Standard

Unit 16

ANTENNAS

ACMA Syllabus February 2024

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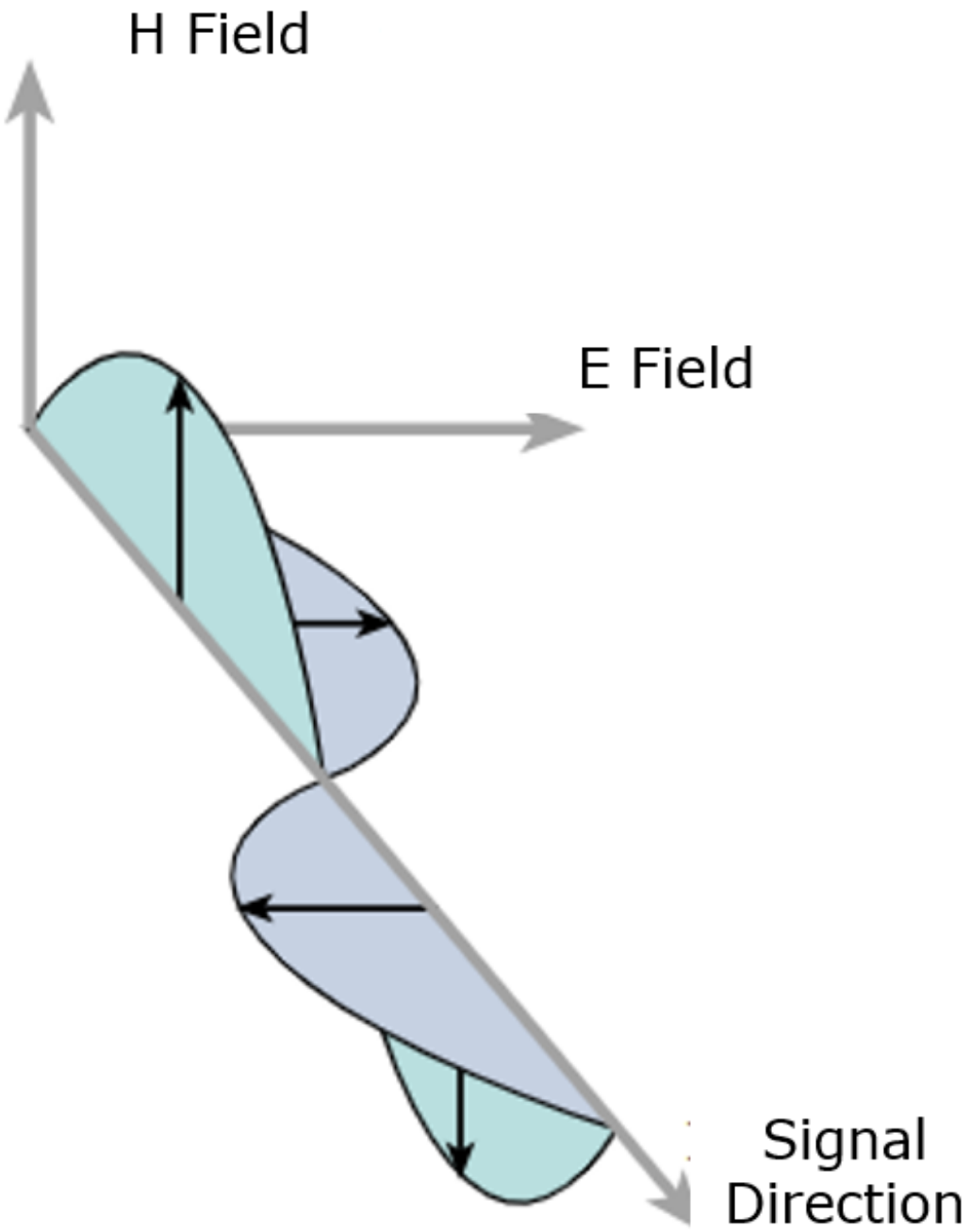
Antennas

Force Fields

An antenna is a transducer that converts alternating voltage electrical signals into electromagnetic fields for transmission and converts electromagnetic fields to alternating voltage electrical signals for reception.

There are two force fields surrounding an active antenna. The E or (electric) and H (magnetic) fields. The E field is at right angles to the H field. The E field is the transmitted signal and defines the line of polarisation.



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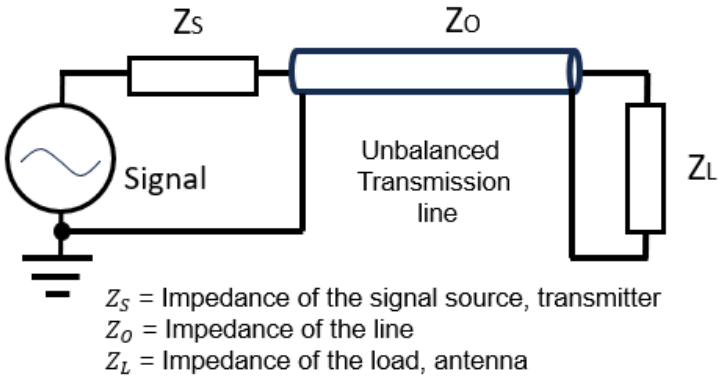
Antenna Matching

The concept of impedance matching, ZS, ZO and ZL, still apply for maximum signal transfer in both transmit and receive.

In amateur radio, the transmitters and receivers have a Zs of 50 ohms.

Unbalanced coaxial lines, Zo are also 50 ohms.

ZL also needs to be 50 ohms or matched to 50 ohms for maximum signal transfer.



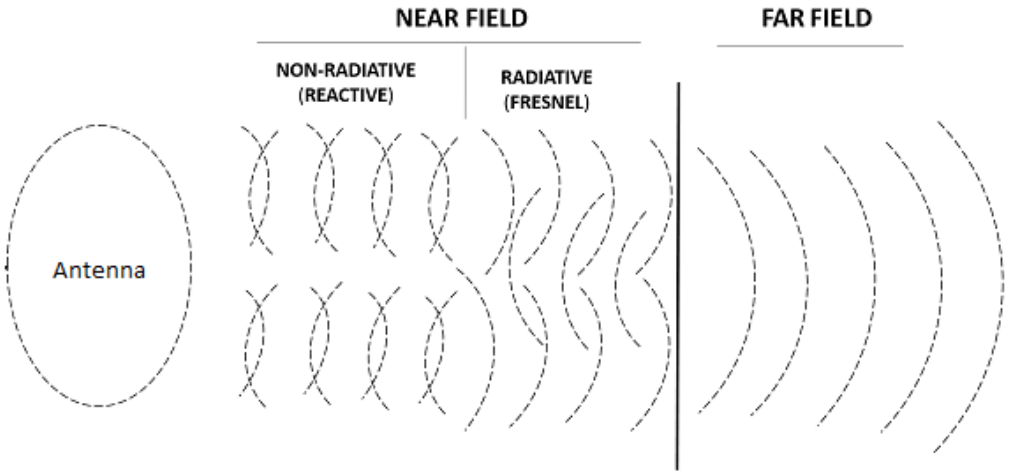
Signal and Distance

The signal from an antenna reduces in strength with distance from the antenna.

These distances are broadly divided into two regions, the near-field region, and the far field region.

The near field is unpredictable, and no measurements are usually made in this region.

In the Far Field, the force fields are dominated by radiating E and H-fields.



Near Field

The near field refers to places nearby the antenna where the emission of electromagnetic waves can be interfered with while the field lines remain electrically attached to the antenna.

Far Field.

The far field is the region in which the field has settled into "normal" electromagnetic radiation. In the far-field region of an antenna, radiated power decreases as the square of distance, and absorption of the radiation does not feed back to the transmitter.

Measurements required for the Amateur Radio Class Licence Regulation are measured in the Far Field.

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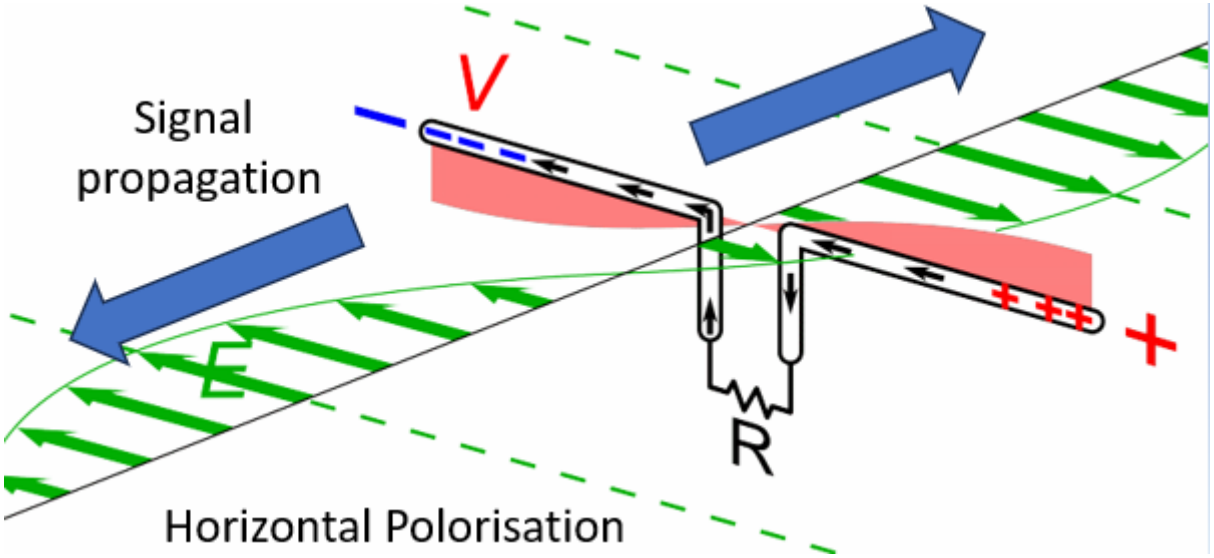
Polarisation

Polarization refers to the plane of the **E-field** (Voltage) looking at the wave from the transmitter.



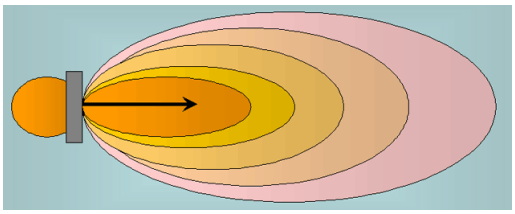
There are three general antenna polarisations.

- **Horizonal** - The E field will move sideways in a horizontal plane.
- **Vertical** - The E field will oscillate up and down in a vertical plane.
- **Circular** - Circular polarisation is represented by the E-field rotates like a corkscrew. Signals rotating to the right are referred to as right-hand circular polarization (RHCP). Signals rotating to the left are referred to as left-hand circular polarization (LHCP)

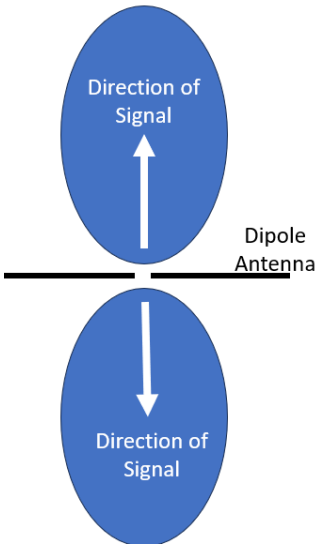
Antenna Groups

The three main groupings of practical antennas.

1. Directional – This antenna can direct the signal in one direction e.g., Yagi.



2. Semi-directional - This antenna can direct the signal in two dominant directions e.g., dipole.



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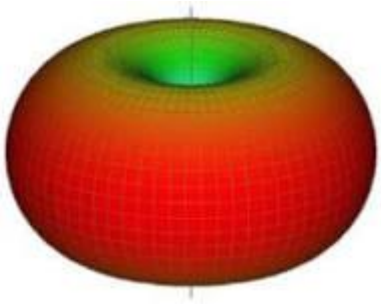
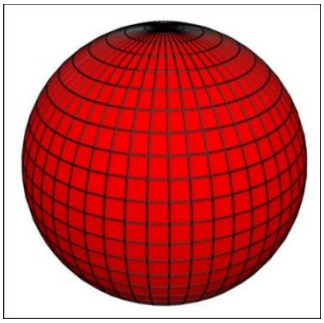
3. Omni-directional - This antenna is not able to direct the signal and radiates in all directions e.g., vertical whip.



Isotropic Antenna

The ideal antenna by which all antennas are compared, is called the isotropic antenna. The isotropic antenna is a theoretical antenna that radiates equally in all directions - horizontally and vertically with the same intensity. The antenna has a gain of 1 (0 dB) in the spherical space all around it and has an efficiency of 100%.



Balanced and Unbalanced Antennas

Antennas can be balanced or unbalanced. A balanced antenna is symmetrical about the feed point (e.g., a dipole) whereas an unbalanced antenna is not symmetrical about the feed point (e.g., a long wire)

Reactance

Antennas will present a reactance either side of their centre frequency (fc). As the frequency decreases below fc, the antenna is too short and will present capacitive reactance Xc. As the frequency increases above fc, the antenna is too long and will present inductive reactance Xl.

- If an antenna resonates at a frequency higher than the desired frequency, the antenna is too short and the antenna behaves **capacitively**. That is Xc is higher.
- If an antenna resonates at a frequency lower than the desired frequency, the antenna is too long and the antenna behaves **inductively.** That is X_L is higher.

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Antenna Types

Dipole

The dipole is one of the most common antennas and it has a theoretical antenna impedance of 72 Ohm. The dipole often hangs too close to the ground, causing the impedance to drop towards the 50 Ohm. Ideally, the dipole should be half the wavelength above the ground.

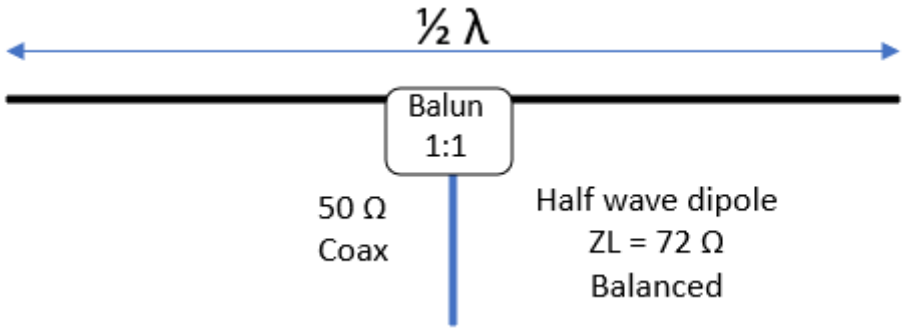
A dipole has two legs each a quarter wavelength long. As the dipole is a balanced antenna with a ZL of 72 Ω, a 1:1 balun is recommended to match to the unbalanced coaxial cable. Wavelength is calculated by Wavelength (λ) = c / f.

Example: What is the overall length of a dipole for 14.2 MHz.

300 / 14.2

= 21.21 / 2 Divide by 2 for half wave dipole.

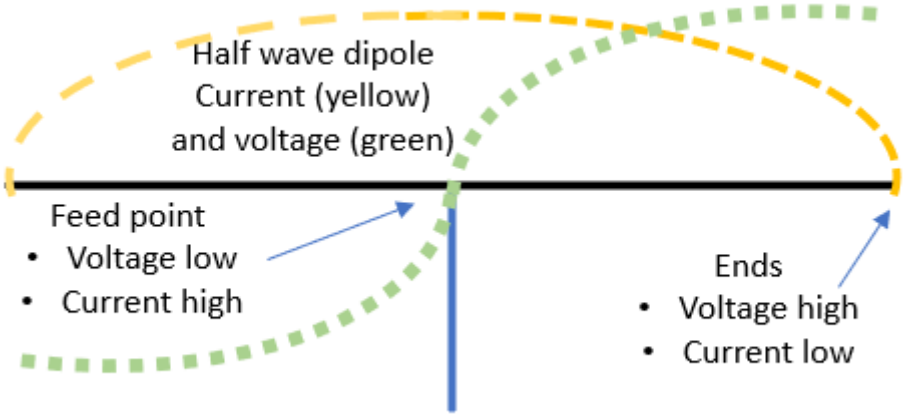
= 10.1 metres



If a full wavelength dipole is used, the ZL is very high at around 2500 Ω.

Dipole Current and voltage

A dipole has maximum current at the feed point and maximum voltages at the ends. If the transmitter is sending 100 W to the antenna, current is over 1 ampere and the voltage at the ends is over 70 V. So be careful, the ends can bite.



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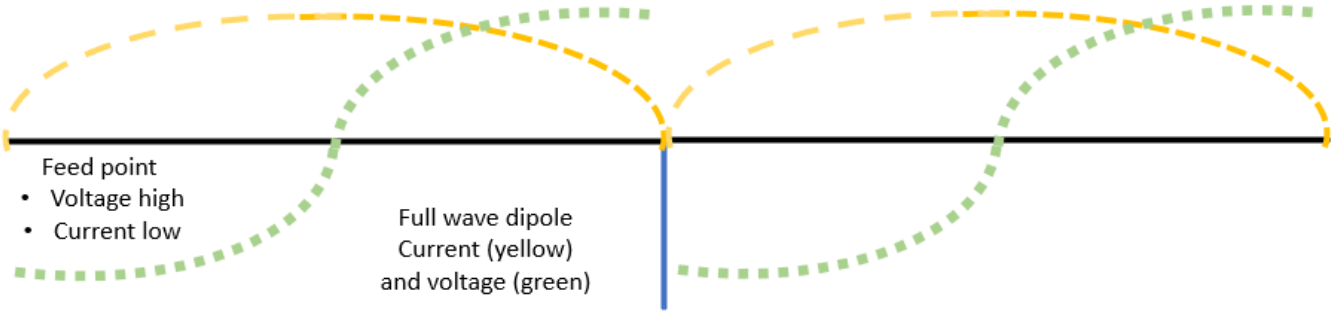
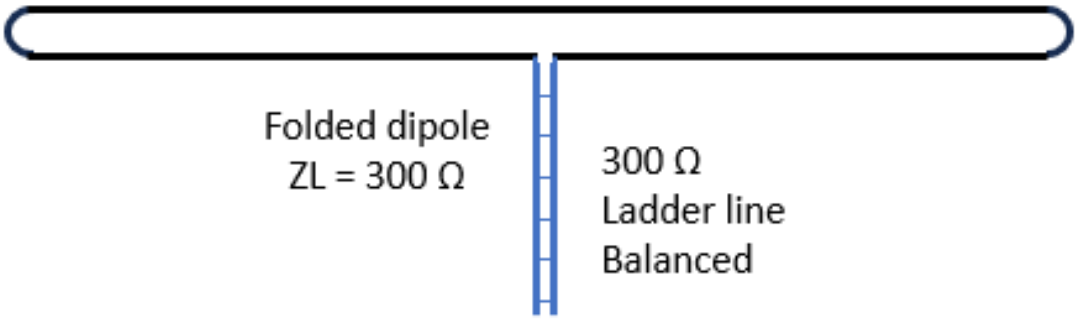
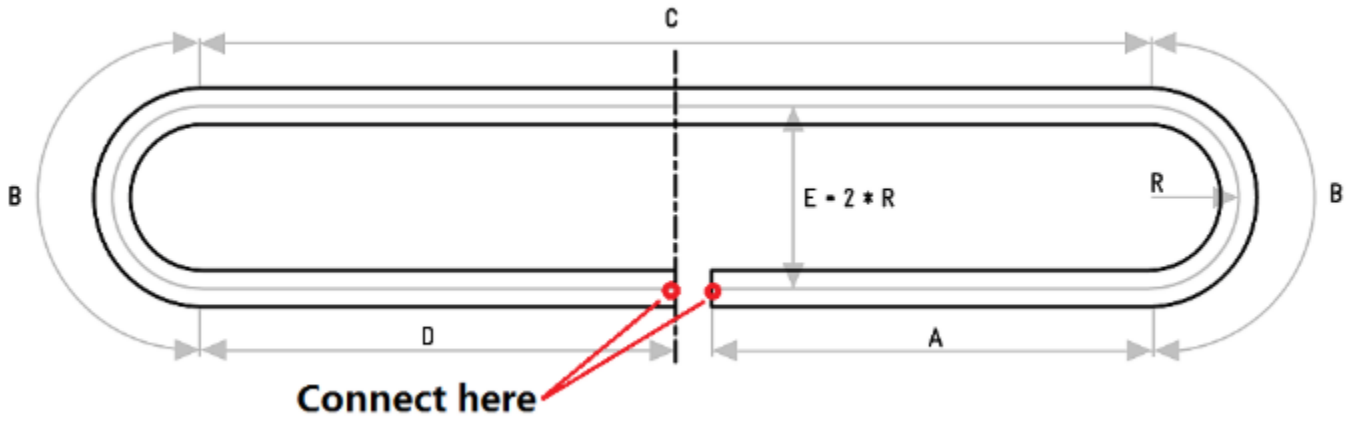


Folded Dipole

A folded dipole has a theoretical impedance of 300 Ω so is ideally fed with a ladder line of the same impedance. If the folded dipole is used with the unbalanced coaxial cable, a balun is needed to match the impedance.





Dimensions A, B, C, D and R need to be calculated.

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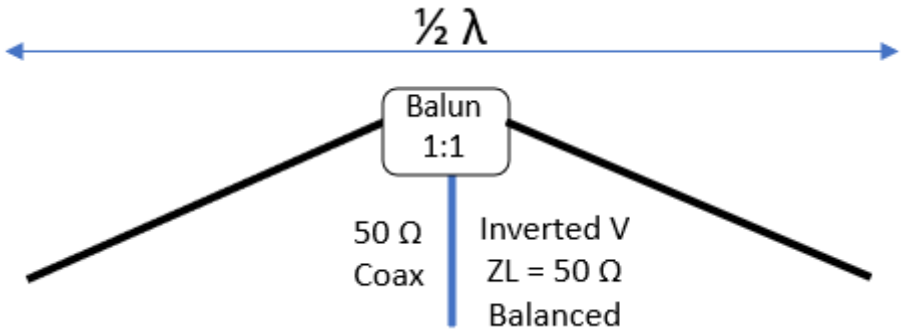
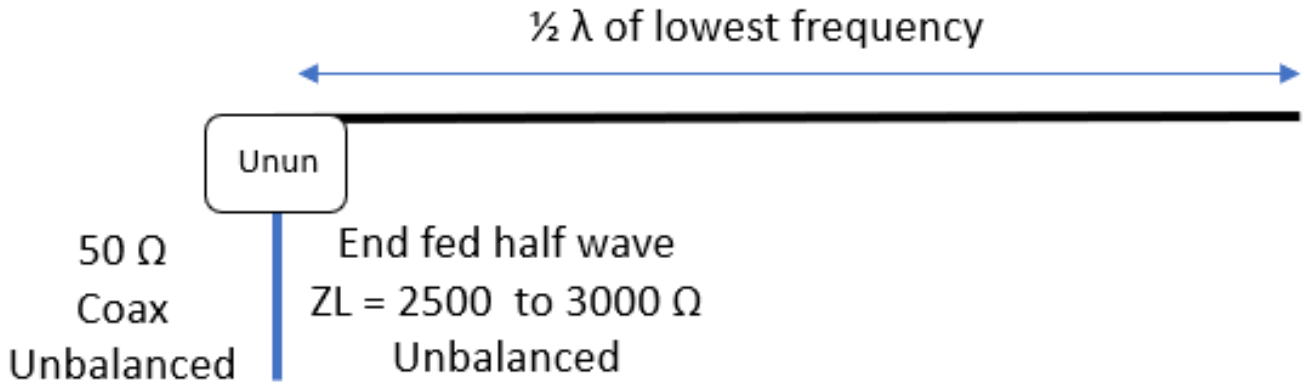
Inverted V

An inverted V antenna is a dipole with the ends dropped. The impedance is close to 50 Ohm, which makes the antenna very popular with amateurs. Ensure the ends are a few meters above the ground.



End fed half-wave antenna.

The End-Fed Half-Wave (EFHW) antenna is a popular, resonant wire antenna designed for multiband HF operation. An unun using a 49:1 or 64:1 impedance matching is required. The antenna operates on a half-wavelength of wire for the lowest band, making it ideal for portable use.



Quarter-wave vertical antenna [ground plane]

A quarter wave vertical can be compared to a vertical half wave dipole. Half the dipole is standing vertically, and the other half of the dipole are radials. A good earth is very important. This reduces the antenna impedance.

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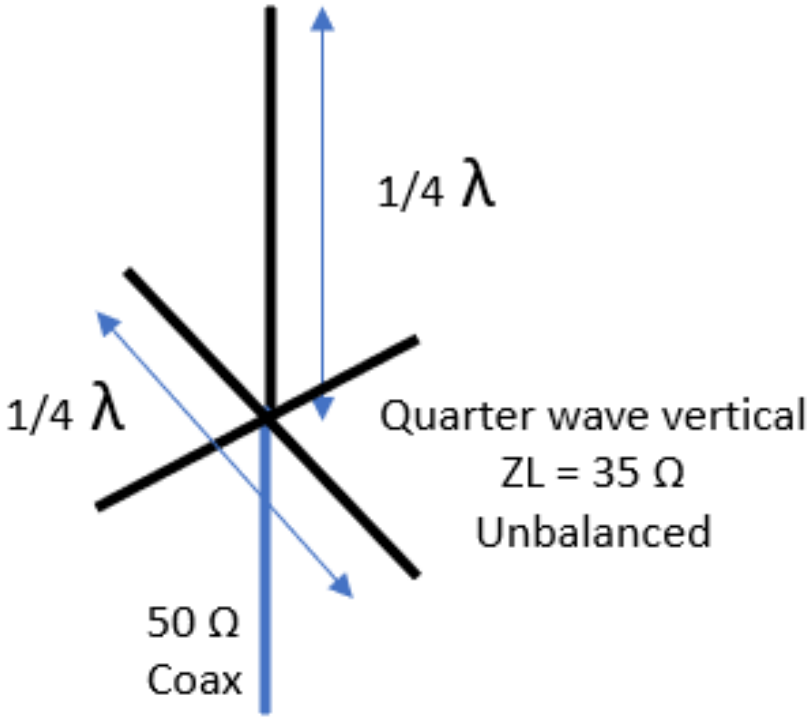
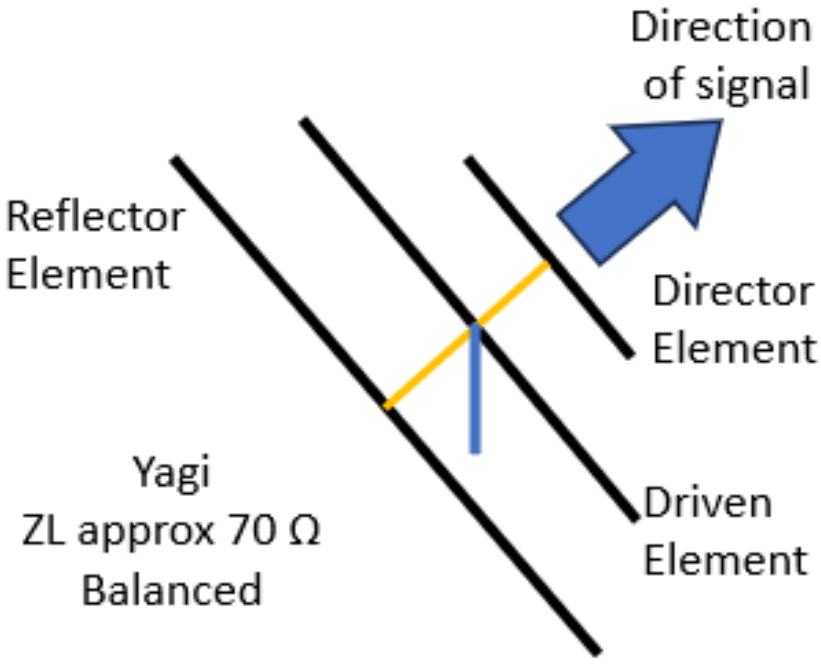


Yagi

The Yagi is a directional antenna concentrating the signal in one direction. The reflector elements reflect the signal from the driven element. The director elements direct the signal. The element lengths and spacing need to be calculated. Yagi calculators available on the internet



Aperture antennas

An antenna with an aperture at the end is known as an Aperture antenna. The aperture may be square, cone, rectangular or circular.

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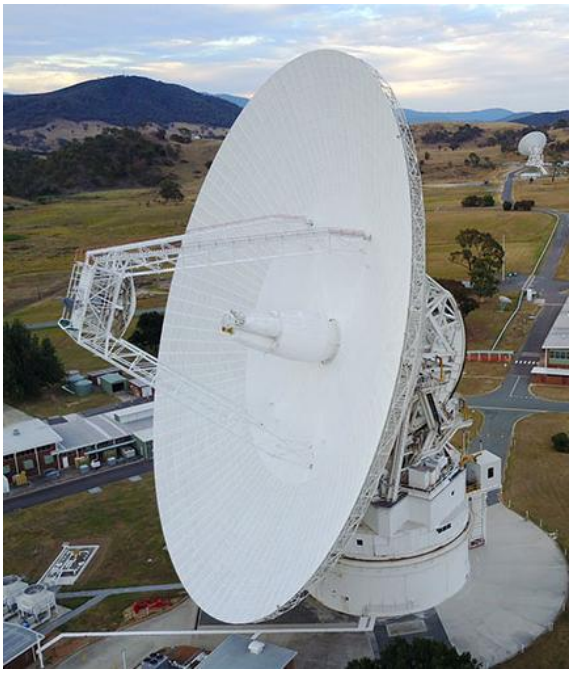
Horn Antenna

The aperture antenna usually is placed within a parabolic reflector to concentrate the signal direction. This concentration works for transmission and reception.

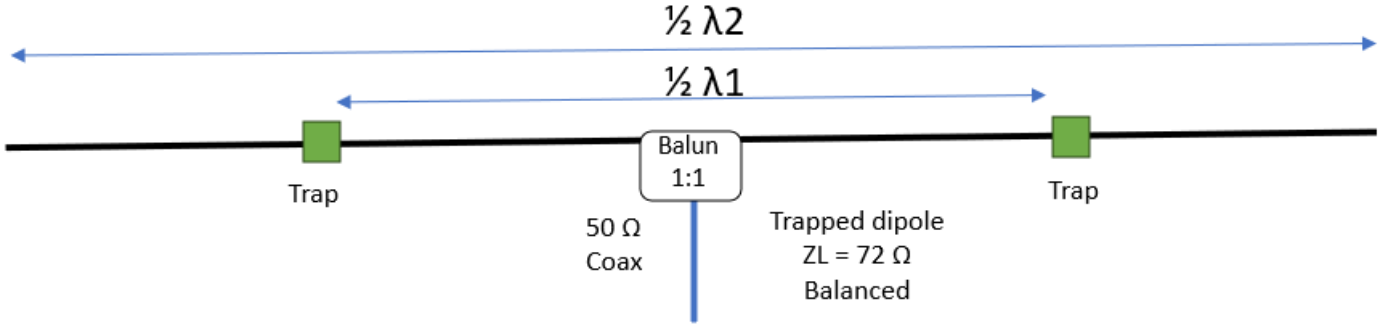
These reflectors vary in size from small TV reception to the example below of the Tidbinbilla tracing station antenna.



Trapped dipole.

A trapped dipole is a multiband dipole. The traps (parallel tuned circuits) allow the antenna to be lengthened for the designated frequencies.

The first dipole, λ1, is cut to the desired frequency. The traps are parallel tuned circuits designed to resonate at λ1 frequency. When the transmitter is tuned to λ2 frequency, the taps will not block the signal, and the dipole will resonate at λ2. The traps do impact on the final length of each dipole, so careful tuning is needed.



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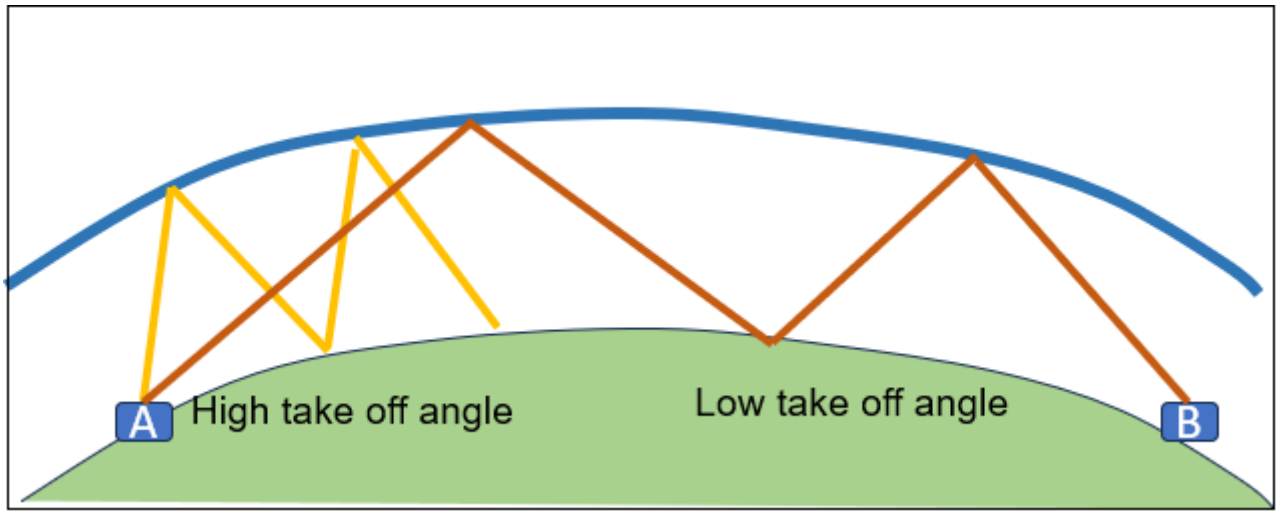
Antenna Height and Take Off Angle

For long distance communications, there are two factors which change the skip distance. One is the height of the ionospheric layer and second the antenna's take-off angle (the lower angle the better it is for far DX)

The ionospheric layer is not controllable, but the antenna height is controllable.

Placing the horizontal antenna as high as possible above ground gives the antenna the lowest take of angle.

Placing the horizontal antenna as high as possible above ground give the antenna the lowest take of angle. If the antenna is placed 1 metre above the ground, the take of angle is 44 degrees. Placing the antenna 10 meters up gives 14-degree angle. At 40 metres up, the angle is down to 4 degrees.



Special Note on antenna height

Australian Building Regulations 2018

97 Masts, poles etc.

(1) a mast, pole, aerial, antenna, chimney, flue or service pipe—

(a) when attached to a building, must not exceed a height of 3 m above the highest point of the roof of the building: or

(b) when not attached to a building, must not exceed 8 m above the ground level.

(2) The report and consent of the relevant council must be obtained to an application for a building permit in relation to a design that does not comply with this regulation.

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Antenna SWR Plot

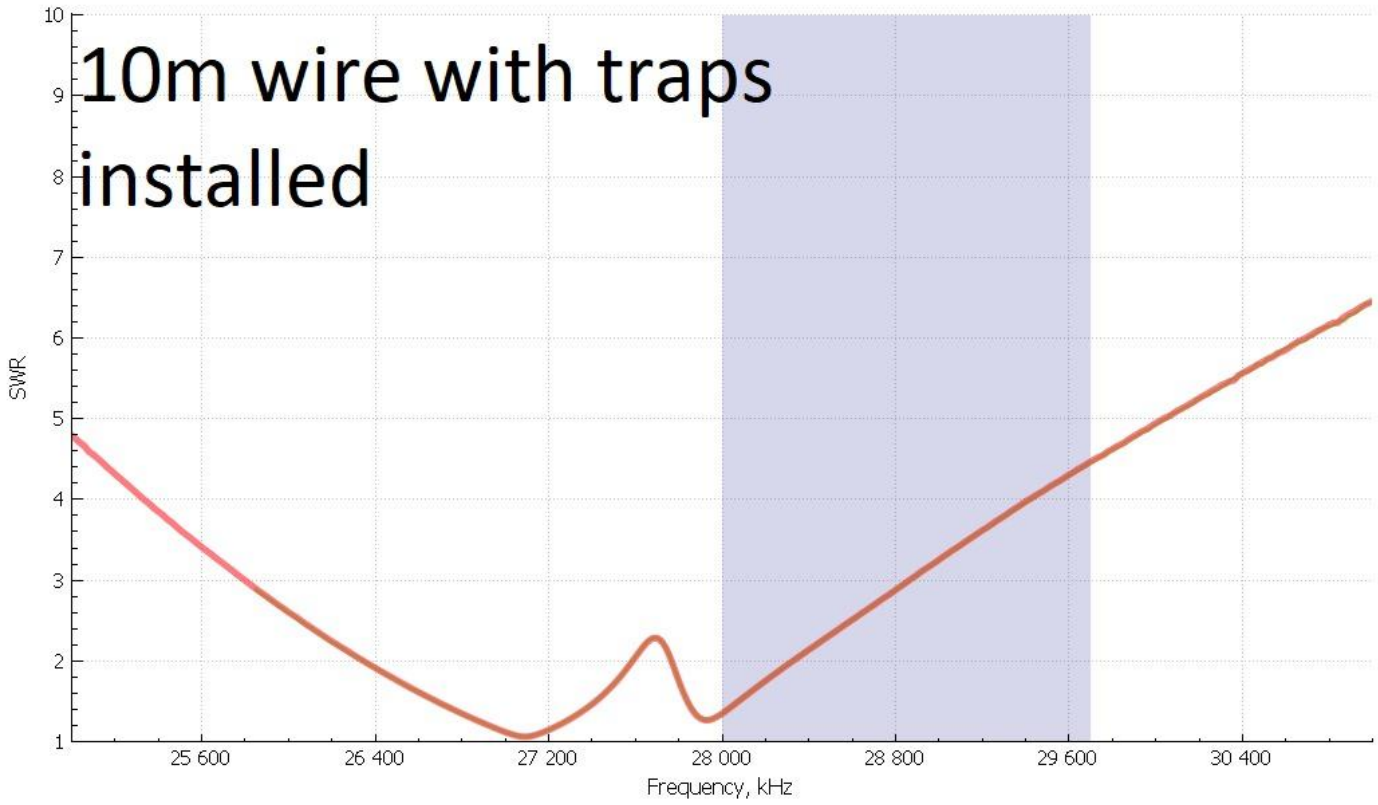
An important action for a new antenna is to plot the SWR of the antenna across the operating band. This plot is essential to check later if the SWR has changed and to ensure the antenna is operating in the correct portion of the band.

The SWR is plotted on Y axis and frequency on the X axis.

Conduct low power tests on different frequencies across your planned band. Plot the SWR on the graph and join the lines.

By running the tests, say annually, you can see if the antenna has changed over time.

One common cause for change in dipole antennas is stretching. The wire in the antenna can stretch over time.



Power

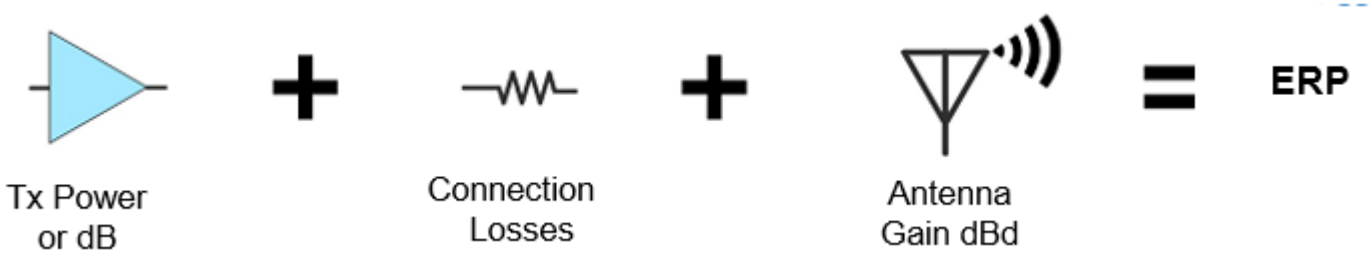
Effective Radiated Power (ERP)

ERP measures the combination of the power emitted by the transmitter and the ability of the antenna to direct that power in a given direction. ERP is equal to the input power to the antenna multiplied by the gain of the antenna.

ERP, in watts, is determined by:

1. The transmitter power at the antenna outlet – watts.
2. Combine the losses of all devices between the transmitter and antenna - dBs
3. The gain of the antenna – dBd (Decibels with respect to a dipole.)

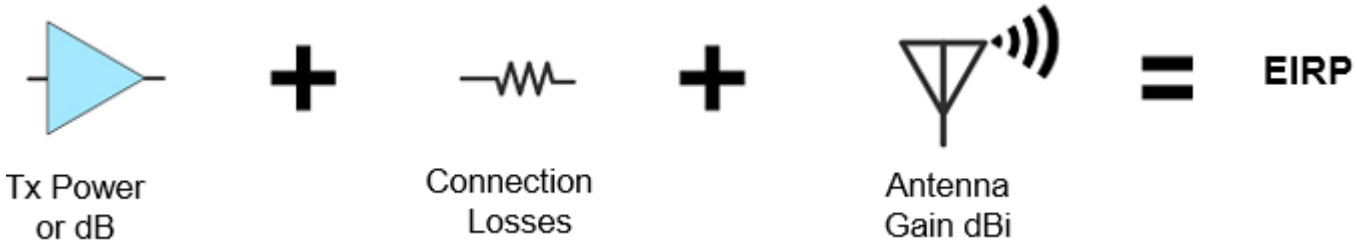
Transmitter power and ERP are both measured in Watts. Items 2-3 are measured in dB, and all measurements must be converted into the same scale. Convert Watts to dBW then back again.



Effective Isotropic Radiated Power (EIRP)

EIRP is the hypothetical power that would have to be radiated by an isotropic antenna to give the same signal strength as the actual source antenna in the direction of the antenna's strongest beam.

Antenna gain is in decibels with respect to an isotropic antenna – dBi.



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Antenna Terms

Capacitance Hat - Where short masts must be used, a capacitive top load (also known as top hat or capacitance hat) is sometimes added at the top of the mast to increase the radiated power. Since the top load acts electrically like an additional length of mast, this is called "electrically lengthening" the antenna.

Capture area - The capture area or aperture of the antenna, is the area of the antenna in correct orientation to the direction of the incoming electromagnetic wave.

Directivity - Directivity of an antenna is that the contraction of the radio waves is in one direction.

Efficiency - The efficiency of an antenna is determined by estimating the total loss of energy at the input terminals of the antenna. This includes mismatch losses and the dielectric/conduction losses.

Front-to-back ratio - The term front-to-back ratio, AKA front-to-rear ratio, is the ratio of power gain between the front and rear of a directional antenna.

Gain – The gain of an antenna is the ratio of the radiation intensity compared to the radiation intensity if the antenna were an isotropic antenna. Gain is defined by the letter G and is a unitless measure that combines an antenna's radiation efficiency and directivity.

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Electromagnetic Radiation (EMR) and Antenna Safety

EMR

Radiofrequency (RF) Electromagnetic Radiation (EMR) is non-ionising radiation and ranges between 3 kilohertz (kHz) to 300 gigahertz (GHz).

Ionising radiation, Gamma rays and X rays, has more energy than non-ionising radiation and can cause damage to living tissue. Not usually experienced in a normal radio shack.

Exposure to high levels of RF EMR can heat biological tissue and potentially cause tissue damage. The amount of environmental RF EMR routinely encountered by the public is too low to produce significant heating or increased body temperature.

Safety

When working with antennas and transmitters, apply safety standards and safe work practices. Minimise or eliminate EMR exposures.

As antennas are located above ground, the additional risks are falls from heights. In 2020-2021, 42% of hospitalised injury cases and 40% of accidental injury deaths in Australia were due to falls. Falls resulted in 243,000 hospitalisation cases in Australia in the same period. This means that around 950 people per 100,000 population were hospitalised due to falls.

A 12 minute video in Wikipedia on antennas can be seen **HERE**. Bit dry but worth a look.

Go to Unit 16 Questions.

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