Antenna Design Guide

This guide is intended to provide a brief overview of the key considerations when selecting an antenna or looking to implement a custom antenna design. Despite the progress made on simplifying radio transmitter and receiver design to the point where simply following the guidelines laid down by the manufacturer can result in a working design, antenna design still requires a grasp of the underlying theory.

Basic Terminology

Bandwidth	The range of frequencies on either side of the centre frequency where the antenna characteristics (such as input impedance, polarization, gain and efficiency) are within an acceptable value of those at the centre frequency.
Directivity	The ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions.
Efficiency	The amount of energy radiated, compared to the amount of energy at the input terminals of the antenna.
Gain	Closely related to directivity but takes into account the antenna efficiency.
Impedance	The impedance presented by an antenna at its input terminals.
Polarisation	The vector traced by the electric field as viewed along the direction of propagation.
Radiation Resistance	The equivalent resistance that would dissipate the amount of power lost through radiation.

Background Theory

As mentioned in the introduction antennas can't be effectively designed and integrated without at least a basic grasp of the underlying principles. Unfortunately while there is some literature that manages to portray the theory without resorting to complex mathematical derivations, most require a solid grasp of Vector Calculus to get much beyond the first chapter. In this article I will keep things as simple as possible.

It does not take long when researching antenna design to realise that the famous Maxwell's equations underpin everything. Fortunately when expressed in "plain English" these are very simple to grasp and I suggest that anyone wishing to understand antenna design should meditate on these equations until they can be expressed in your sleep!

Maxwell's equations are essentially a set of four equations from three of the times greatest scientists (Ampere, Faraday and Gauss). These are:

1. **The electric flux through a closed envelope equals the charge contained.**
2. **The magnetic flux through a closed envelope is zero.**
3. **The electric field integrated around a closed loop is equal to the negative of the rate of change of the magnetic flux through the loop.**
4. **The magnetic field integrated around a closed loop is equal to the total current that passes through it.**

In summary one of the basic requirements for radiation is to maximise the magnetic field, and this is most effectively done by maximising the current and loop area.

There are three regions or zones when considering radiation from an antenna:

1. Reactive near field
2. The radiating near-field (Fresnel region)
3. The far field (Fraunhofer region)

The size of the reactive near field is given by $R = 0.62\sqrt{D^3/\lambda}$, where D is the largest dimension of the antenna, and λ is the wavelength.

For electrically small antennas the Fresnel region does not exist. The Far-field can generally be assumed to start at $2*D^2/\lambda$.

Antenna Types

Dipole

Possibly the most well-known antenna is the dipole, which simply consists of a quarter-wave driven element and a quarter-wave element on the ground or return, this results in overall dimensions equivalent to a half wavelength. The dipole impedance is approximately 73 ohms, and gain is approximately 1.5dB

While providing a very simple and low cost antenna they are not very common for low power radio links due to the relatively large size.

Monopole

A monopole or quarter wave antenna is extremely common in low power radio links and the design is very simple. The impedance is approximately 37 ohms and gain is approximately 5dB. A monopole requires a large ground plane with dimensions of at least quarter of a wavelength, although it is quite acceptable to build your circuitry onto this ground plane. The radiating element should be at 90 degrees to the ground plane to maximize radiation.

A monopole can be “shortened” by inductively loading the antenna to reduce the over-all dimensions but the radiation efficiency will be reduced.

Printed Antennas (PCB)

PCB antenna’s come in many forms and in fact both dipoles and monopoles can be implemented as copper on the PCB substrate to keep costs down and ease manufacturing. Some of the most common PCB antennas though are both the patch antenna and inverted F (PIFA).
To design an effective patch or PIFA requires both modeling software and a number of iterations, with the appropriate skills to optimize the design. The size of a rectangular patch is normally ¼ wavelength long and the width dictates the bandwidth. The impedance is a function of where the patch feed-point is located providing a degree of flexibility in matching to different chipsets. The dimensions of the patch can be reduced by loading the patch antenna; this is normally achieved using shorting posts to the ground plane at appropriate locations. The overall loop area should be maximized to ensure efficient radiation.

A PIFA antenna is a special case of patch antenna and gets its name from the appearance of the antenna as an “inverted F”.

Antenna Measurements

Input impedance

The input impedance of the antenna is ideally measured using a Vector Network Analyzer (VNA), however an SWR meter or scalar analyzer can be used to test the return loss. The impedance is measured and specified at the centre frequency of the antenna.

Bandwidth

The bandwidth of the antenna is measured using a VNA or SWR meter and is typically specified for an SWR less than 2:1 or Return loss of either -6dB or -10dB.

Pattern

The radiation pattern is best measured in an open field environment ensuring that the receiving or reference antenna is in the far-field. The antenna is then rotated through 360 degrees in both the horizontal and vertical planes to obtain polar plots of the radiation pattern.

Efficiency

In order to calculate the efficiency both the absolute gain and the directivity need to be measured.

Design Service

TrimeriX offer a design service to clients looking for custom antenna designs. Please call our team to discuss your specific requirements. We have over 10 years developing wireless products from baseband through to antenna and have implemented solutions across a diverse range of applications.