Module 12 ANTENNAS (AERIALS)

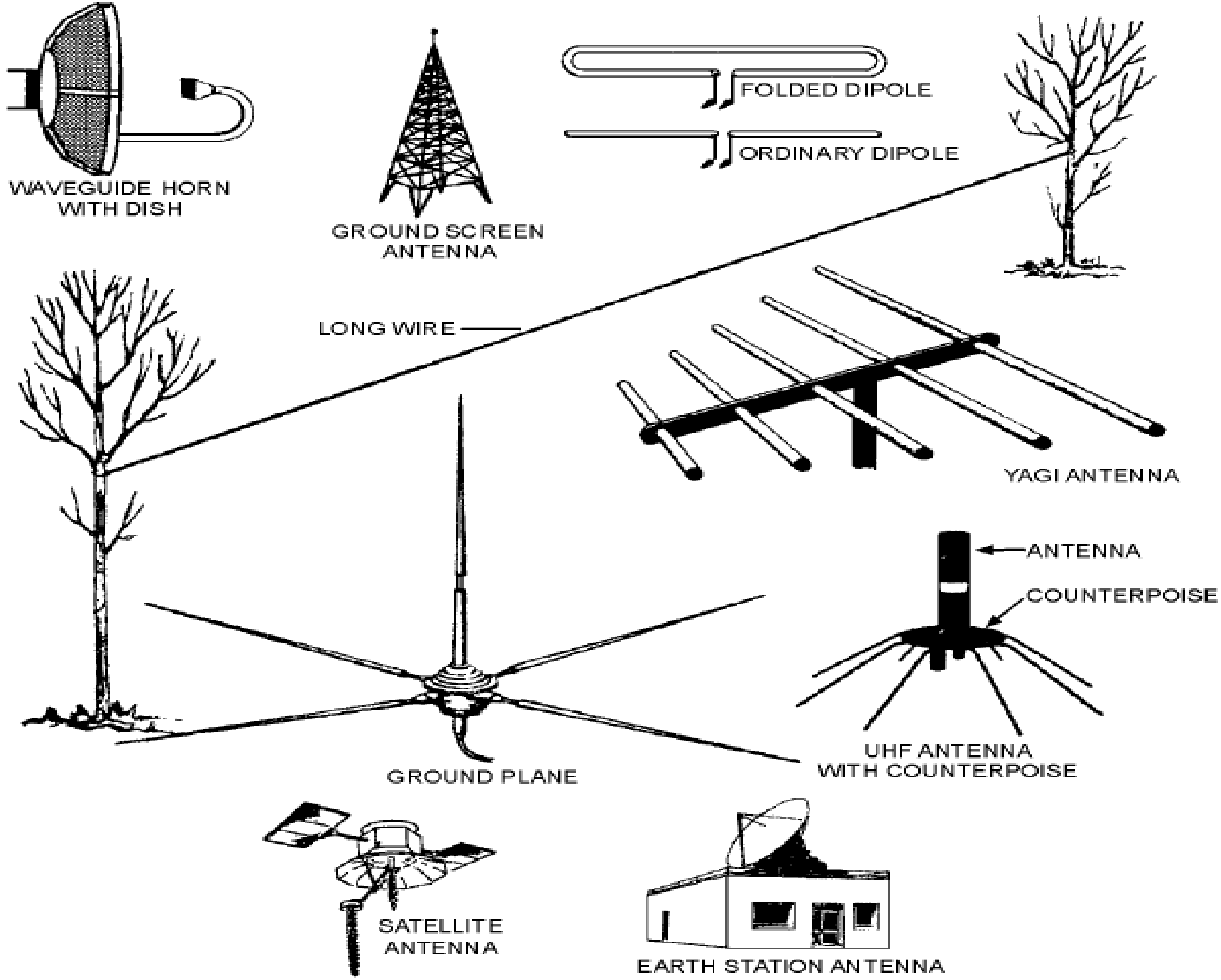


Figure 4-3.—Typical antennas.

Antenna Overview

- An antenna is a device that
  - converts RF power applied to its feed point into electromagnetic radiation (transmitting)

  - intercepts electromagnetic radiation which then appears as RF voltage across the antenna feed point (receiving)

Antenna Overview

- The electromagnetic radiation from an antenna is made up of two components, the E field and the H field.
- The two fields occur 90 degrees out of phase with each other.
- These fields add and produce a single electromagnetic field. The total energy in the radiated wave remains constant in space except for some absorption of energy by the Earth.
- However, as the wave advances, the energy spreads out over a greater area and, at any given point, decreases as the distance increases.

Antenna Overview

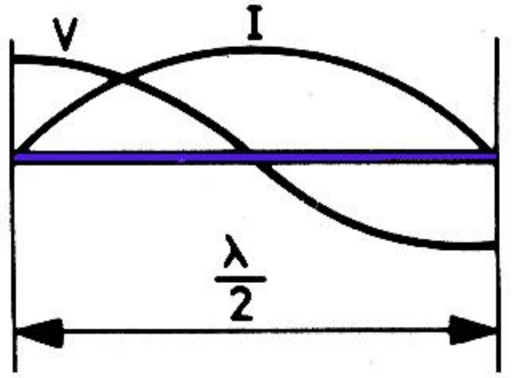
- The intensity (density) of radiation propagated by an antenna is not usually the same in all directions. The radiation/capture pattern is the same whether the antenna is used for transmitting or receiving

- The ratio of maximum radiation by a given antenna in a particular direction to the radiation of a reference antenna in the same direction (usually a half wave dipole) is called directivity

Antenna Overview

- Antennas can be made from any conductive material although high conductivity materials such as copper or aluminium are the preferred choices
- RF currents flow only on or near the conductor's surface (skin effect) and so antennas can be made from tubing without reducing performance
- Meshed elements can be used provided the mesh holes are smaller than the wavelength at which the antenna will be used by a factor of 12 or more, e.g., some satellite dishes

Half Wave Antenna



- Fundamental antenna is a length of wire which is a electrical half wavelength long
- The antenna is said to be resonant at the frequency at which it is an electrical half wavelength long; it will present a resistive load
- The voltage and current distribution on a half wave antenna is shown above

Half Wave Antenna

- The ratio of voltage to current (impedance) varies along the wire – at the ends the current is low and the voltage is high (high impedance) while at the centre the current is high and the voltage is low (low impedance)
- Feed-point impedance depends on where the feed point is. It varies from high impedance at the ends reducing to low impedance at the centre
- At the centre of a resonant half wave antenna the impedance is resistive and in free space is about 70Ω

Half Wave Antenna

- If a half wavelength of wire is cut at the centre and fed with RF power at the frequency at which it is resonant it is called a half wave dipole

- It has a feed point impedance of about 40-70Ω depending on height above ground

Half Wave Antenna

- A half wave dipole is a balanced antenna and needs a balanced feed. This can be either coaxial cable and a balun (balance-to-unbalance transformer) or 75 or 450Ω balanced line.

- The loss due to the 6:1 mismatch (6:1 SWR) on 450Ω line is inconsequential because this type of line is very low loss, though it needs to be matched to the Tx output

Half Wave Antenna

- An antenna that is shorter than a half wavelength at the frequency of operation will have capacitive reactance as well as resistance at its feed point

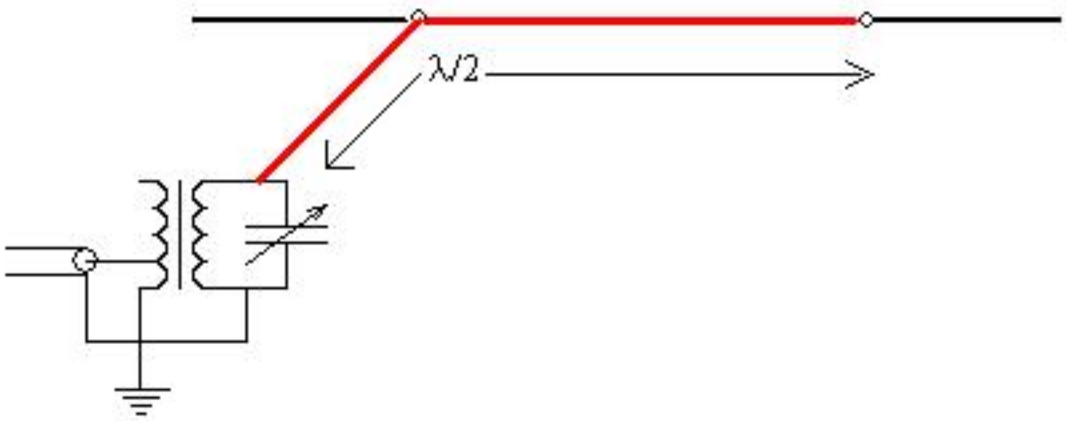
- An antenna that is longer than a half wavelength at the frequency of operation will have inductive reactance as well as resistance at its feed point

Half Wave Antenna

- An aerial tuning unit would generally be used to “tune out” the capacitive or inductive reactance and present a resistive load to the 50Ω output of the transmitter (Tx)

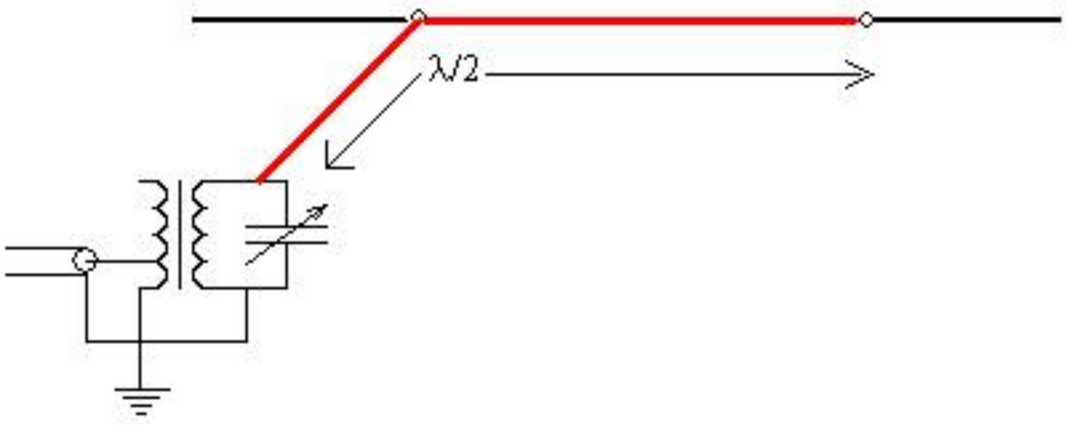
- The antenna and Tx are then said to be “matched”

End-Fed Half Wave Antenna



- As discussed, a half wavelength antenna has high voltage and low current at its ends, i.e., the ends are high impedance feed points

End-Fed Half Wave Antenna



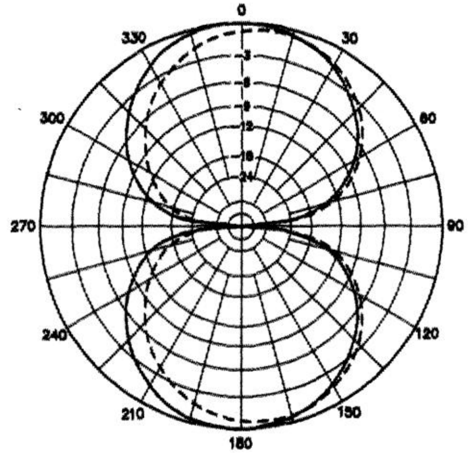
- A parallel-tuned matching network comprising a coil and variable capacitor suitable for the frequency is used to resonate the system and the feeder is tapped to the point on the coil that gives the lowest SWR

- A good ground (earth) for one end of the matching network and the braid of the coax is required

End Fed Half Wave Antenna

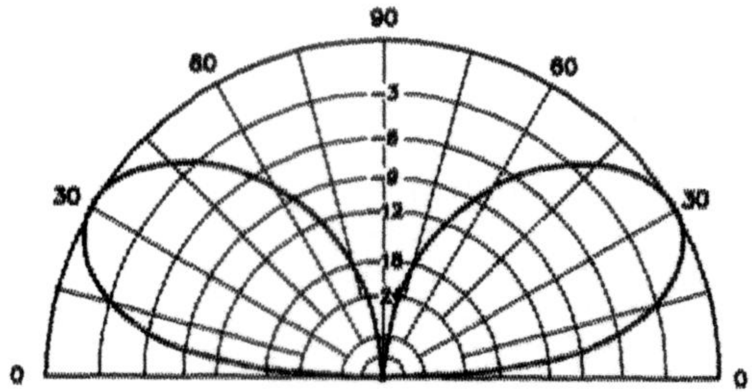
- Care must be taken as there is high RF voltage at the feed point. It should be located so that it cannot be touched by humans or animals
- The matching network should preferably be located outside the shack, protected from the enviromment. This is safer and will help to eliminate RF in the shack and reduce the likelihood of interference to TV, Radio and Telephones

Half Wave Antenna – Radiation Patterns



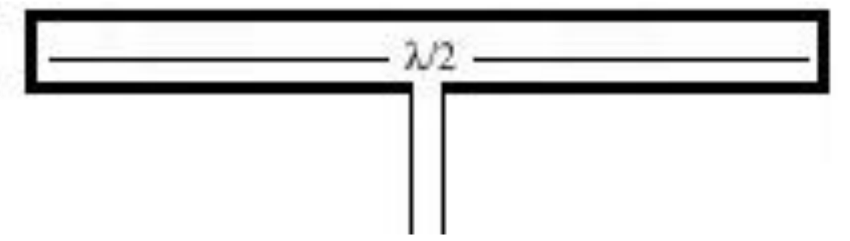
- The theoretical radiation pattern in the horizontal plane from a half wave dipole is shown above
- The theoretical radiation pattern is in the form of a "ring doughnut shape", i.e., the radiation is maximum all around the wire and at right angles to it with little or no radiation off the ends

Half Wave Antenna - Radiation Patterns



- The radiation pattern in the vertical plane of a half wave antenna one half wavelength above perfectly conducting ground is shown above
- Due to ground reflection the pattern is modified and maximum radiation takes place at right angles to the wire and at an angle of 30 from the horizontal

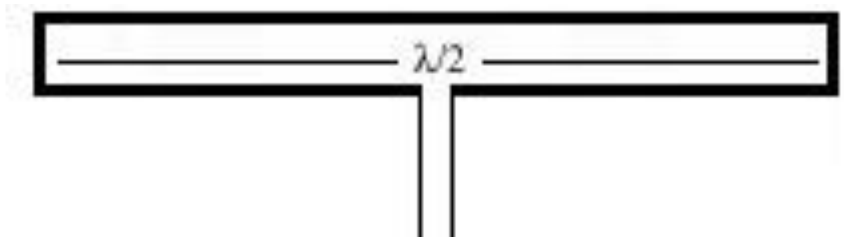
Folded Dipole



- Another conductor is placed slightly above a half wave dipole and connected to it at the ends

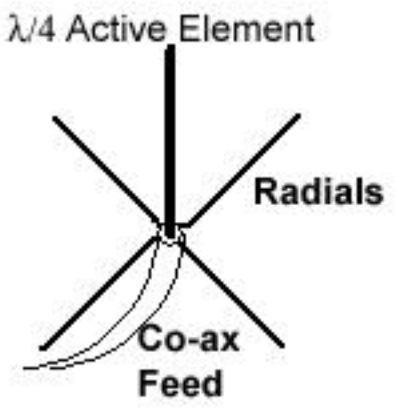
- Has the same radiation pattern and a broader frequency response between the 2:1 SWR points than a single wire dipole

Folded Dipole



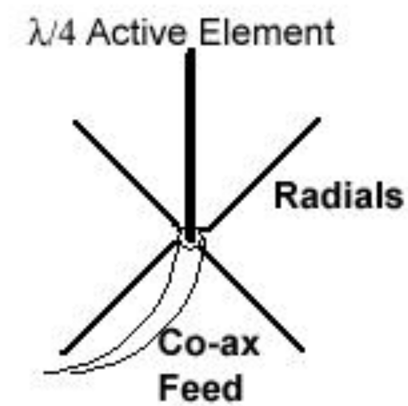
- Feed point impedance is about 300Ω so it is a better match for 450Ω line than a single wire dipole
- Will **not** operate on harmonics of its resonant frequency
- Feed point impedance can be modified by varying the diameter of the conductors and their spacing

Quarter Wave Ground Plane



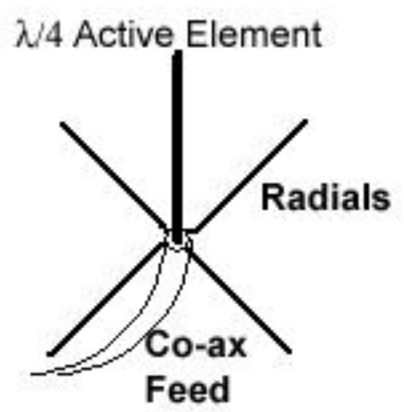
- A half wave dipole cut in half and standing on a mirror would look like a full dipole
- The mirror can be the earth, a metal sheet or a number of radials as shown above

Quarter Wave Ground Plane



- Feed point impedance is about 35Ω and is unbalanced
- It can be fed with coaxial cable, the inner to the vertical radiator and the outer to the radials
- Radiation is omni directional and is maximum at about 30 elevation to the ground

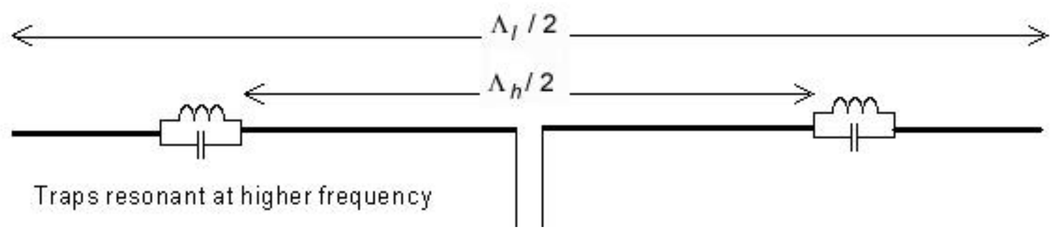
Quarter Wave Ground Plane



- Elevating the feed point and drooping the radials downward at an angle of 25-30 will help provide a better match to 50Ω coaxial cable; elevated radials are normally tuned by cutting to length of λ/4

- Increasing the number of radials improves the efficiency of a ground plane antenna

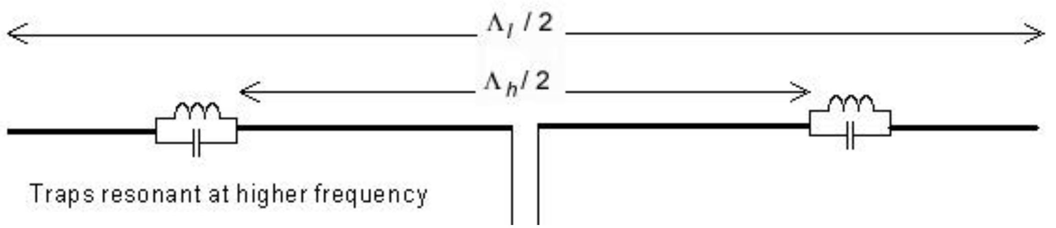
Trap Dipole



- A 7 MHz half wave dipole fed with a balanced line will look like two end fed half waves on 14 MHz; feed point impedance will be very high and consequently there will be a high SWR on the feeder

- To construct a dual-band antenna a parallel resonant circuit called a trap can be inserted in each half of the antenna

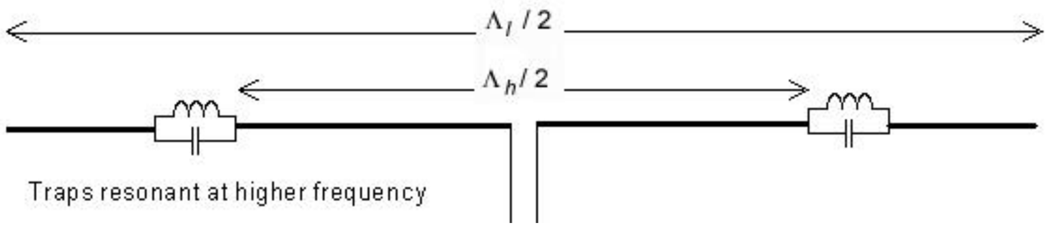
Trap Dipole



- The traps are resonant at the higher frequency (14MHz) and present a high impedance to RF energy at that frequency effectively cutting off the parts of the antenna outside the traps

- The traps are placed so that the centre portion of the antenna inside the traps resonates at the higher frequency (14 MHz)

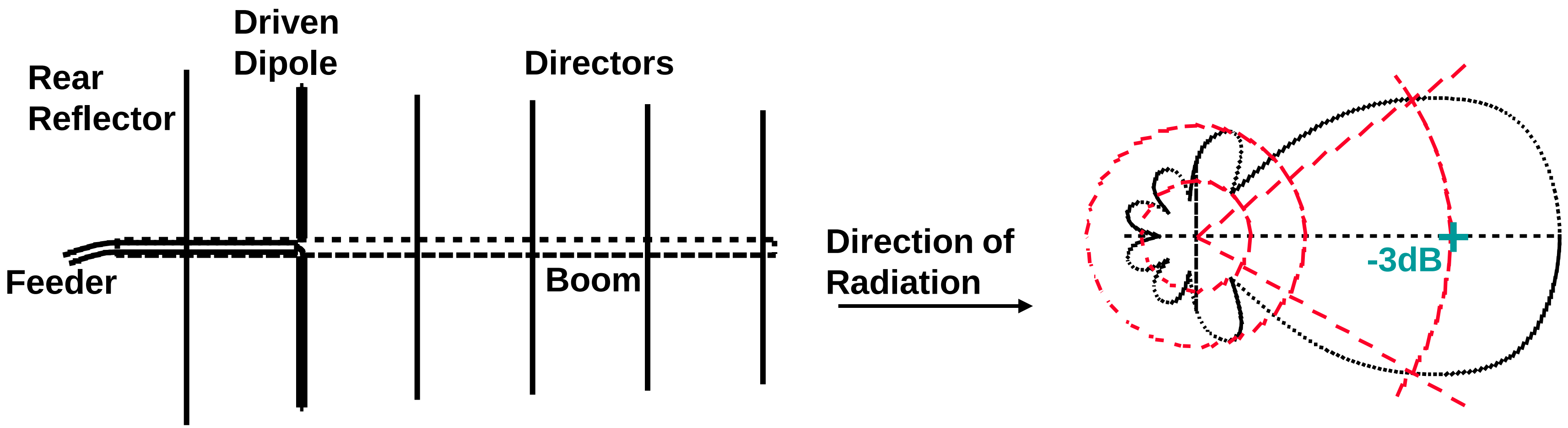
Trap Dipole



- To 7 MHz RF energy the traps just look like inductors and the whole antenna resonates at the lower frequency (7 MHz)

- The traps have a lengthening effect so at resonance at 7 Mhz the antenna will be somewhat shorter than a half wave dipole

Yagi Antenna



- The pattern and direction of maximum radiation from an antenna can be modified by the addition of extra elements (directors) in front of and an extra element (reflector) behind the element to which RF energy is fed, i.e., the driven element

Yagi Antenna

- Where no RF energy is fed to these extra elements they are called parasitic elements and they get power through electromagnetic coupling with the driven element
- The three element Yagi shown on the previous slide has a parasitic reflector, a parasitic director and a dipole driven element to which the RF signal is fed
- Parasitic reflectors and directors are respectively about 5% longer and shorter than the driven element and further directors would usually get progressively shorter

Yagi Antenna

- The length and spacing of the parasitic elements are such that they reinforce radiation in the direction of the director and reduce it in the opposite direction. This is how the antenna achieves its gain over a half wave dipole (see radiation pattern on a previous slide)

- Because of the radiation pattern of Yagi antennas they need to be rotated in the direction to which a signal is to be transmitted/received

- The maximum theoretical gain of a three element Yagi antenna over a half wave dipole is about 7dBd (about 5 times). An important advantage is that the gain also applies to received signals

Yagi Antenna

Two common methods of gain measurement:

- \- dBi which is dB (deciBels) relative to an isotropic antenna, i.e., a theoretical antenna in free space with equal radiation in all directions.

- dBd which is dB relative to a half wave dipole. This is a more meaningful comparison as a half wave dipole has a gain of 2.1dB over an isotropic radiator

Yagi Antenna

- Because the Yagi antenna increases gain in one direction (the forward direction) by reducing it in others, particularly in the reverse direction it is said to have a **front to back ratio**.

- This ratio represents the property of attenuating signals (both transmit and receive) off the reverse side (reflector end) of the beam.

- A good three element beam would have a front to back ratio of up to 18dB about three ‘S’ Units

Yagi Antenna

- The additional elements reduce the driven element feed point impedance from about 70 to about 20Ω.

  A folded dipole is often used to raise this impedance and provide a better match for coaxial cable.

  More often a matching device called a gamma match is used to give an almost perfect match to 50Ω coaxial cable

Multiband Antenna

- An antenna about a half wavelength long at the lowest frequency to be used fed with a balanced line of say 450Ω will operate on all the higher frequency bands

- Impedances at the shack end of the feed line will contain reactance and will vary very much from band to band

- An aerial tuning unit is therefore essential to “tune out “ the reactance and transform the load so as to present a resistive load in the region of 50Ω to the transmitter output stage

Effective Radiated Power

- Radiated power is power supplied at the antenna system multiplied by the antenna gain in a given direction.

  This can be referenced to a half-wave dipole (Effective Radiated Power ERP) or an isotropic radiator (Effective Isotropic Radiated power EIRP)

- For a transmitting system it is determined by subtracting system losses from system gains

- For example if an antenna system has a 6dBd gain and a feeder loss of 3dB then the system (antenna and feeder) has an effective gain of 3dBd (a power gain of two)

Effective Radiated Power

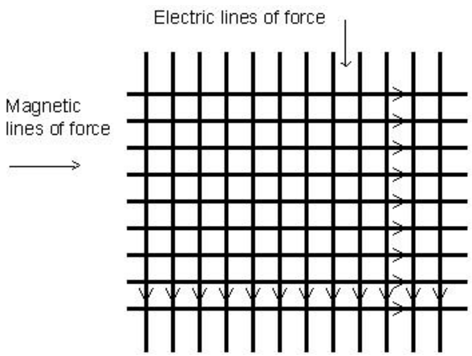
- If the transmitter outputs 100 watts, the system will have a ERP of 200 watts;

  A Tx power level of 20 dBW becomes ERP of 23dBW

- Note: Gain in db = 10 log (power out/power in).

  If the ratio power out/power in is less than 1, then a loss is involved and the dB figure will be negative

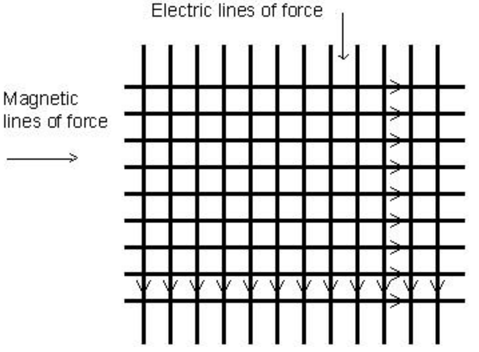
Polarisation



- A wave is said to be polarised in the direction of the electric lines of force relative to the surface of the earth.
  In the above diagram the wave is vertically polarised

- Polarisation is determined by the transmitting antenna. Horizontal antennas transmit horizontally polarised waves and vertical ones vertically polarised waves

Polarisation

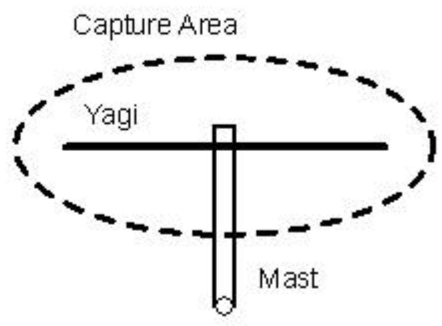


- Polarisation of waves will alter during ionospheric propagation

- For line-of-sight propagation, transmitting and receiving aerials should have the same polarisation.

- If one is horizontally and one vertically polarised there are significant losses

Capture Area



- A receiving antenna captures a portion of the power radiated by a remote transmitter
- The received power available at the terminals of the antenna depends on the capture area, also called effective aperture of the antenna
- For a Yagi it is rougly elliptical as shown above.
- It is an important parameter at UHF for parabolic and horn antennas

Antenna Length

- A half wavelength in free space is $150/f_{MHz}$ metres long
- The velocity of a wave in antenna wire is less that in free space, so antenna lengths are shorter than equivalent free space lengths
- This fact coupled with the capacitive effect of end insulators mean that a half wave antenna is about 5% shorter than its free space length
- The figure generally used for the length of a half wave antenna is

$$142.5/f_{MHz} \text{ (metres) or } 468/f_{MHz} \text{ (feet)}$$

Parabolic Antenna

- An antenna located at the focal point of a parabolic reflector (dish) can provide considerable gain with a large capture area

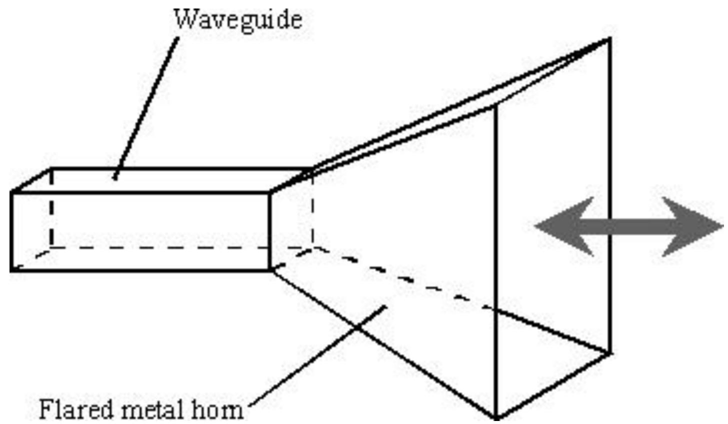
- A 1.2m diameter parabolic dish at 432 MHz (70 cms) provides about 10dB gain over a half wave dipole

- The beam width of the signal will be very narrow provided all of the signal energy is at the focal point of the dish

- These antennas are used at UHF and microwaves and specialised feed systems, often using waveguides

  (a rectangular section of tube) are used

Horn Antennas



- Used at microwaves, can be regarded as “flared out” or “opened out” waveguides

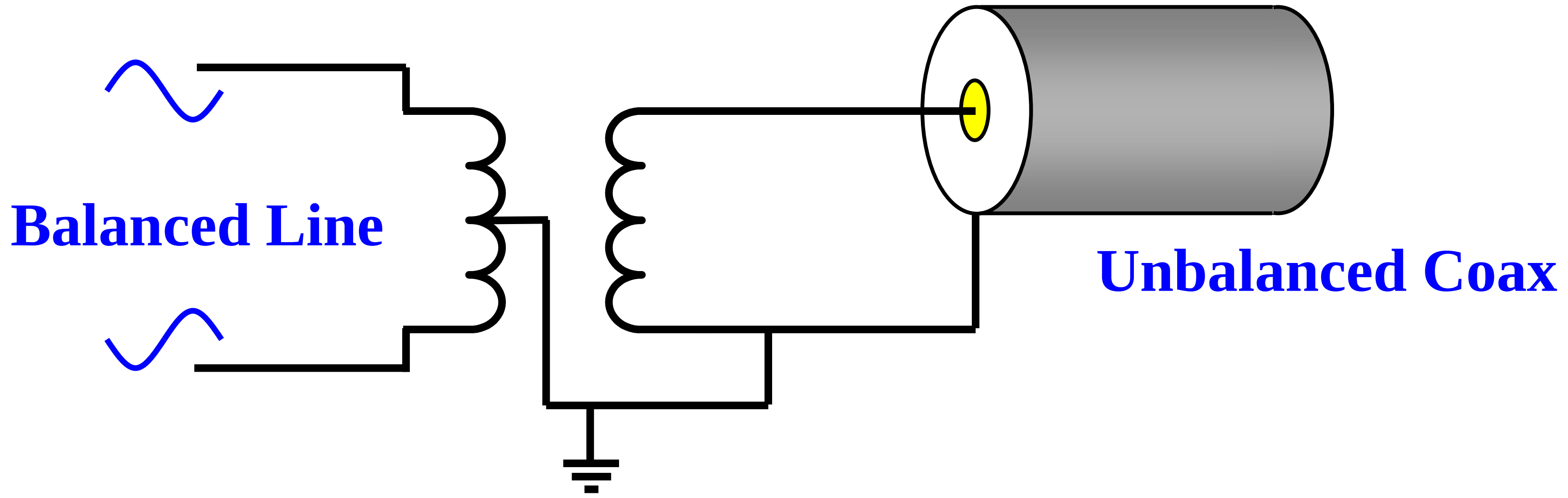
- Produces a larger effective aperture (capture area) than that of the waveguide itself and hence gain and greater directivity

Baluns

- Remember BALUN = Balanced Unbalanced
- Many antennas are balanced devices, such as dipoles etc.
- Connecting a dipole to an unbalanced coax cable causes currents to flow in the outer sheath.
- These currents give rise to unwanted radiation which may cause EMC problems.
- A solution is to match the balanced antenna to the unbalanced line using a BALUN
- There are three basic types and we will deal with each in turn.

Baluns - Basic Format

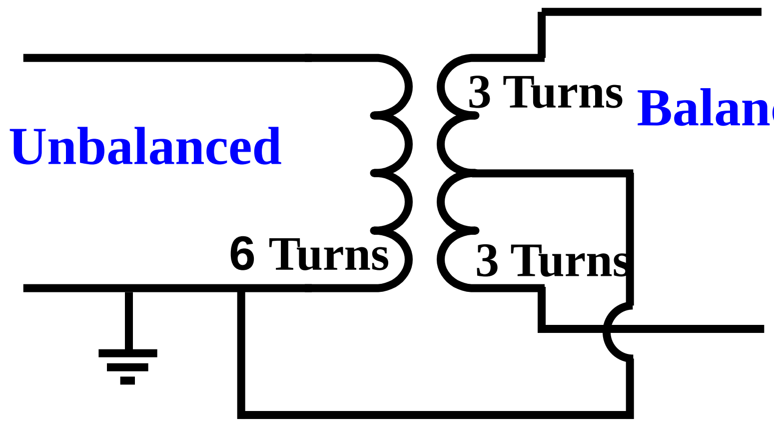
- Below is the basic format of The Transformer BALUN
- These are normally wound on ferrite cores and are used to match a balanced system such as ladder line or a dipole to an unbalanced line such as a coaxial cable.



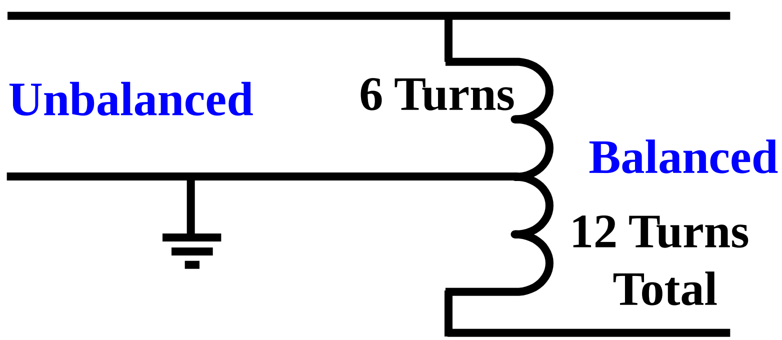
Transformer Baluns

1:1 Transformer BALUN

Primary turns equals Secondary Turns

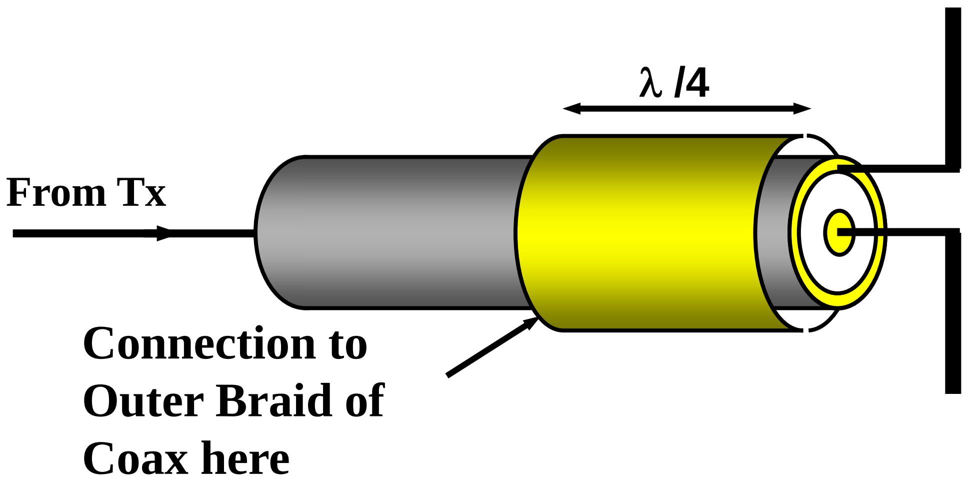


1:4 Transformer BALUN



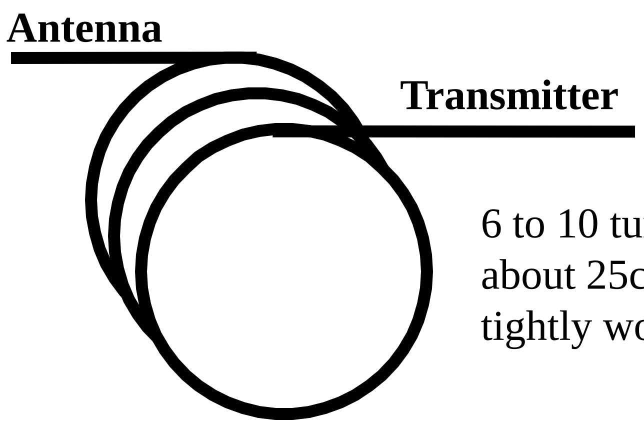
- **Recall: Zp = Zs . (Np / Ns)** ^{2}
- **1:2 Turns Ratio will create a 1:4 Impedance Transformation**

Sleeve Balun

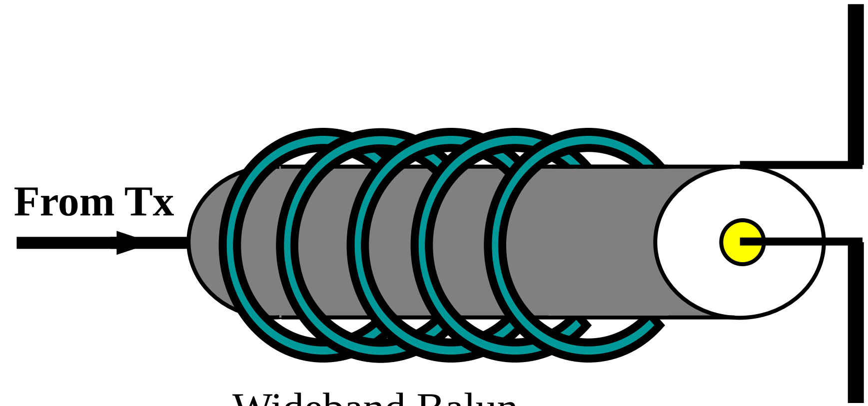


- A λ/4 long braided or solid extra outer conductor is located around and insulated from the coax screen and connected to the screen at the rear
- The high impedance of the open circuit present a low impedance to the currents on the coax screen λ /4 on to the rear
- The sleeve acts as choke coil to isolate remaining line from antenna.
- As it is based upon λ /4 on one band, this is a single band device

Choke Baluns



6 to 10 turns
about 25cm diameter
tightly wound



Wideband Balun
using Ferrite rings

- Current or Choke Baluns prevent current flowing on the screen of the coaxial feeder cable.
- Such currents may cause unwanted radiation which might lead to EMC problems.