Antennas – Getting your signal out there.

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This article is purely for the beginner to appreciate the basic extent to which an antenna is critical to getting your signal out there.

What is an antenna?

An antenna falls into the component category as a ‘transducer’[i]. A transducer converts energy from one form to another. An antenna converts electromagnetic waves to Radio Frequency (RF) current in receive mode and vice versa in transmit mode.

Wavelength

The wavelength, signified by the Greek letter Lambda λ, of a signal is defined as the distance in free space where the wave travels one complete cycle[ii].

In Figure 1, the wavelength is the distance the signal travels from point A to point B.

For the electromagnetic energy to be emitted by the antenna, there needs to be a correlation between the wavelength of the signal and the length of the antenna.

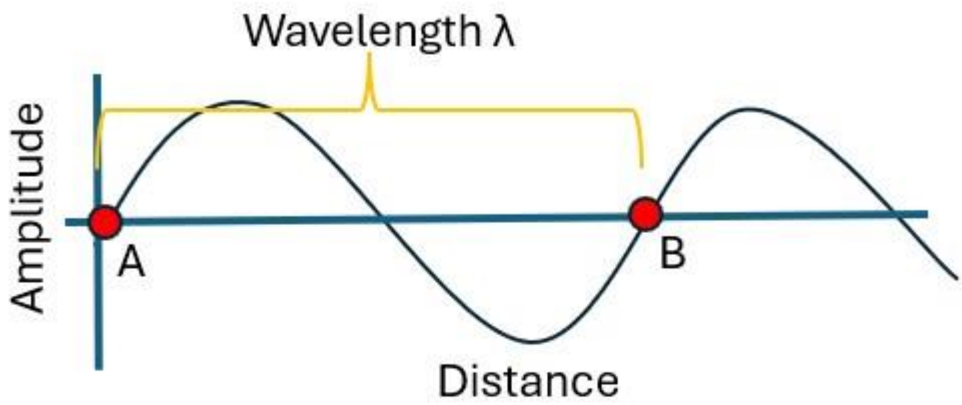

Figure 1 Signal Wavelength.

This correlation for wavelength in free space is shown in the formula.

$$Wavelength\ (\lambda) = \frac{Speed\ of\ light\ (C)\ in\ metres\ per\ second}{Frequency\ (f)\ in\ hertz.}$$

C = 299,792,458 meters per second in free space (generally rounded to 300M m/s).

Example The wavelength of a signal in free space at 144MHz is 2.08189207 metres.

Characteristics

Whether the antenna is a simple dipole or a complex array, there are several important characteristics that need to be considered.

Impedance

There are two impedances impacting any antenna.

- Self-Impedance – The self or feed point impedance is measured at the feed point of the antenna.
- Mutual Impedance – Mutual or coupled impedance is the impedance caused by conductors located near the antenna.

In this article, we will only look at the impacts of self-impedance.

When the voltage and current at the feed point are in phase, the antenna presents a resistive load, and the resistance can be calculated by dividing the voltage by the current. This will only occur at the one point where the antenna is resonant at that frequency.

This impedance match is required for the antenna to transfer the total output to the antenna effectively as shown in Figure 2.

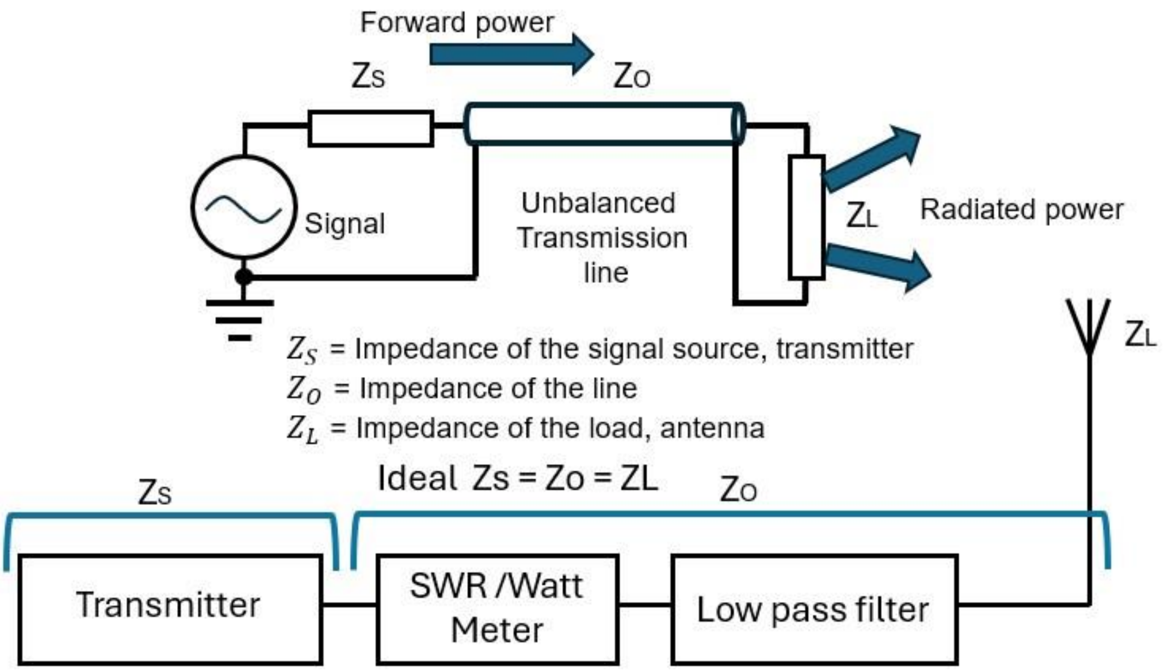

Figure 2

Impedance match

Antenna Length

If this antenna is subjected to any other than the resonant frequency, the feed point will include a resistive and reactive component making the result an impedance. The added reactance can be either capacitive or inductive.

An antenna that is too long and has an inductive reactance if the signal frequency is lower than the resonant frequency of the antenna.

An antenna that is too short and has a capacitive reactance if the signal frequency is higher than the resonant frequency of the antenna. See Figure 3.

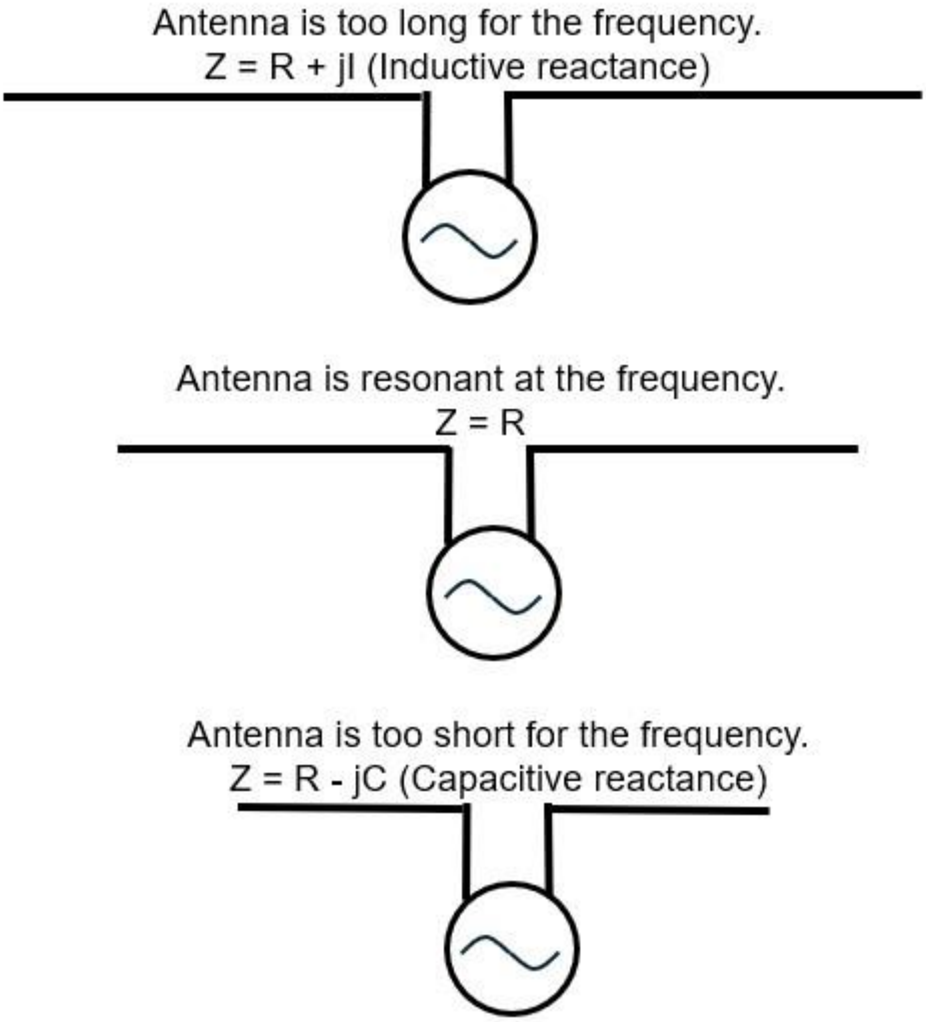

Figure 3 Antenna too long or too short.

Conductor Diameter

The feed point impedance is also affected by the wavelength to antenna conductor diameter ratio (λ / Conductor diameter)[iii]. The thicker the antenna conductor, the less the range of reactive variations.

The antenna λ / conductor diameter ratio can also impact other antenna characteristics such as bandwidth, gain and electrical length.

A long dipole made with a thin conductor has a high impedance and a narrow bandwidth making it suitable only around its resonant frequency.

A long dipole made with a thick conductor has a lower impedance and a wider bandwidth making it suitable to operate effectively over a broader range of frequencies.

Example: If a 30-metre antenna made with 0.001mm wire is scanned with a frequency range of 1 – 30 MHz, the measured reactance range is 7000 to -7000 Ohms. This antenna also has a very narrow antenna Quality factor (Q). See Figure 4.

If a 30-metre antenna made with 250 mm** wire is scanned with a frequency range of 1 – 30 MHz, the measured reactance range is 700 to -700 Ohms. This antenna also has a very wide antenna Quality factor (Q).

** I know this size is not practical. This example is only meant to show the difference.

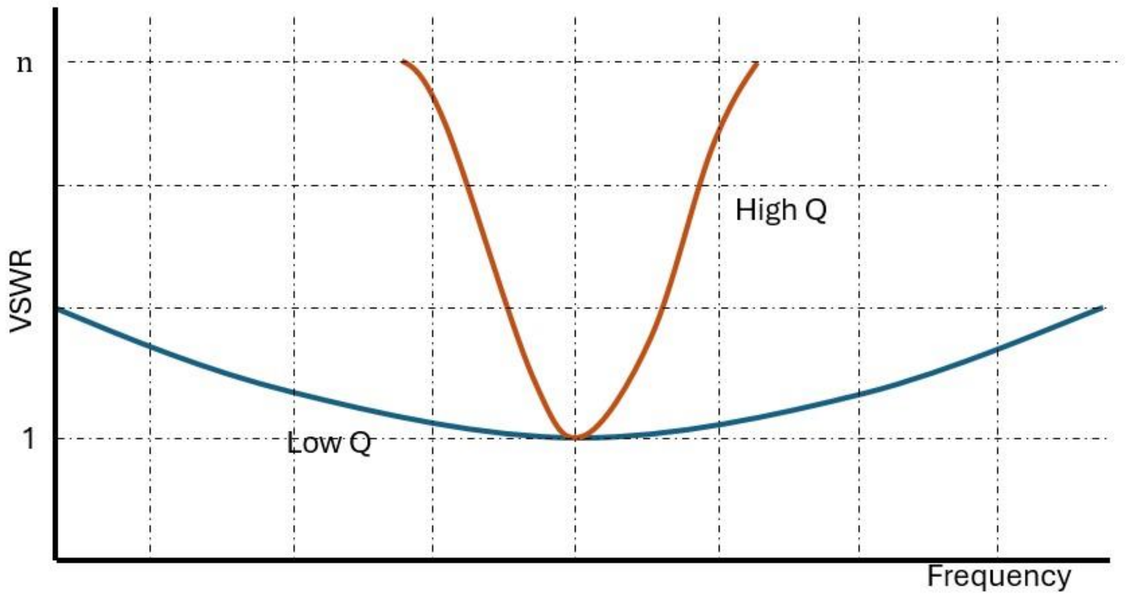

Figure 4

Antenna Q Factor.

The Q or Quality factor of the antenna determines the bandwidth of the antenna shown in Figure 5.

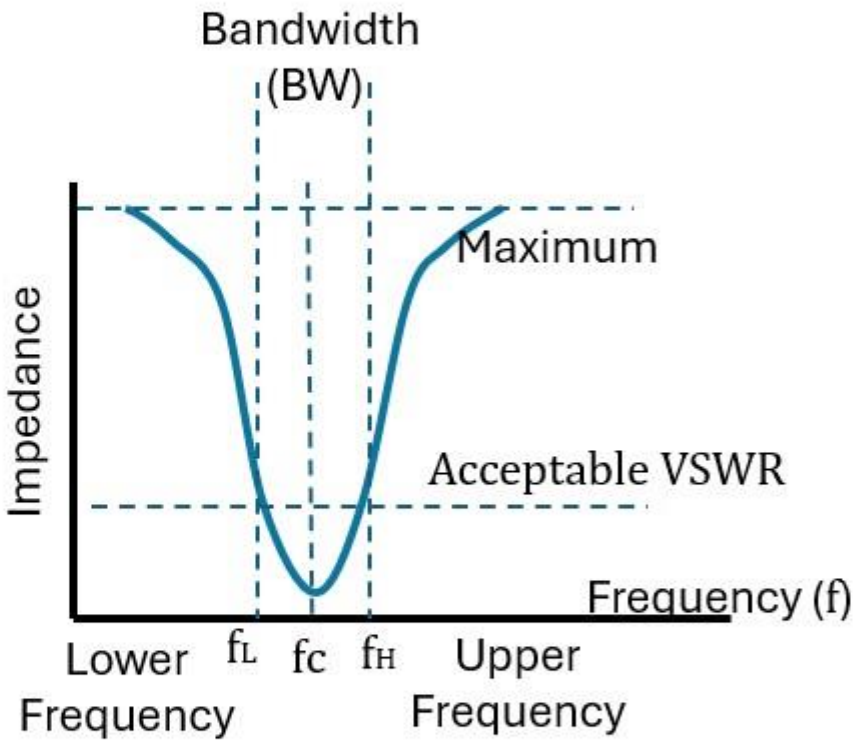

Figure 5 Antenna Bandwidth.

Directivity

Directivity is the antenna's ability to direct and concentrate the RF signal in a predetermined direction. All practical antennas are directional in some form, however, being able to control the directivity of the antenna allows the signal to be focused in a predetermined direction.

All practical antennas favour radiating in one or more directions.

Example A horizontal dipole radiates broadside to the direction of the dipole elements. A Yagi is an example of a unidirectional antenna.

Isotropic Antenna

The basis for any antenna comparison is predicated on the purely theoretical isotropic antenna or isotropic radiator.

The isotropic antenna is a point source in free space where the radiated signal will radiate equally from the point in all directions.

This antenna is used as the comparison for all practical antennas.

Antenna Gain

Antenna gain is defined as, 'The ratio of the radiation intensity in a given direction to the radiation intensity that would be produced if the power accepted by the antenna were isotopically radiated[iv]'.

Measuring the gain of an antenna compared to the isotropic antenna is expressed in decibels isotopic (dBi).

Measuring the radiated power in the front of the Yagi antenna and comparing this with the theoretical power at the same point as radiated from an isotropic antenna calculates the antenna gain. This ratio is expressed as dBi as shown in Figure 6.

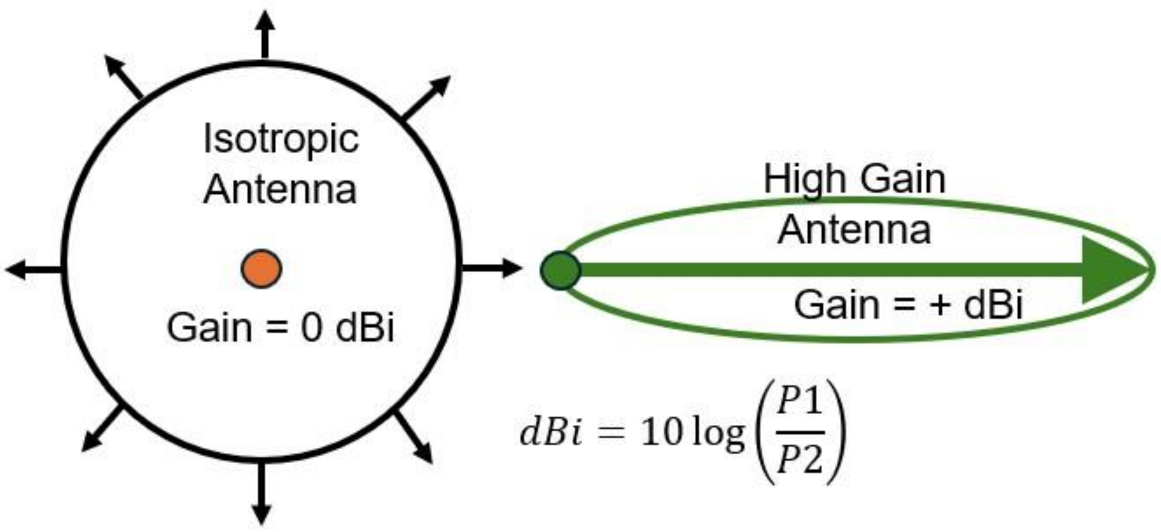

Figure 6

Antenna Gain.

No additional power is added to the antenna. The antenna can focuses all the radiated power in one direction and not omnidirectionaly.

Efficiency

Antenna efficiency is a measure of how effectively an antenna converts input power into radiated electromagnetic energy. This is expressed as the ratio of radiated power to input power. This can be a percentage or in decibels (dB). The higher the efficiency of an antenna, the more power is used for signal transmission rather than being wasted as heat.

Antenna efficiency varies, but a typical 'good' antenna radiates 50–60% of the power fed to it, while ideal antennas approach 100%[v].

Polarisation

The signal radiated from an antenna has energy in two planes. The E plane is the electrical signal, and the H plane is the magnetic signal. These two signal planes are ninety degrees apart. See Figure 7.

The polarisation of the antenna is determined by the E field plane.

The three main polarising patterns are vertical, horizontal and circular.

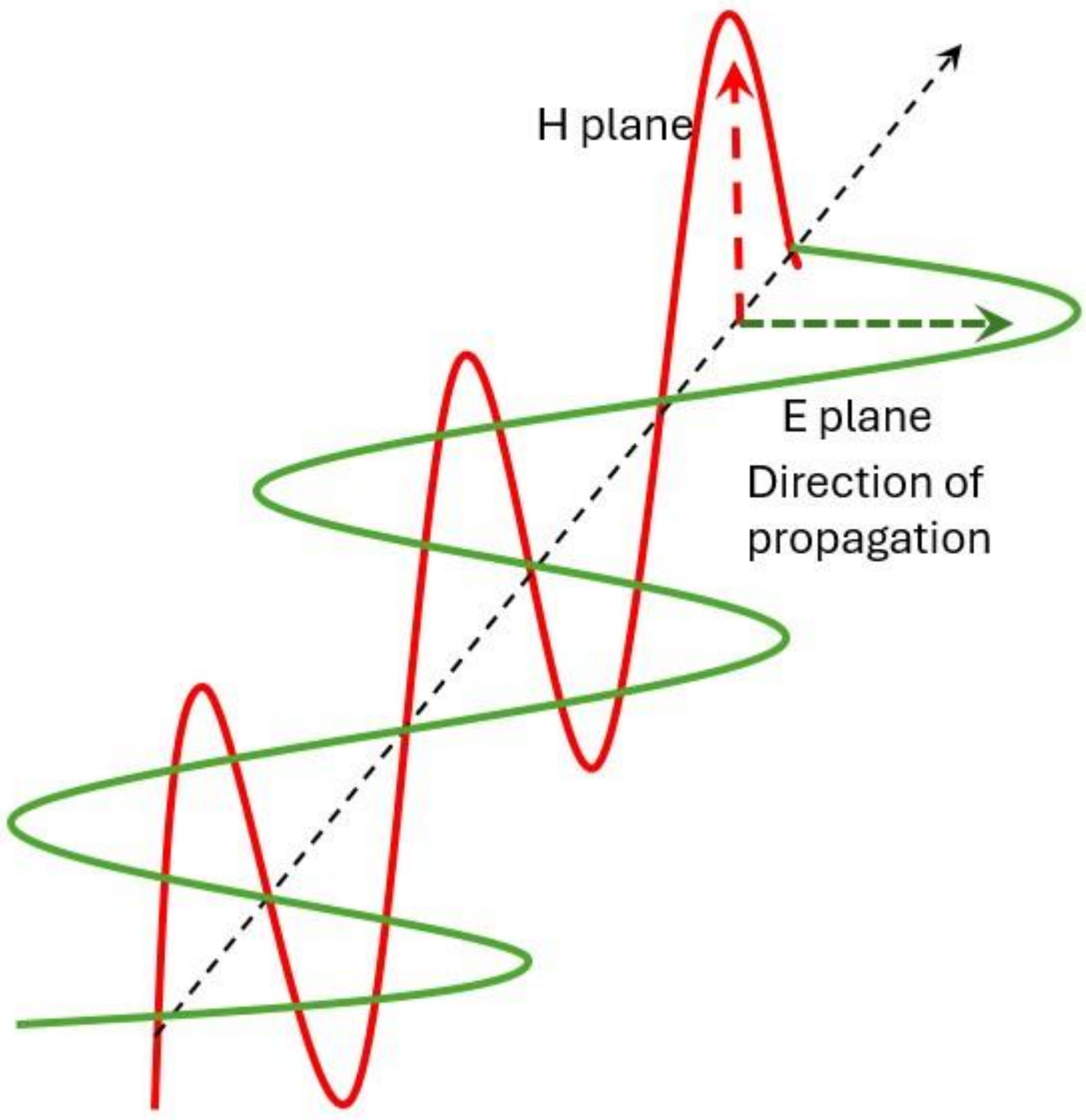

Figure 7

Antenna Polarisation.

Considerations

This article just scratches the surface on antennas and intended to raise operator's awareness of some antenna characteristics. In the end, these are just some of the considerations you need to address if you want to get your RF signal out there.

Further reading is encouraged from the many established and reliable texts from authors and publishers such as the ARRL, RSGB, Kraus, Orr, et al. Beware of material and opinions expressed on the www and social media, some of which is incorrect or highly questionable.

Have fun and stay safe.

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[i] ARRL Antenna Handbook 19th Edition.

[ii] Ibid

[iii] Ibid

[iv] I EEE Std 145-2013, IEEE Standard for Definitions of Terms for Antennas. IEEE

[v] Antenna Efficiency The Antenna Theory Website