FAQs Antennas - An Introduction

An Introduction:

Antennas are the fundamental components of an electrical system which uses free space as the transmitting medium. Antennas are devices used in the transmission or reception of electromagnetic waves carrying some signal and are used to interface the transmitter or receiver to free space. The theory behind antenna design is not yet fully understood so the development of antennas involves quite a bit of trial and error to find a design that performs best in a certain system. Obviously, different types of systems transmit and receive different types of waves, so the operational characteristics of the system are designed according to the properties of the antennas. There must be two types of antennas in any system: a transmitting and a receiving antenna. The ideal transmitting antenna is one that will radiate all the power delivered to it in the desired direction and with the desired polarisation, while the ideal receiving antenna is one that will obtain the maximum possible signal voltage from that available in the air with the minimum possible noise. There are many types of antenna each is designed to transmit or receive a specific type of radiation. The shape and number of antennas in a system depends largely on the type of waves being used and the frequency at which they are transmitted. Today, an increasing number of different antennas are being seen everywhere.

For the next few issues Antennas from simple loops to complex dishes will be discussed with a brief explanation of their properties as well as their advantages and drawbacks. Also covered will be the practical side of antennas: how they are designed and implemented for their specific applications in the real world. There are a countless number of antenna available, and all these have varying advantages and disadvantages. Some designs are limited to certain frequency ranges only.

Antenna Basics

The operation of a simple transmitting antenna can be illustrated by thinking of an open-circuited transmission line. At the open end, a phase reversal results, causing some of the incident voltage to be radiated away from the transmission line instead of reflected as is normally the case. The radiated energy is in the form of transverse electromagnetic waves and the amount of radiation emitted can be varied by increasing or decreasing the distance between the conductors.

Basically, a transmitting antenna transmits by exciting it at the base or at a pair of antinodes while in a receiving antenna, the applied EMF is distributed throughout the entire length of the antenna to receive the signal. Antennas have a number of important properties which vary according to their application. The properties of most interest include the gain, radiation pattern, bandwidth and polarisation.

Antenna Gain

There are two measurements of gain, namely directive gain and power gain. Directive gain is the ratio of the power density radiated in a particular direction to the power density radiated to the same point by a reference antenna, assuming both antennas are radiating the same amount of power. The power gain is the same as directive gain except that antenna efficiency is taken into account and the total power fed to the antenna is used in the calculations. It is assumed that the antenna and the reference have the same input power and the reference is lossless. The power gain is equal to the directive gain if an antenna is lossless (it radiates 100% of the input power and gain of 0 Db). The gain of an antenna is often used as a figure of merit.

Receiving Cross Section

Whereas gain is the most useful parameter to describe the transmitted signal, a receiving antenna is best described by the quantity receiving cross section. A signal at the location of the receiving antenna will have a certain power density. This can be thought of as the amount of power passing through the plane perpendicular to the receiving antenna. This power will excite a current (and voltage) in the antenna which can be delivered to a receiver circuit. The power received at this point is called the received signal power. The receiving cross section of the antenna is the ratio of the received signal power to the power density at the receiver.. The receiving cross section, however, is not directly equal to the physical cross-section of the antenna. However, for some antennas with high gains these areas may be almost equal, and some small antennas may even have much larger receiving cross sections.

Radiation Pattern

The radiation pattern of an antenna is a polar diagram representing the spatial distribution of the radiated energy.
There are four common radiation patterns used:

1. Omni directional (broadcast-type) pattern
2. Pencil-beam patterns
3. Fan-beam patterns
4. Shaped-beam patterns

The broadcast pattern is used mainly for communication services where all directions are to be covered equally. In the horizontal plane the pattern is horizontal while in the vertical direction may have some directivity to increase the gain. The pencil-beam pattern is used to get maximum gain in a single direction and the radiation pattern is the same in both planes. The fan-beam is very similar to the pencil-beam except that the cross-section of the beam is elliptical. The beamwidth in one plane may be larger than the beamwidth in the other plane. Shaped-beam patterns are used when the pattern in one plane requires a specific type of coverage.

Bandwidth

The bandwidth is not easily defined and depends on a number of factors including the shape of the radiation pattern, gain, impedance and polarisation. An adequate definition would be the frequency range over which the antenna performs suitably for the given specifications. For example, a TV transmitting antenna must have at least the BW of all the frequency components of the TV signal that it must transmit and a TV receiving antenna must have sufficient BW to receive all the channels to which the receiving set can be tuned.

Polarisation

This is the orientation of the electric field radiated from the antenna. For example a horizontally polarised antenna radiates a horizontally polarised electromagnetic wave and a circularly polarised antenna has the electric field rotating in a circular pattern.

Impedance

The input impedance of an antenna affects the transmitting or receiving efficiency of the antenna. The total input impedance depends not only on the antenna elements, but also the mutual impedance between the elements as well as the transmission line components used to connect the antenna elements.

Size

Generally (but not always) some proportionality exists between the size of an antenna and the wavelength at the frequency of operation. For example, some half wave dipoles used at microwave frequencies can be under 3cm long, while the largest antennas are used for low frequencies. The U.S. Navy have a large VLF antenna which consists of two wires supported by 300m towers over an area of 2km^2.

PRACTICAL DESIGN OF ANTENNAS

The design of an antenna system will revolve around the characteristics of the system in which it will be used. In the transmitting case, the main requirement is to radiate as much of the available energy as possible, whereas in the receiving case the main aim is good signal to noise ratio. In most aspects the antennas are similar so the properties of both transmitting and receiving antennas will be almost identical. Hence the design process will be the same, except that a receiver will require reception over a wide range of frequencies.

For an antenna to work properly, it must be the right shape and size. However, given how common antennas are today, they must be made small and pleasing to the eye. This is another problem for antenna designers.

In navigational systems for example, the directional properties of the antennas will be paramount to the design, while broadcasting systems will use antennas to radiate the signal in all directions.

TYPES OF ANTENNAS RADIATORS

Short dipole

The simplest radiating unit is the electrically short dipole (short meaning short compared to a half wavelength). If a short dipole has no initial charge and a current starts to flow in one direction, one half of the dipole will acquire a surplus of charge while the other will acquire charge deficit. This means that a potential difference exists between the two halves of the dipole. If the current is reversed, the imbalance of charge will be firstly eliminated and then be reversed in direction. This oscillating current thus causes an oscillating voltage. A sinusoidally oscillating current causes the induced voltage to be 90o lagging.

This current and voltage induce a magnetic and electric field respectively around the wire. As the current and voltage continues to oscillate in the dipole, the outward travelling field is effectively an electromagnetic wave, radiated by the dipole. Short dipoles are limited to large frequencies (above 2MHz) and are difficult to feed. Also, high directivities cannot be obtained by these antennas.

Loop antennas

A current can be made to flow in a loop (single turn of wire) by breaking it at some point and connecting the terminals to some source. So that the current in all parts of the loop is of the same amplitude and phase, the radius of the loop is small compared to the wavelength. To analyse the loop, consider it as made up of many elemental dipoles (a short dipole with uniform current). Elemental dipoles have straight length, so the loop can be thought of as made up of an infinite number of straight dipoles. The individual fields of all these dipoles are added vectorially and the result is that the pattern is the same shape as a single elemental dipole with the axis perpendicular to the plane of the loop.

Low Frequency Antennas

Low frequencies usually means in the order of 10 to 500 kHz. Operating at these frequencies provides a low attenuation rate and relatively stable propagation characteristics. The major dilemma with antennas in this frequency range are their shear size. For example a frequency of 100 kHz has a wavelength of 3 km, if this was to be implemented with a basic single dipole antenna, you would have to manufacture a length of metal capable of handling the required current 3 km long. no mean feat.

There is in fact only a few choices when it comes to low frequency antenna designs that will work effectively. The four most common types are: The Base-insulated monopole, the Top-loaded monopole, the T antenna and the Inverted-L antenna. The potential performance of a low frequency antenna can be predicted from three basic parameters: effective height, antenna capacity, and self resonant frequency. .Generally low-frequency antennas are designed to be operated well below their self-resonant frequency. The antenna impedance is therefore capacitive, and the antenna may be tuned with a series inductor.