lower frequencies like 3 MHz or so which are less prone to punch through.
- HF prone to more interference at night time.

# The Ionosphere, skywave

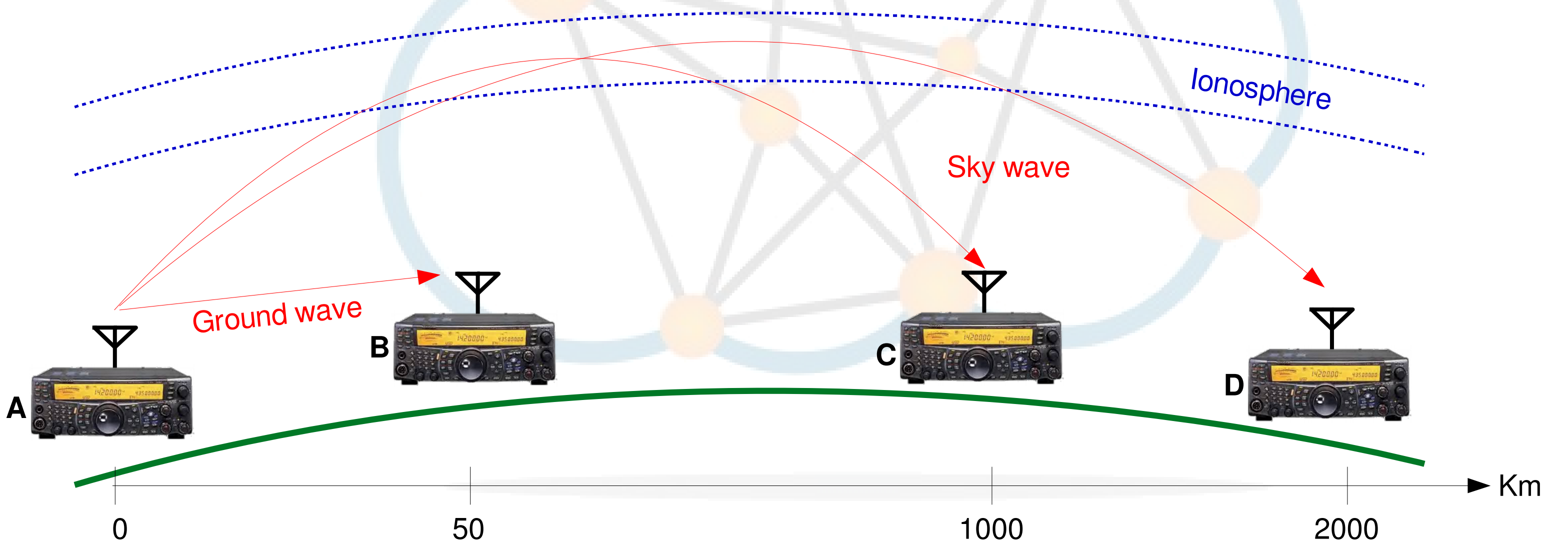


# HF propagation

- The higher in the ionosphere the greater the density of ions which cause the bending of the HF frequencies.
- D - Layer
  - Low number of ions and this layer has no effect on HF.
- E - Layer
  - Greater refraction than the D Layer.
- 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.

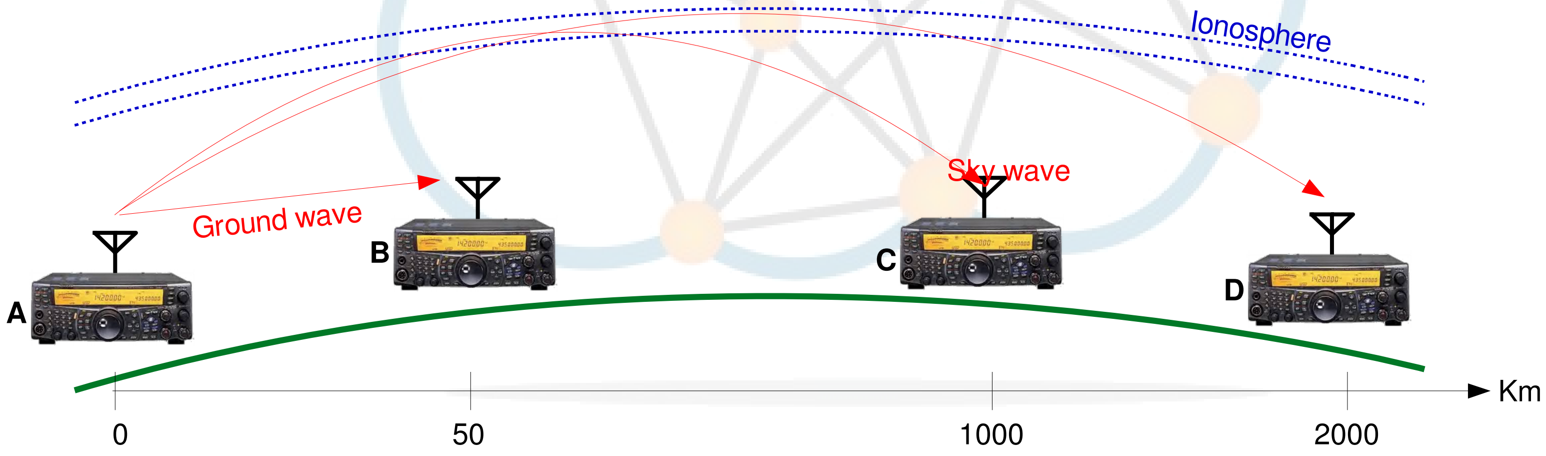
# HF propagation - Day

- The sun is higher, the best frequency to use is higher:
  - A to B - Possible optimum frequency is 3 MHz
  - A to C - Possible optimum frequency is between 7 - 9 MHz
  - A to D - Possible optimum frequency is between 13-16 MHz



# HF propagation - Night

- The sun is lower, best frequency to use is lower
  - A to B - Possible optimum frequency is 3 MHz
  - A to C - Possible optimum frequency is between 5 - 7 MHz
  - A to D - Possible optimum frequency is between 9 -12 MHz



# Factors which affect HF/SSB comms

- **Frequency selection**
  - For HF/SSB communications the greater the distance over which you want to communicate, the higher the frequency you should use.
- **Time of day**
  - As a rule, the higher the sun, the higher the frequency that should be used.
  - Low frequency to communicate early morning, late afternoon and evening
  - Higher frequency to cover the same distance during times when the sun is high.
- **Weather Conditions**
  - Stormy (lightning) conditions increase background noise due to 'static'.
- **Man-made electrical interference**
  - Overhanging power lines, high power generators, air-conditioners, thermostats, refrigerators and vehicle engines.

# Types of Radiation

## Very/Ultra High Frequency (VHF/UHF)

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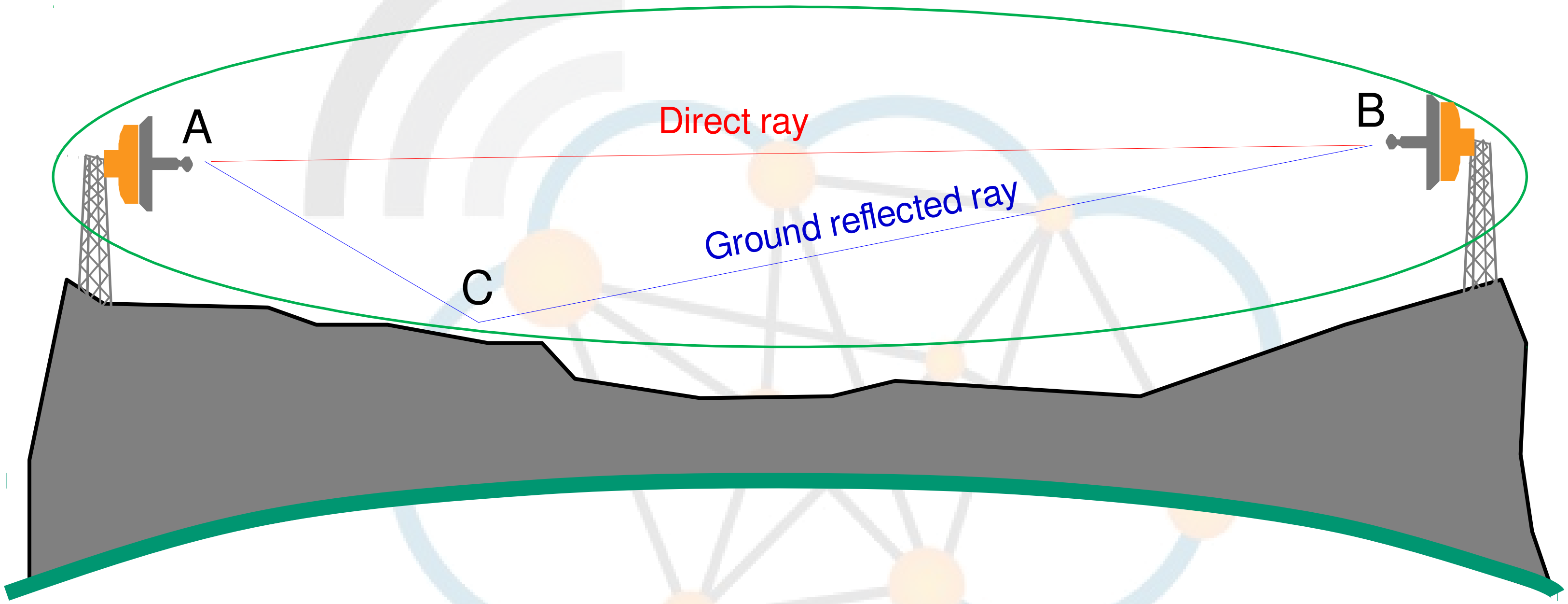
# VHF/UHF Communications

- VHF and UHF frequencies' propagation characteristics are ideal for short-distance terrestrial communication.
- The ionosphere does not reflect VHF and UHF radio and transmissions are restricted to the local area.
- Less affected by atmospheric noise and interference from electrical equipment than low frequencies.
- Easily blocked by land features but is less infleuenced by buildings and other less substantial objects than higher frequencies.

# VHF/UHF Communications

- The VHF spectrum is used for:
  - Broadcast Audio
  - Broadcast Television
  - Two-way radios
  - Aircraft radios
- The UHF spectrum is used for:
  - Terrestrial television
  - Point to point microwave links

# VHF/UHF propagation



# VHF Propagation

- Propagation in VHF is in the main the result of Space wave propagation.
  - Direct ray
  - Ground reflected ray.
- Both rays combine to form the space wave.
- This means of propagation VHF is typically limited to line of sight applications.

# Tropospheric Propagation

- Troposphere, lowest portion of earths atmosphere.
- 17 – 20 Km from the earth.
- Tropospheric Propagation can refract VHF radio waves though such refraction typically cannot be predicted with standard VHF radios.

# HF and VHF

# antenna

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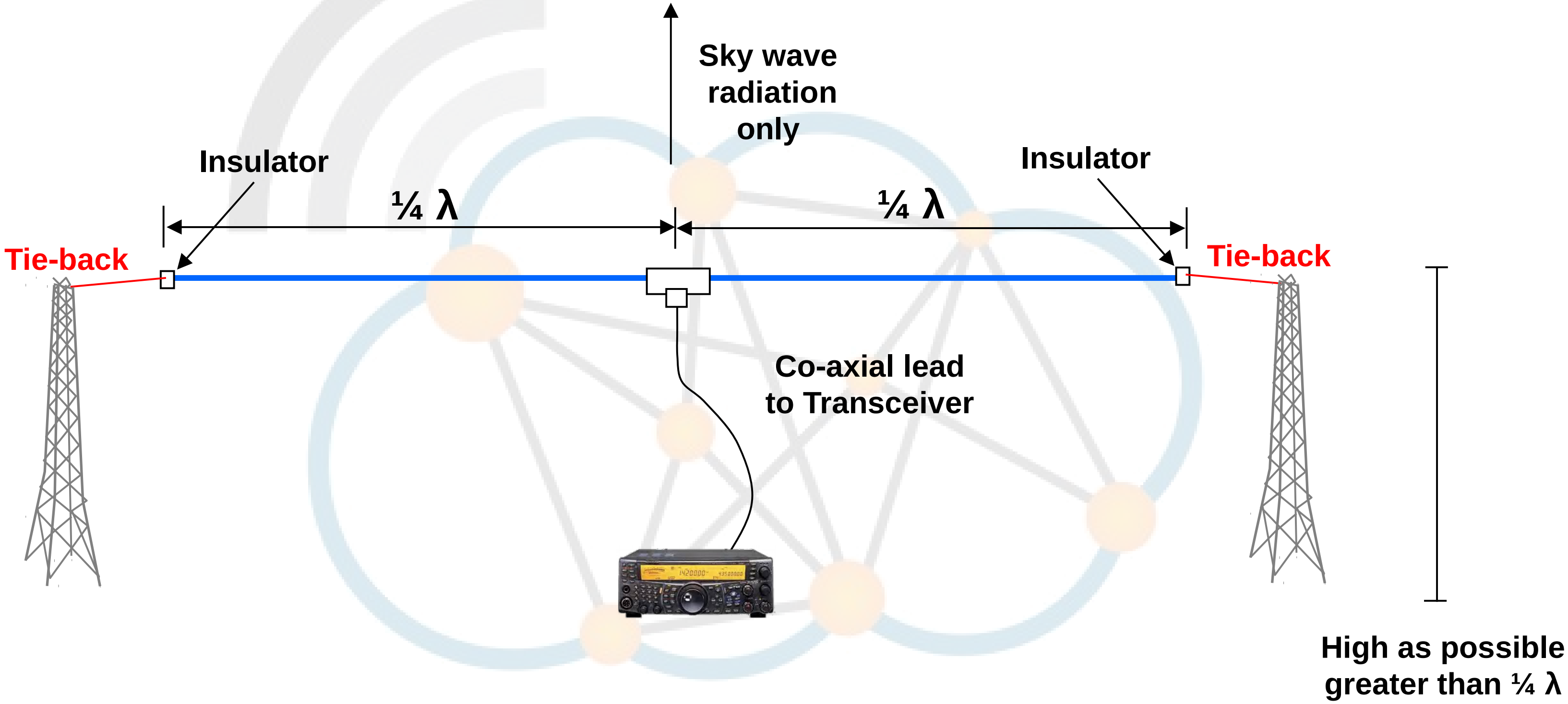
# Dipole Antenna

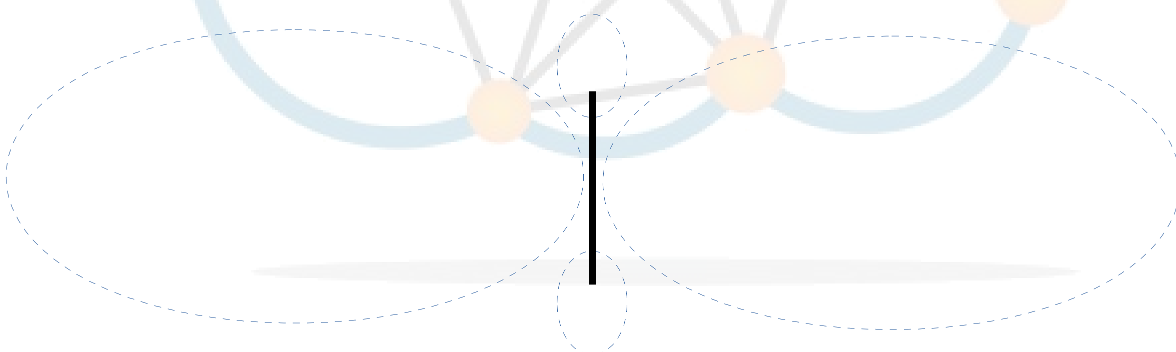


# Dipole Antenna

- The most basic form of antenna is called the Dipole. It is suitable for both HF and VHF applications.
- A dipole antenna is a straight electrical conductor measuring 1/2 wavelength from end to end and connected at the centre to a radio-frequency (RF) feed line.
- 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.

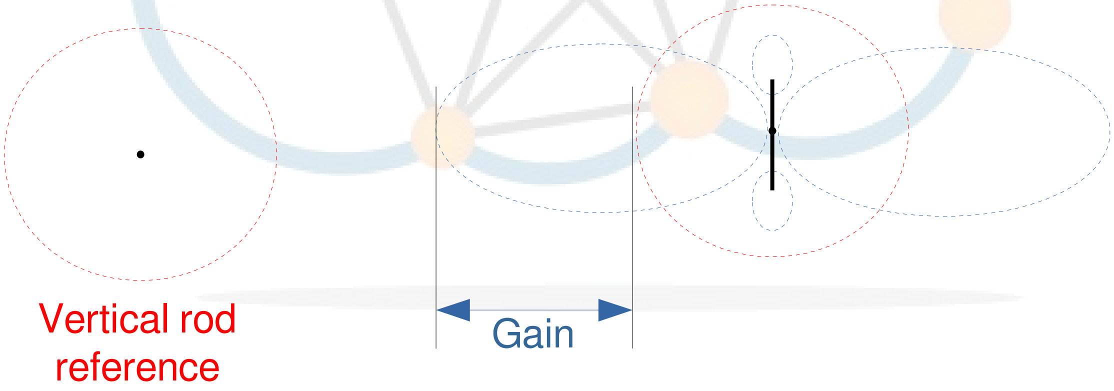
# Dipole Antenna

- Dipole antennas can be oriented horizontally, vertically, or at a slant.
- The polarisation corresponds to the antenna orientation.
- 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.



# 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).
- Compare vertical rod antenna with an omnidirectional radiation pattern compare it to the radiation pattern of a dipole antenna.

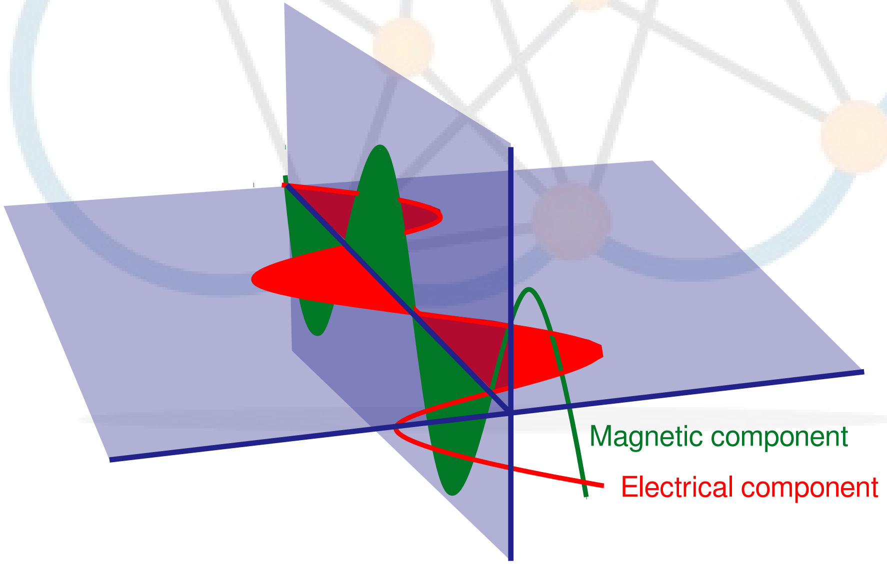


# Antenna Gain

- Isotropic radiator, an antenna that exists theoretically only.
- A radiation pattern in 3 dimensions, like a sphere, radiating equally in every direction with the antenna as a point in the centre.
- Useful tool to use as a yardstick to measure real antennas by.
- A gain of Zero (0 dB).

# Antenna polarisation

- A radio wave is actually made of an electric and a magnetic field.
- 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".



# Antenna polarisation

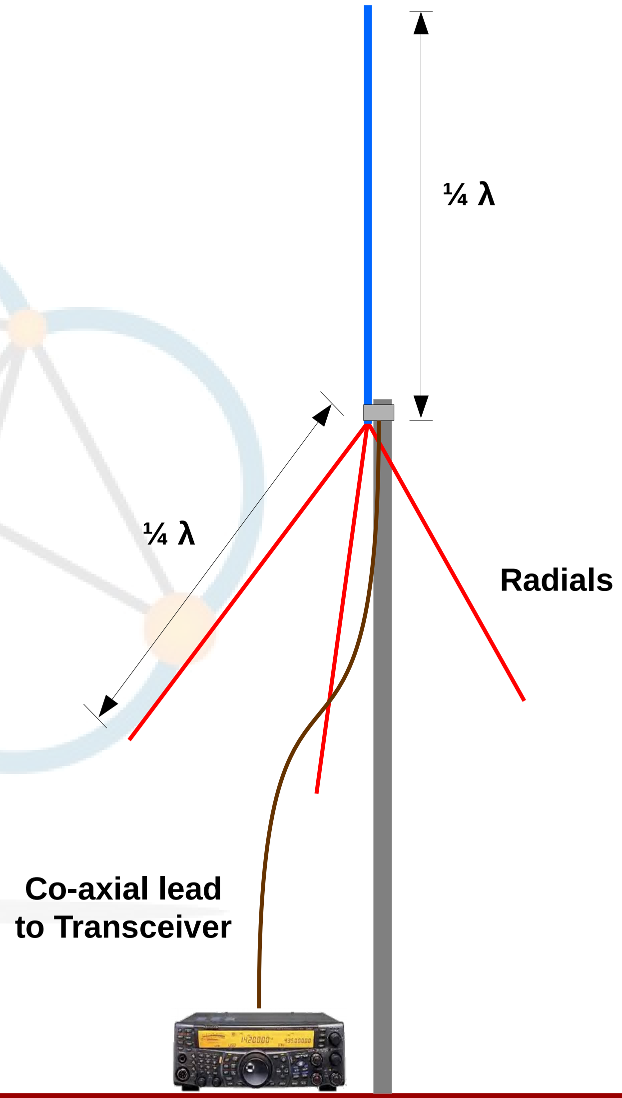
- Electric field is the same plane as the antenna's element.
- If the antenna is vertical, then the polarisation is vertical.
- A 1/2 wave dipole in a vertical position has a different radiation pattern than the 1/2 wave dipole in the horizontal position.

# Standing Wave Ratio (SWR)

- Standing Wave Ratio (SWR).
  - A ratio of how much power a radio is sending out compared to how much power is reflected by the antenna.

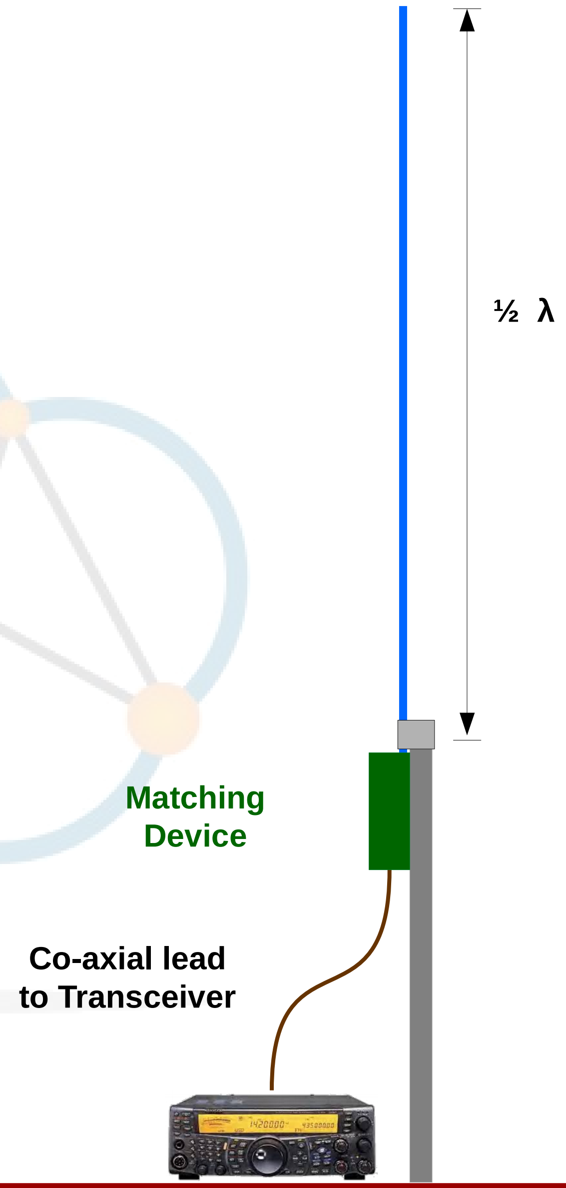
# Omni-directional Antennas

- Antenna of hollow tubing is now instead brought out at a 45 degree angle (and split into 3 sections) out from where it is on the vertical dipole.
- Rods arecalled "radials".
- Low gain antenna.



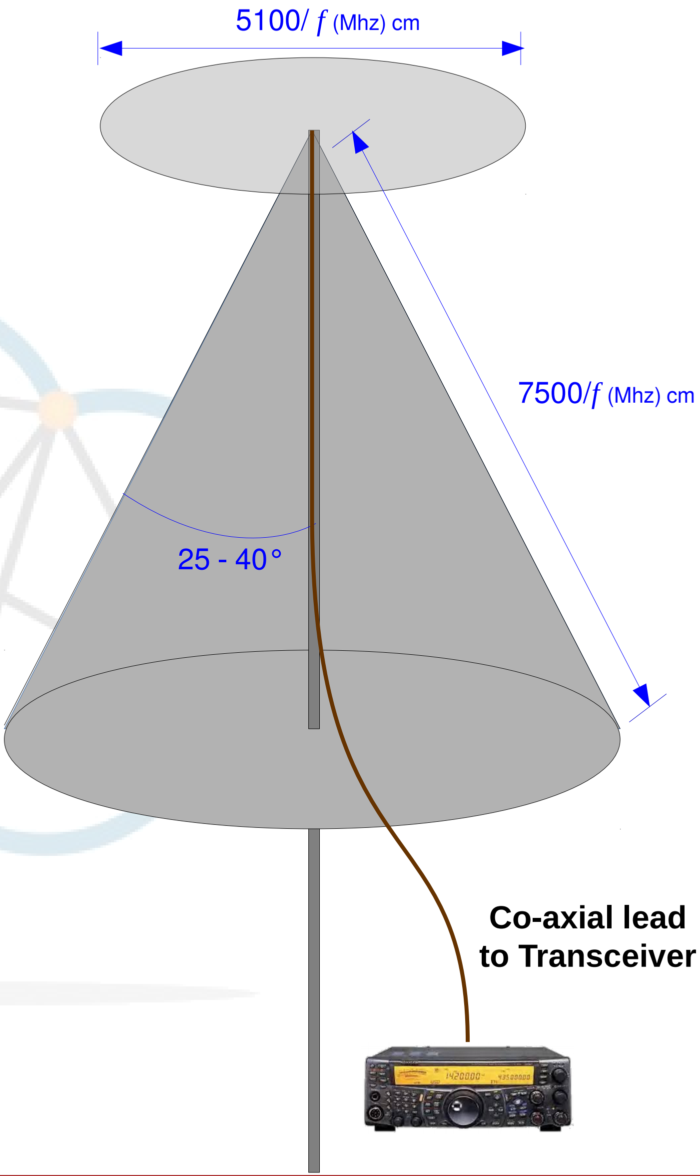
# Omni-directional Antennas

- A much better type of antenna that has more gain is the ½ λ vertical.
- Impedance of the ½ dipole known 70 Ω
- Co-axial cable 50 Ω
- Matching device 70 Ω to 50 Ω.



# Omni-directional Antennas - Discone

- True omni-directional pattern required.
- Gain is several dB higher than competing omni-directional designs.
- The ideal situation for this antenna would be mounted on a tower or tall structure to provide access 360 over a full degrees.
- 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 PVC pipe.

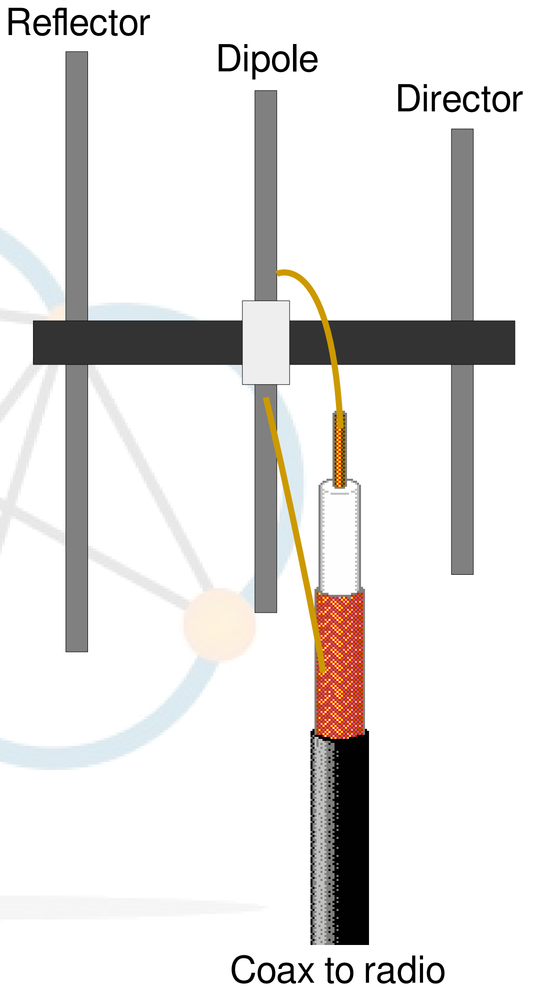


# Directional Antennas

- 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.

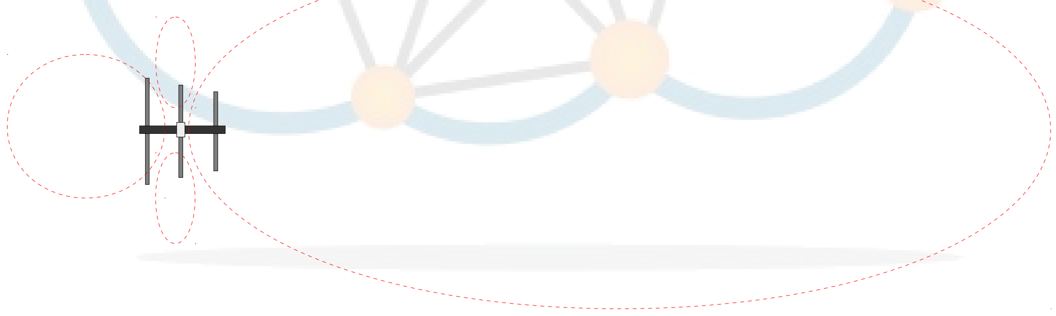
# Directional Antennas - Yagi beam

- The yagi consists of three or more elements.
- The middle element is an antenna is a 1/2 wave dipole antenna.
  - driven element
- Reflector.
- Director.



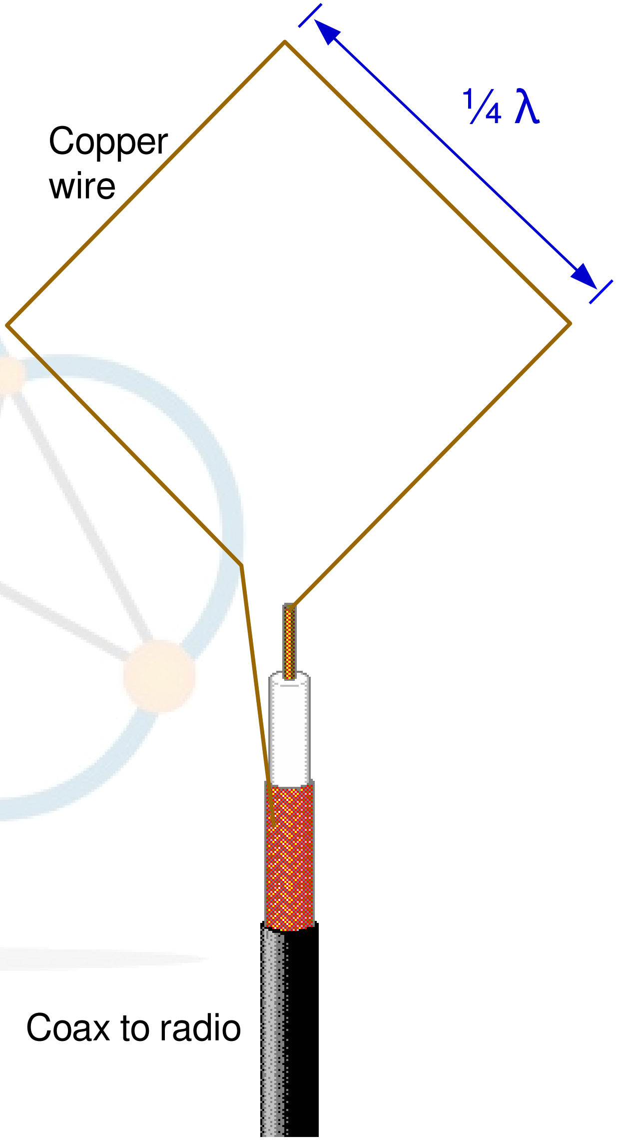
# Directional Antennas - Yagi beam

- The reflector reflects RF energy, the director directs RF energy. The reflector element is typically 5% longer than the driven element and the director is typically 5% shorted than the driven element.
- As a signal comes in it strikes all three elements hence generates a current on each element. The signals reinforce each other and make the incoming signal much stronger.

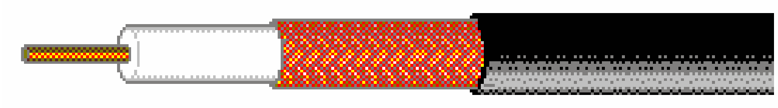


# Directional Antennas - Cubical Quad

- Principle is identical to the Yagi beam.
- The quad loop measures exactly ¼ wavelength on each side.
- This antenna actually is a Full wavelength antenna as compared to the ½ Wavelength driven element of the Yagi.
- The Quad loop alone has 2 dB of gain over the dipole antenna. So, using this as the driver element has at least 2 more dB gain over a yagi antenna with the same number of elements.



# Radio Transmission Lines



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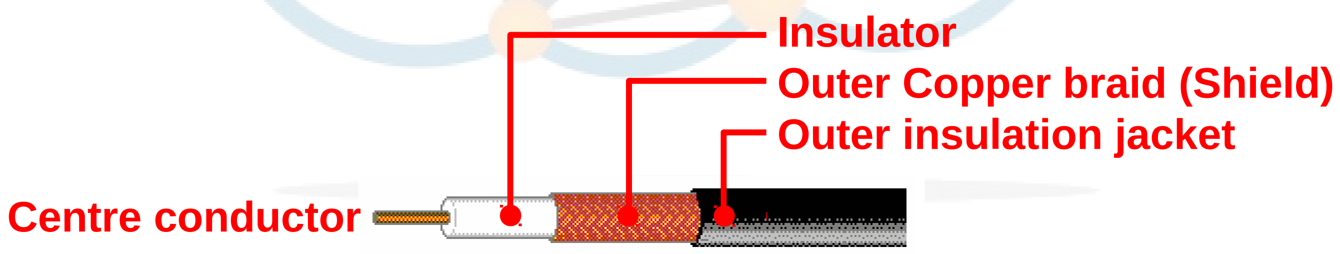
# Co-axial Cable

- Most radios use coaxial (coax) cable to feed their antenna.
- Coax cable consists of two concentric wires, as shown in the diagram.
- It is important to note that coax cable is unbalanced, no current flows on the outside shield of the cable.



# Co-axial Cable

- Coax Impedance
  - Again, the term impedance in "Coax Impedance" has different meaning you can not measure it with your multi meter.
  - It is determined by the spacing (ratio) of the inner wire and outer braid.
  - The two impedance's mainly used are:
    - 50 Ohm – Radio and networking
    - 75 Ohm – TV and video.

# HF Antenna

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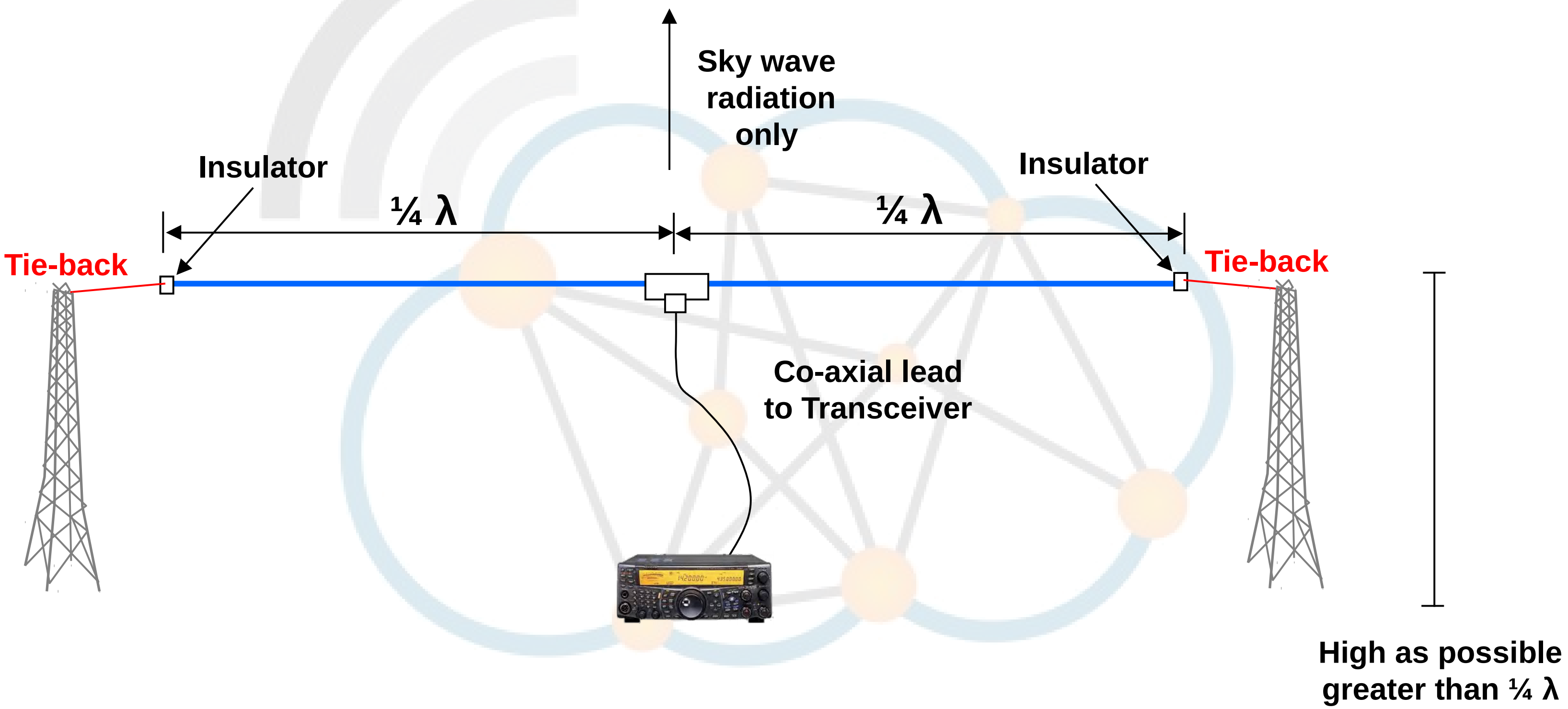
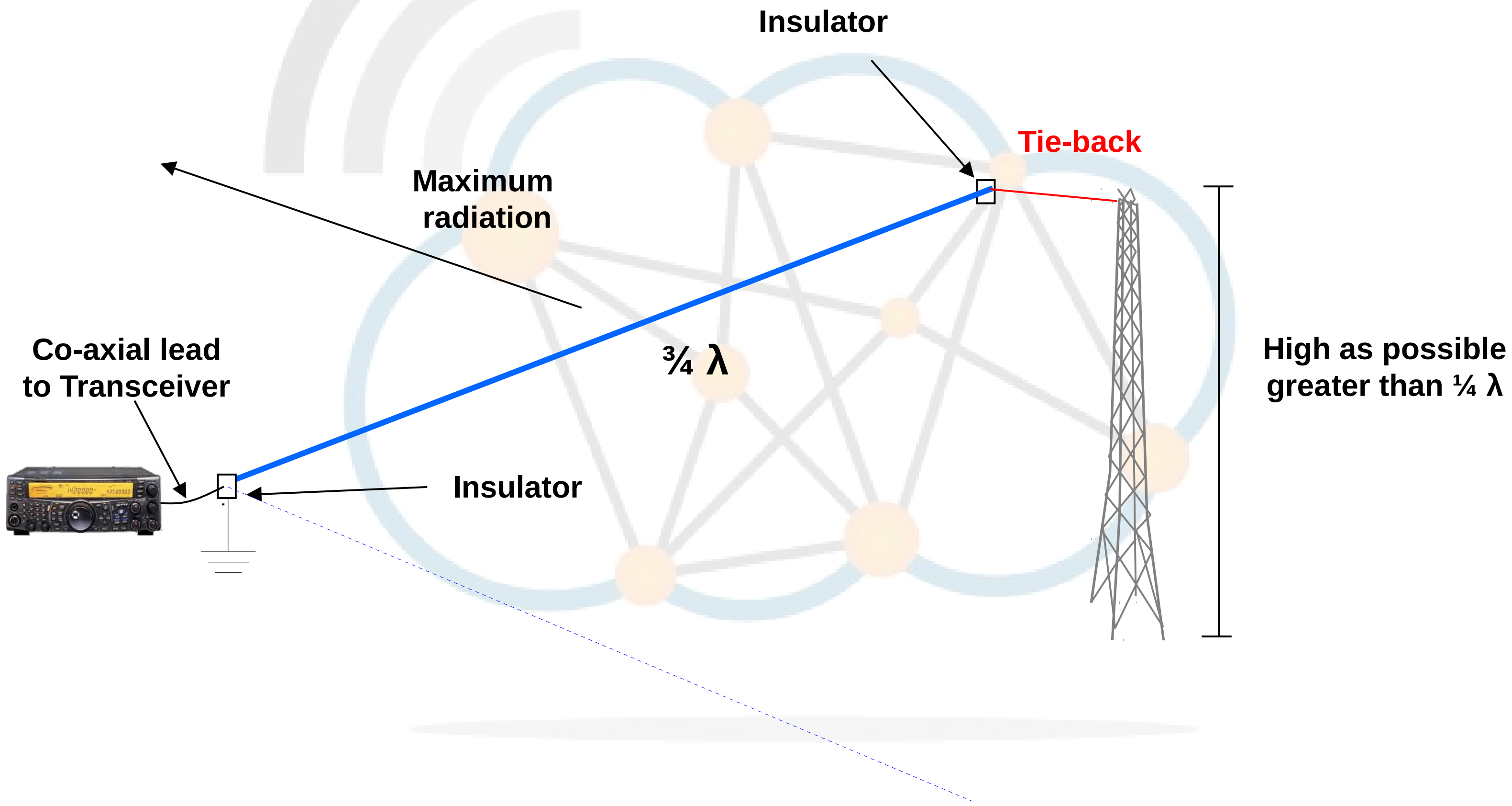
# HF Antenna

- Dipole Antenna



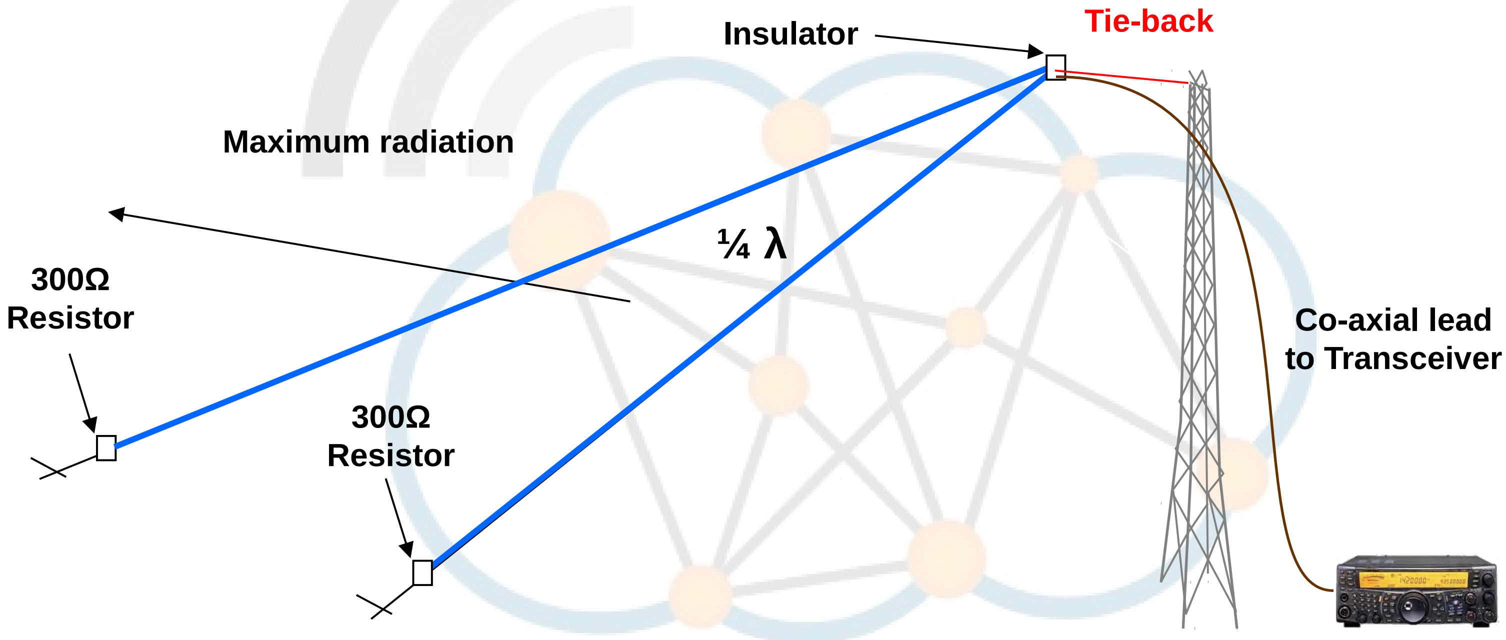
# HF Antenna

- Long Wire (Sloping) Antenna



# HF Antenna

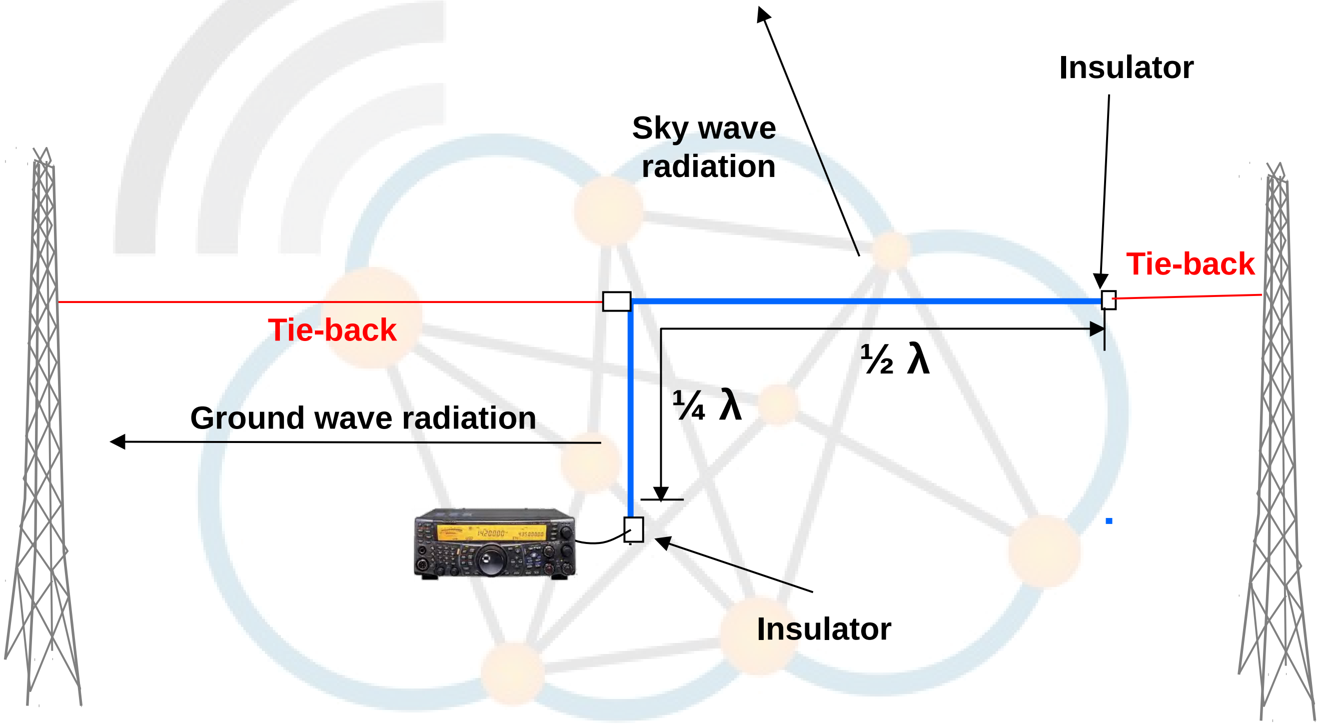
- Sloping-V Antenna



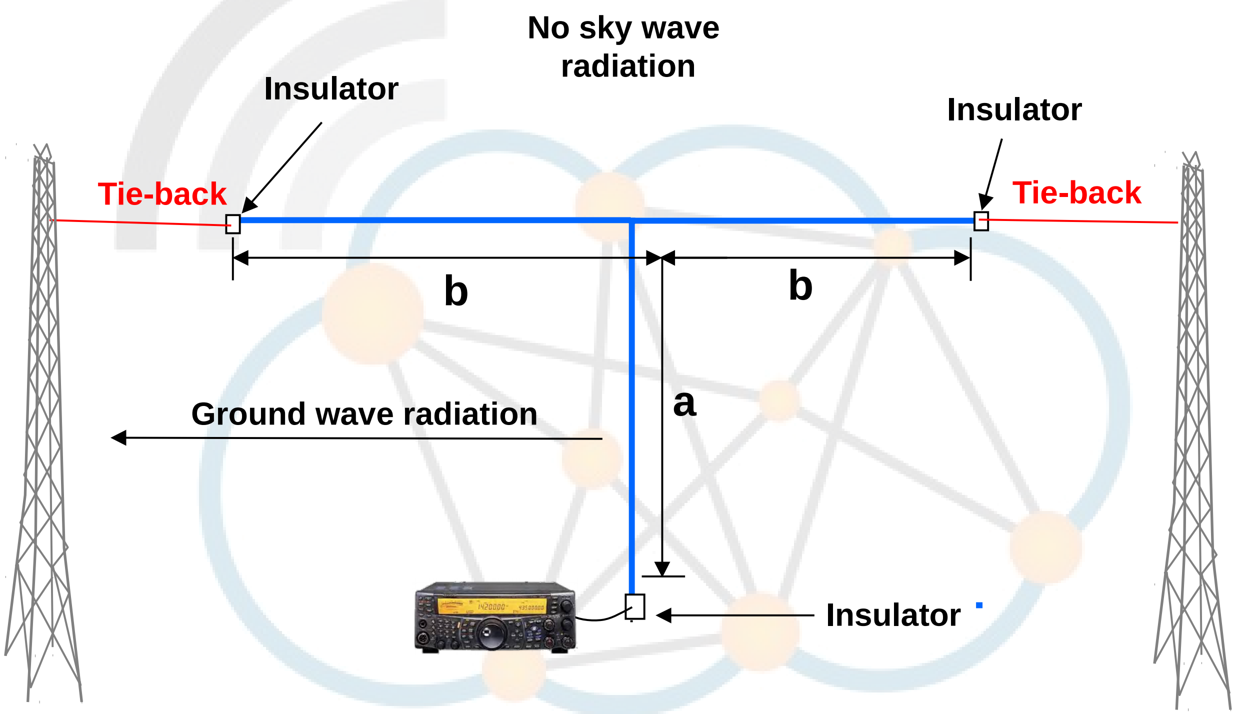

300Ω Resistors prevent standing waves

# HF Antenna

- ¾ λ Inverted-L Antenna



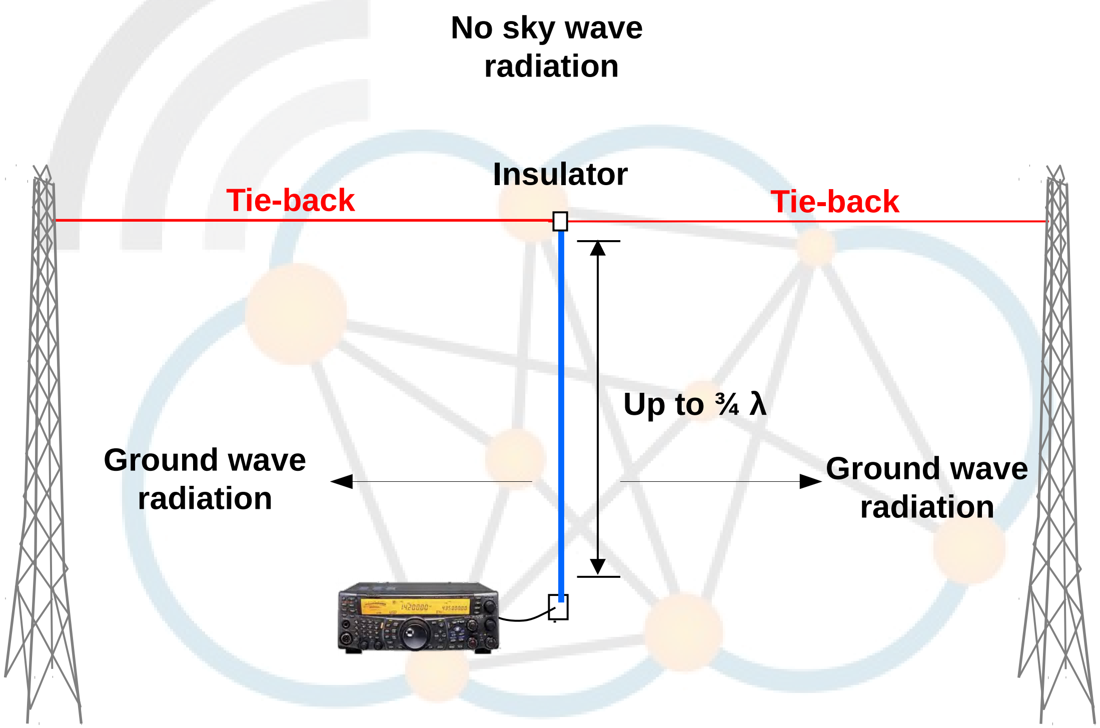
- T Antenna




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

# HF Antenna

- Vertical wire Antenna



# Thank You

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