



Chapter 5-2

ANTENNAS

ACMA Foundation Syllabus 5.4 - 5.11 and 5.13

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Antennas

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

Simple antennas are designed to be **resonant** at a particular frequency. That is, they are cut to the correct length for that frequency.

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

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%.

Antenna Configurations

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)

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 $\text{Wavelength } (\lambda) = c / f$. Covered previously in Chapter 1-3.

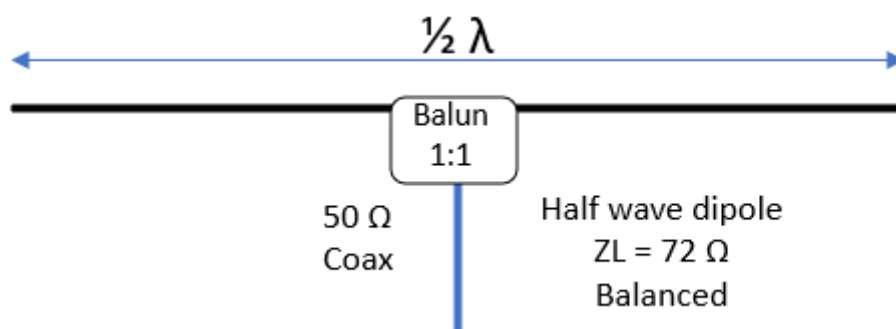
Example: What is the overall length of a dipole for 14.2 MHz.

$$\text{Wavelength} = 300 / 14.2$$

$$\lambda = 21.21 \text{ metres}$$

$$\text{Dipole (half)} = 21.21\text{m} / 2$$

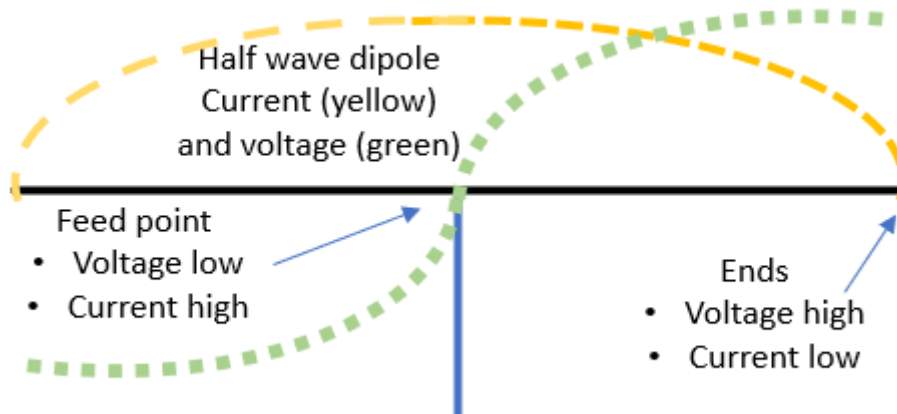
Dipole is 10.1 metres long.



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

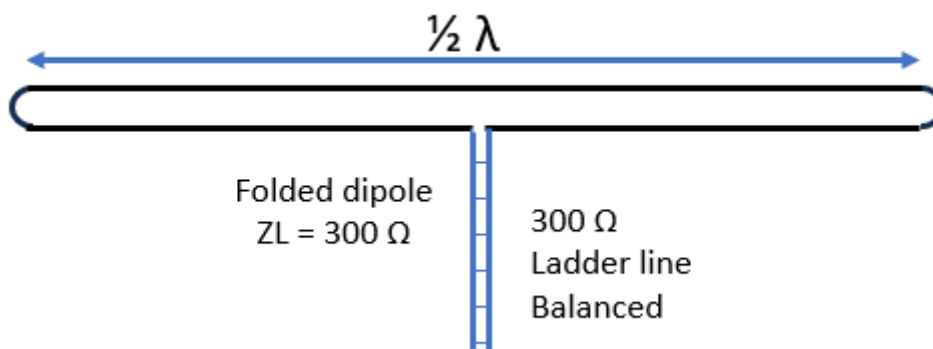
Dipole Current and voltage

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.



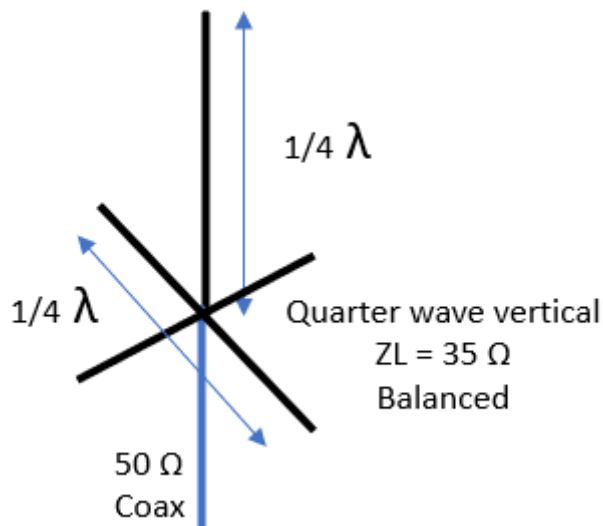
Folded Dipole

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.



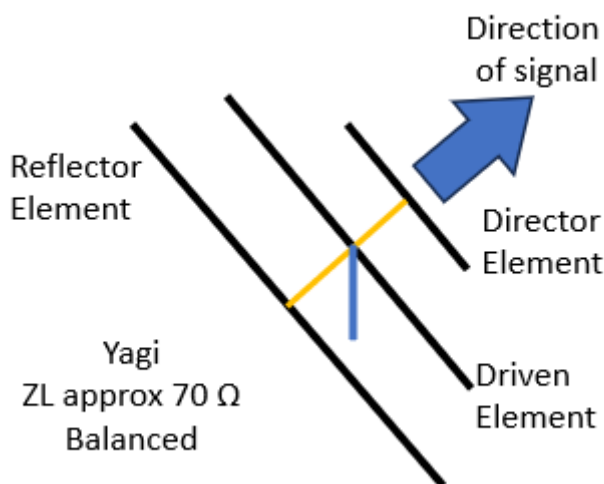
Quarter-wave vertical antenna [ground plane]

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.



Yagi

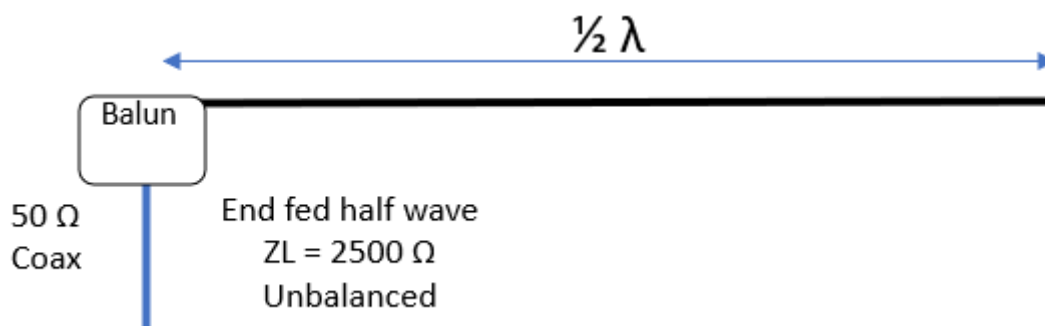
The Yagi is a directional antenna concentrating the signal through the director element direction. The element lengths and spacing need to be calculated. Yagi calculators available on the internet.



End fed half-wave antenna.

Many amateurs find this very practical because there is no long transmission line needed. The downside is that a large impedance transition is required. An antenna tuner is ideal in this situation.

The half wavelength would be set at the lonest frequency. This makes the antenna as long and straight as possible.



Non-resonant antenna

If an antenna resonates at a frequency higher than the desired frequency, the antenna is too **short** and behaves **capacitively**.

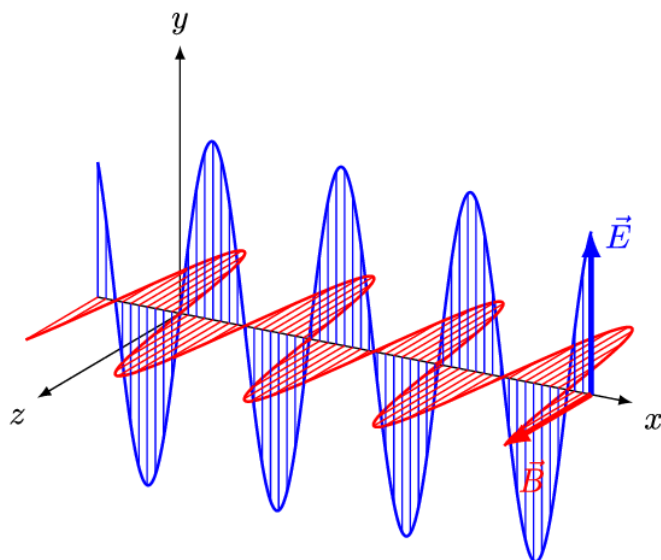
If an antenna resonates at a frequency lower than the desired frequency, the antenna is too **long** and behaves **inductively**.

The table below is an analysis of antenna behaviour when conducting tests. The method of testing an new antenna is to test ad both ends of the amateur frequencies in that band. Refer to this table to assess what actions are needed to tune the antenna.

| Desired Frequency | SWR | Antenna Length | Antenna Behaviour |
|---------------------|------|----------------|-------------------|
| Above the frequency | Good | Too short | Capacitive |
| On Frequency | Good | Ideal | Resistive |
| Below frequency | Good | Too long | Inductive |

Polarisation

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



There are three general antenna polarisations.

- Horizontal - the electric field will move sideways in a horizontal plane.
- Vertical - the electric field will oscillate up and down in a vertical plane.
- Circular - the polarisation represented by the E-field rotates as the signal propagates. 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 Terms

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

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.

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.

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.

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.

Effective Radiated Power (ERP) –The ERP corresponds to the power that should be radiated by a half-wavelength dipole 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 - dBs

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

Example (For information only): What is the ERP of the follow configuration?

TX Power: 100 W

Connecting devices: - 3dB

Antenna gain: 5dB

Loss of – 3dB = $100 \times 0.5 = 50W$

Antenna gain of 5 dB = $50 \times 3.16 = 158 W$

(Refer to Lesson 8 for review of Decibels.)

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.

Electromagnetic Radiation (EMR) Safety

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.

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 risk is falls from working at 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. 26 Apr 2023.

Balun

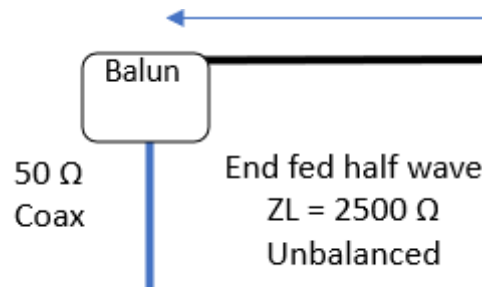
A balun is a type of transformer for matching impedances between transmission lines and antennas.

The term Balun comes from **balanced** and **unbalanced** transmission lines.

A 1:1 balun is a good idea for connecting coax to dipoles.

Other baluns can be made to suit the situation.

In the case of an end fed antenna, a balun is needed to match the big difference in impedances.



Go to Chapter 5-2 Questions.

Have fun and stay safe.