SECTION TWO

BASIC THEORY & CONCEPTS

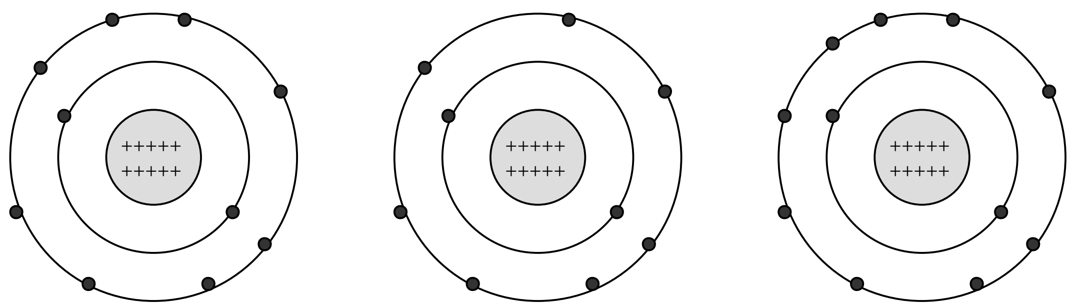
7

FUNDAMENTALS OF ELECTRICITY

No Amateur Radio equipment can function without electricity. So lets look at the magic behind voltage current, resistance, alternating current (AC), direct current (DC) as well as insulators and conductors.

Everything physical is built up of atoms, particles so small that they cannot be seen even through the most powerful microscope. The atom in turn consists of several different kinds of still smaller particles. One is the ***electron***, essentially a small particle of electricity. The quantity or charge of electricity represented by the electron is, in fact the smallest quantity of electricity that can exist and has a ***negative*** charge.

An ordinary atom consists of a central core called the ***nucleus***, around which one or more electrons orbit, somewhat as the earth and other planets revolve around the sun. The nucleus has a net ***positive*** electric charge. In a neutral atom, the net charge of the electrons orbiting the nucleus is equaled to the net positive charge of nucleus.



In a neutral atom

Net positive charge = 10+
Net negative charge = 10-

∴ Net charge = 0

In a positive ion

Net positive charge = 10+
Net negative charge = 9-

∴ Net charge = 1+

In a negative ion

Net positive charge = 10+
Net negative charge = 11-

∴ Net charge = 1-

● Electrons (negative charge)

The important fact about these two opposite charges is that they are strongly attracted to each other. Also, there is a strong repulsion between two charges of the same kind. The positive nucleus and the negative electron are attracted to each other, but two electrons will be repelled from each other and so will two nuclei.

In a neutral atom, the positive charge on the nucleus is exactly balanced by the negative charges on the electrons. However, it is possible for an atom to lose one of its electrons. When that happens, the atom has a little less negative charge and thus it now has a net positive charge. The atom is said to be ***ionized*** and in this case, it is now a ***positive ion***.

If an atom picks up an extra electron, it will have a net negative charge and is called a ***negative ion***. A positive ion will attract any stray electron in the vicinity, including ones that may be attached to a nearby negative ion. This is the way that electrons travel from atom to atom and the movement of electrons constitutes an ***electric current***.

7.1 TYPES OF MATERIALS

Conductors are materials, notably metals, which will give up electrons readily and allow an electric current to flow through it. Examples of good conductors are: copper, brass, steel, carbon, gold and aluminum.

In **insulators**, their atoms will not part with their electrons even if the electrical force is extremely strong. These materials will not give up electrons, to become positive ions, to allow the movement of electrons. Insulators are poor conductors of electricity. Some examples of insulators are: glass, rubber, dry wood, dry air, mica and porcelain.

Electricity has three main effects that can be seen in its everyday uses. The three effects are as follows: *a heating effect, a magnetic effect and a chemical effect.* The heating effect can be observed while using an electric iron, an electric toaster, or an incandescent light bulb. The magnetic effect comes to play in the operations of electric motors, generators, transformers and radio waves propagation, to name a few examples. The chemical effect is used in battery cells (where electricity is produced by the action of two or more dissimilar compounds), fluorescent lights, your computer monitor screen, as well as your television screen.

7.2 BASIC ELECTRICAL TERMS

Voltage means is a measure of potential difference.

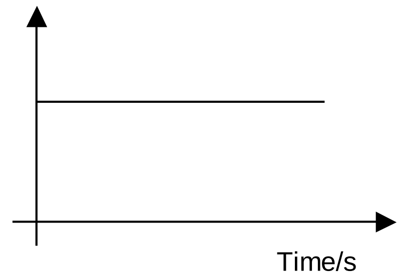
It is called *potential* because the electrical charge is capable of doing some work but may or may not be doing work. Voltage is also called electromagnetic or electromotive force (emf for short) and generally, voltage is a measure of the electrical pressure or force ready to be put to work.

Current is the flow or movement of electrons.

Electron flow can only take place when there is a voltage (potential difference) and a conductor through which the electrons can freely move. As an analogy, picture two adjacent lakes that we will call High and Low. Lake High has a water level that is several feet higher than Lake Low. If we cut a small channel between them but put a barrier in the channel, no water will flow, but there will be a pressure difference. When we remove the barrier, water will flow from Lake High to Lake Low until the difference in height is gone and both lakes are at the same level. In electricity, water level in this analogy is similar to electron flow. Thus, an electric current will flow until the potential difference is eliminated or the path is blocked.

Direct Current (DC) is defined as a unidirectional current in which the changes in value are either zero or so small that they may be neglected.

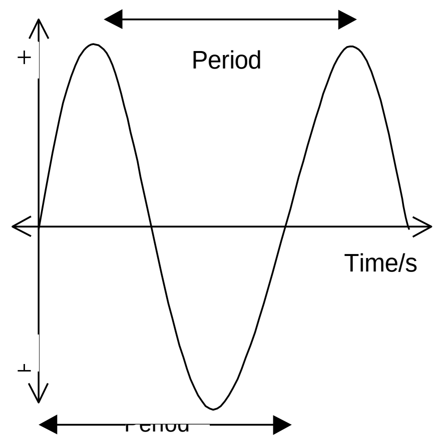
What this means is that if we could see direct current with our eyes, it would flow in only one direction (like a river) and would appear as a straight line with no humps or bumps. Common sources of DC voltage are batteries. Only direct current can be stored in batteries.



Direct Current (DC)

Alternating Current (ac) is defined as, a periodic current the average value of which over a period is zero. Note that, unless distinctly specified otherwise, the term *alternating current* refers to a current that reverses at regularly recurring intervals of time and that has alternately positive and negative values."

What does all this mean? Simply that ac voltage has a starting point (zero reference) of no value (zero voltage), then it rises to a particular peak (high) value, falls back to zero and then drops to a negative value that is equal to the peak value. This particular shape created by the electric current is known as a sine wave or is said to have sinusoidal properties. The rise and fall of the wave (a cycle) occurs within a precise time frame, which is known as the *period* of the wave, with units in seconds. The number of cycles that the wave performs in a second is known as the *frequency* of the wave.



Alternating Current

In St. Lucia, the frequency of the ac electrical supply is 50 cycles per second or 50Hz (Hertz). This means the current will travel through one complete cycle: zero to plus, plus to zero, zero to negative and negative back to zero, in 0.02 seconds. This happens 50 times per second with the current from our electrical mains and may occur several million times per second with the radio frequency energy that amateurs use to communicate.

The electric power lines carry ac voltage. Some of them carry thousands of volts from the power stations to communities miles away. The high AC voltage is lowered before it enters our homes and other buildings, using step-down transformers, where the output voltage is specified factors less than the input voltage.

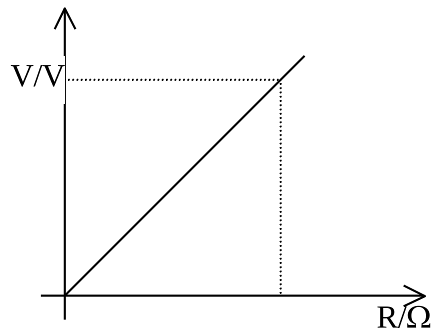
Alternating current is used mainly to power our buildings, to illuminate the bulbs in our lamps, to operate fans, electric irons, toasters and the like. On the other hand, most electronic equipment requires a dc-voltage source.

The shape of radio waves is identical to alternating current, but the cycle rate is very high. For example, a 3800-kHz (3.8 MHz) radio signal goes through its ac cycle 3.8 million times a second. Audio energy (sound waves) is also ac and the cyclic rate continually varies, as it is dependent on the particular tone at a given instant.

7.3 OHM'S LAW

Ohm's Law states that the flow of electricity in a circuit is directly proportional to the applied voltage and the total resistance in the circuit. In order to best understand the Ohm's law, there are a few terms that must be understood in order to be able to work with the different algebraic formulas.

- The measurement for electromotive force (emf) or *Voltage* has symbols E or V and the units of this measurement is Volts, abbreviated V.
- Electron flow or current (I) is measured in *Amperes* (or Amps) and is abbreviated A.



Gradient of line = V/R,
where V/R = I, the current in the system

- The opposition to the electric current, Resistance (R) is measured in *Ohms* (Ω).
- Electric Power, P, (the ability to do work) is measured in *Watts* (W).

Thus, from Ohm's Law,

$$\text{Current, } I = \frac{V}{R}$$

From this equation, we can derive that

$$\text{Voltage, } V = I * R \qquad \text{and} \qquad \text{Resistance, } R = \frac{V}{I}$$

Electrical Power, $P = V * I$

Using Ohm's Law, this the formulae for Electrical Power can be rewritten as

$$P = \frac{V^2}{R} \qquad \text{and} \qquad P = I^2 * R$$

<u>Worked Examples</u>

1. What would be the resistance of a light bulb if it is connected to the domestic mains, operating at 230Vand requires a current of 0.50 A? What would be the power of the light bulb?

From Ohm's Law, we know that resistance $R = \frac{V}{I}$

Therefore, the resistance of the light bulb is $\frac{230}{0.5} = 460\Omega$

The power of the light bulb, using $P = V * I =$ $230 * 0.5 = 115W$

Note that if the equation $P = \frac{V^2}{R}$ *or* $P = I^2 * R$ *were used instead the answer for the power of the light bulb would be the same*

2. A device uses four (4) 1.5V batteries and requires 0.1W of power in order to operate. What is the resistance of the device? What current is required for the device to work successfully?

   Firstly, since the device uses four 1.5V batteries, the total voltage requirement of the device is 4*1.5 = 6V

   Using the equation for power, $P = \frac{V^2}{R}$, resistance $R = \frac{V^2}{P}$

   $= \frac{6^2}{0.1} = \frac{36}{0.1} = 360\Omega$

   To calculate the current in the device, we can use Ohm's Law, $I = \frac{V}{R}$

   Therefore, current, $I = \frac{6}{360} = 0.0167A$

3. A hair dryer is rated at 1200W and operates on the 240V mains. Calculate the current is required by the dryer and its resistance.

   Transposing the equation for power, $P = V * I$, current, $I = \frac{P}{V}$

   Therefore the current required by the hair dryer is $\frac{1200}{240} = 5A$

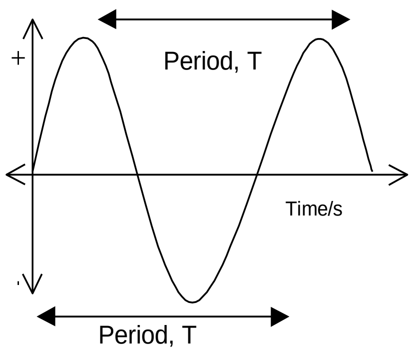
   Using the equation to calculate resistance from Ohm's Law, $R = \frac{V}{I}$

   The resistance of the components of the dryer is $\frac{240}{5} = 48\Omega$

8

FREQUENCY BANDS

All radio waves move at the speed of light, which is approximately 300,000,000 (300×10^6) metres per second. We often speak of radio waves in terms of their frequency, which as discussed in the previous chapter is the number of cycles that the wave makes per second and is measured in Hertz (Hz). From the radio wave's frequency, we can determine the time taken for the wave to make one cycle, its period and using the speed of the radio wave we can also determine the distance moved or the length of one cycle of wave, its *wavelength*.



Wavelength, λ = Distance move within a period, T

Frequency, f = Number of cycles of the wave in 1 second

$$= \frac{1}{T}$$

The frequencies allocated to the Amateur Radio Service are designated by *bands*[1], which are small slices of the radio spectrum. When one hears "the 40 Meter Band", that means that the length of one entire cycle of a radio wave, its wavelength (λ), measured from peak to peak, horizontally, (360 degrees) will be 40 metres in length.

What is a *meter*? A *metre* or *meter, m,* is a metric unit to measure length. One meter is the same as 39.37 inches (3.276 ft), which is the equivalent of a yard, plus approximately 10%. Many of the popular antennas, such as the *Yagi Uda*, have antenna elements are 95% of the half-wave long. Thus, by knowing the length of the antenna and you can determine what frequency band will be appropriate for proper operation.

<u>Worked Example</u>

1. A radio wave of frequency 13.2 MHz is being considered for use in amateur radio operation. Determine the period of the wave and its wavelength.

    Converting MHz (MegaHertz) to Hz (Hertz)[2]:

    $13.2 \times 1{,}000{,}000 = 13{,}200{,}000$ Hz

    $\Rightarrow$ In 1 second, the wave makes 13,200,000 cycles

[1] See Appendices for Frequency Bands allocated to Amateur Radio
[2] See Appendices for conversion of units

$$\therefore \quad 1 \text{ cycle, } T = \frac{1}{f} = \frac{1}{13{,}200{,}000} = 0.00000007576 \quad \text{seconds (s)}$$

$$= 0.00007576 \text{ millisecond (ms)}$$

$$= 0.07576 \text{ microsecond } (\mu s)$$

$$= 75.76 \text{ nanosecond (ns)}$$

Thus, knowing that one cycle of a 13.2 MHz wave, *T*, takes 75.76 ns and its speed, *c*, is 300 x 10^6 metres per second,

Its wavelength, $\lambda = c \text{ x } T$

$$= 300{,}000{,}000 \text{ x } 0.0000000757$$

$$= 22.727 \text{ meters (m)}$$

2. As an amateur radio operator, you are assigned to operate at 7.0 MHz. What is the length of the antenna that is best suited for this frequency?

   We know that most antennas are 95% of the length of half the wavelength of the radio wave. From the previous worked example, we know that

   Period, $T = \frac{1}{f}$ Wavelength, $\lambda = c \times T$

   Substituting for *T*, in the equation for wavelength,

$$\lambda = c \times \frac{1}{f} = \frac{c}{f}$$

$$= \frac{300 \times 10^6}{7 \times 10^6} = \frac{300}{7} = 48.857m$$

   Therefore the length of the antenna required is

$$95\% \times \left(\frac{48.857}{2}\right) = 95\% \times 21.429 = 23.208\text{m}$$

3. An antenna measures approximately 35 ft in length. What frequency is most appropriate for this antenna?

   Converting feet (imperial) to metres (metric),

   Length of the antenna is $\frac{35}{3.276} = 10.684\text{m}$,

   which is 95% of half of the wavelength of the radio wave appropriate for this antenna

   Therefore, the wavelength of the radio wave,

$$\lambda = \left(\frac{10.684}{0.95}\right) \times 2 = 22.492m$$

   Knowing that the speed of radio waves is 300x10^6m/s,

   Its frequency $f = \left(\frac{300 \times 10^6}{22.492}\right) = 13.338 \times 10^6 \, Hz$

=13.338 MHz

Therefore, we see that what we call the 160-meter band is really the 166,551 to 149,896-meter band. So here are the meter bands as we call them, with the frequencies in Mega Hertz (MHz) and the wavelengths in meters.

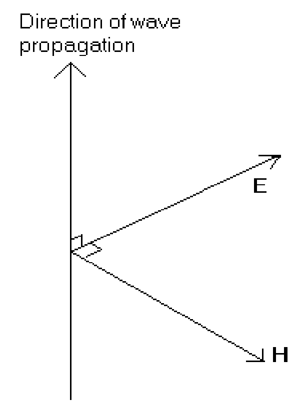
FREQUENCY BAND	**FREQUENCY RANGE/MHz**	**WAVELENGTH RANGE/m**
80M	85.655 to 74.948	3.500 to 4.000
40M	42.827 to 41.067	7.000 to 7.300
30M	29.682 to 29.536	10.100 to 10.150
20M	21.413 to 20.891	14.000 to 14.350
17M	16.592 to 16.501	18.068 to 18.168
15M	14.275 to 13.976	21.000 to 21.450
12M	12.044 to 11.990	24.890 to 24.990
10M	10.706 to 10.094	28.000 to 29.700
6M	5.995 to 5.551	50.000 to 54.000
2M	2.82 to 2.025	144.000 to 148.000

9

PROPAGATION

Radio propagation depends on the radiation of electromagnetic waves from the transmitting antenna. These waves are created by alternating radio frequency (RF) currents in the antenna, due to coupling of the output of the transmitter into the antenna system.

The transmitted signal may be regarded as a succession of concentric spheres of ever increasing radius, each one a unit of wavelength apart, formed by forces moving outwards from the antenna. These hypothetical spherical surfaces, called *wave fronts* and approximate plane (flat) surfaces at great distances. There are two inseparable fields associated with the transmitted signal, an "electric field" (E) due to voltage changes and a "magnetic field" (H) due to current changes, and these always remain at right-angles to one another and to the direction of propagation as the wave proceeds. The electric field is measured by the change of potential per unit distance, and this value is termed the *field strength*.



There are three main modes of propagation of radio waves. They are:

1) Ground (or surface) wave propagation;
2) Ionospheric (or sky wave) propagation;
3) Tropospheric propagation.

9.1 GROUND-WAVE PROPAGATION

In ground wave propagation, the radiated wave follows the surface of the earth. It is the major mode of propagation for frequencies up to 1 MHz or 2 MHz. Attenuation of the ground wave increases very rapidly above 2 MHz and it may extend for only a few kilometres at frequencies of the order of 15 – 20 MHz.

At very low frequencies the attenuation decreases to such an extent that reliable worldwide communications is possible at all times. The ground wave is more resilient to atmospheric conditions or the effects of time of day than other modes of propagation, particularly at frequencies below 500 kHz.

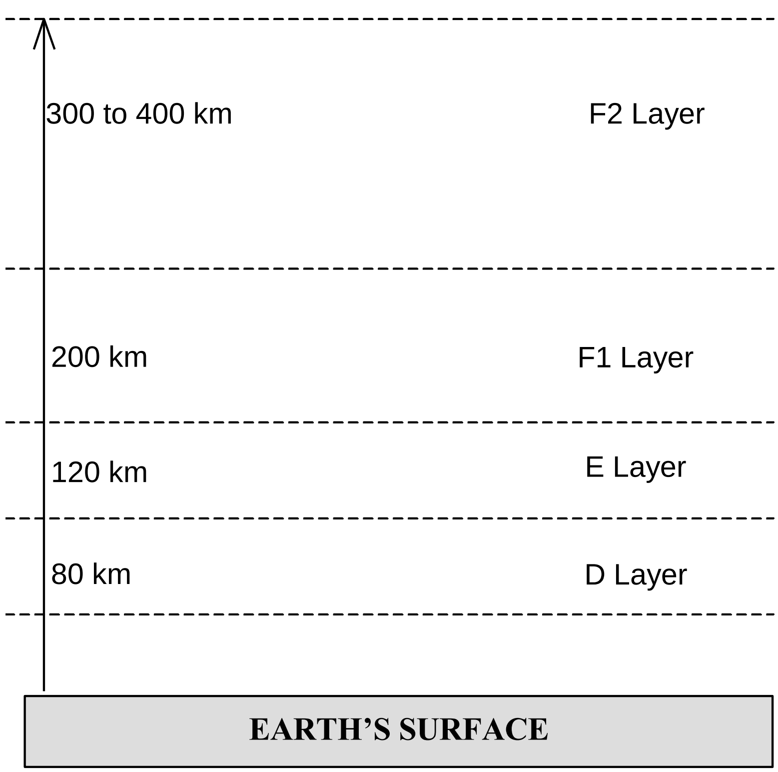
9.2 IONOSPHERIC PROPAGATION

The ionised layers in the atmosphere are the result of the ionisation of the oxygen, nitrogen and nitric oxide by X-rays and ultra-violet radiation from the sun. When these gases are ionised the molecules split up into ions and free electrons, which recombine after sunset due to the absence of the sun and its radiation. The region where this phenomenon occurs is called the *ionosphere*.

Ionospheric (sky wave) propagation uses refraction (i.e. bending) and hence reflection of radio waves back to earth by the layers of ionised gases in the upper atmosphere and is the normal mode of propagation over the frequency range of about 1MHz to 30MHz. The atmospheric layers used in ionospheric propagation are

- the **F2** layer (height 300-400km above the earth's surface),
- the **F1** layer (about 200km above the earth's surface) and
- the **E** layer (about 120km above the earth's surface).

At night and at certain times of the year, the F1 and F2 layers combine into a single layer at a height of about 250km above the earth's surface. At about 80km there is a much less distinct layer, which is generally known as the D region.



The solar radiation that causes ionisation is continually varying; hence the degree of ionisation varies considerably according to season and even the time of day. It has also been found that the number of sunspots on the sun affects the degree of ionisation in the earth's atmosphere. The maximum frequency reflected in the ionosphere, is known as the *maximum usable frequency* (*muf*). This maximum frequency depends on a number of factors such as time of day, path latitude and the state of the sunspot cycle. Signals above the maximum usable frequency pass through the F2 layer and are lost in space. When the number of sunspots is at its maximum, the *muf* may exceed 50MHz for short periods, but for the minimum number of sunspots, the *muf* rarely exceeds 25MHz.

9.3 TROPOSPHERIC PROPAGATION

This is the major mode of propagation over long distances (i.e. beyond line-of-sight range) at frequencies above about 50MHz.

Troposphere is the name given to the lower part of the atmosphere. Its height varies from about 6km to about 17km and depends upon latitude and atmospheric pressure. Changes in temperature, pressure and humidity of the atmosphere (i.e. weather changes), result in changes in the density, which is measured as a *refractive index*.

Refractive Index is a ratio to indicate to what degree waves are bent when passing through materials of different densities. In the case of radio wave propagation, these changes in the refractive index affect the propagation within the troposphere for waves of frequencies between approximately 40-50MHz, in a number of ways:

1) Localized variations in the atmospheric density cause scattering of radio waves.
2) Sharp changes in densities between horizontal layers, resulting in an increase in the refractive index, can cause reflection of the waves (ionospheric propagation).
3) A sharp decrease in refractive index with height can create the phenomenon of *ducting*.

A duct is a region of indeterminate shape that may cover a very large area but only be 40 to 50m high. It has the property of propagating radio waves with extremely low attenuation and such waves tend to hug the earth's surface. A duct may last for several days.

A wave that gets 'trapped' in such a tropospheric duct can travel for very long distances (1500km or more) but can leak out at any point. This is not a reliable mode of propagation, as it can cause severe interference to very distance services. However, it is of very great interest in amateur radio, as it enables long distance contacts on the Very High Frequency (VHF) and Ultra High Frequency (UHF) bands to be made with low power and simple antennas.

Periods of enhanced tropospheric propagation can often be forecast by observation of weather changes. It should be noted that the most suitable mode of propagation of radio waves depends on the frequency used, but there is no sharp transition from the use of one mode to another due to changes in frequency. Radio wave propagation depends on many factors and at some frequencies significant propagation can occur by more than one mode. For example, long distance transmission on the Medium-Wave (MW) broadcast band and the 1.8MHz amateur band during the hours of darkness is by sky wave (ionospheric) propagation.

10

TRANSMISSION

From the previous chapters, the reader should have a basic understanding of power and should be able to use the formulae given to calculate electrical power. However, in amateur radio communications, and radio wave propagation in general, greater emphasis is placed on the transmitting power from the antenna and correspondingly, the power of the received signal. This chapter will introduce some of the concepts involved in understanding the transmitting power from the antenna.

10.1 THE DECIBEL

Decibel is a measurement of sound or power levels, expressed as a ratio or relative to something and is abbreviated dB. One decibel is about the smallest change in sound or power level that someone with exceptional hearing would detect if they were listening to one single continuous audio tone. Probably for most of us, the minimum change in sound we would be able to detect, under test conditions, would be 2 dB. Table 10.1 shows the power in dB, using a transmission power of 100 Watts (W) as the reference.

16000 W	+	12	dB
800 W	+	9	dB
400 W	+	6	dB
200 W	+	3	dB
100 W		0	dB
50 W	-	3	dB
25 W	-	6	dB
12.5 W	-	9	dB
6.25 W	-	12	dB

Table 10. 1

Other decibel ratios can be calculated using

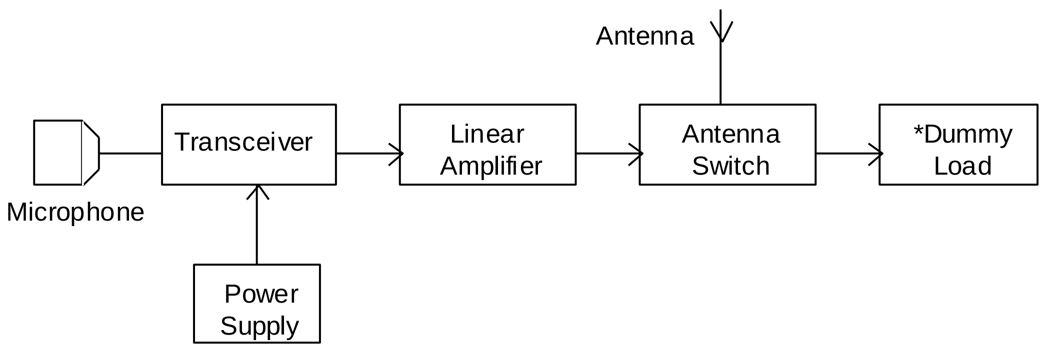
$$Power(dB) = 10 \times \log_{10}\left(\frac{P}{P_{ref}}\right),$$ where P_{ref} is the base or reference power

Conversely,

$$P_{ref} = \frac{P}{a\log_{10}\left(\frac{Power(dB)}{10}\right)} \qquad\qquad P = a\log_{10}\left(\frac{Power(dB)}{10}\right) \times P_{ref}$$

$$\text{where } a\log_{10}\left(\frac{Power(dB)}{10}\right) \text{ is the anti- or inverse logarithm of } \left(\frac{Power(dB)}{10}\right)$$

The diagram below shows one of the popular configurations for an amateur radio station[3].



Transceiver	Comprises both a transmitter and receiver. Depending on the equipment these could be separate units
Linear Amplifier	Special type of amplifier used in voice (phone mode) transmissions, which produces an output signal that varies in exact proportion with the input signal. Used to increase the power of the signal to the legal limit
Antenna Switch	Isolates unwanted antennas (and dummy loads) from each other
***Dummy Load**	Useful for adjusting the linear amplifier without causing QRM to other amateur operators

If you were operating with 100W and you were to reduce your power down to 75W that would result in a 1.25dB change in the transmitting power. The person that you were communicating with would not detect a change at his receiver. However, if you were to cut back your power to 25W, from 100W (6dB change), the receiver would detect a difference in your signal, in terms of the power at which they are receiving your transmission and the clarity of your transmission.

[3] It should be noted that it is not the intention of the writers to advocate particular brands of equipment or configurations of amateur radio stations.

Antennas also have **<u>gain figures</u>** in terms of dB attached to them, where the higher the gain in dB, the higher performance. Note however, that gain figures on antennas without the reference usually mean nothing. Most references would be to a half-wave dipole, which has no gain and the gain figure would be followed by designation dBd.

Lets say, for example, that you were considering using a Yagi-Uda (Yagi for short) antenna for 10 meters with an advertised gain of 6dBd. This means that with 100W transmitting power into the antenna, there would be an effective radiated power of about 400W, or you would get almost the same transmitted results with a half-wave dipole transmitting at 400W.

Gain figures also have implications for improved signal reception. Generally, the higher the gain figure, the better the power and quality of the received signal.

11

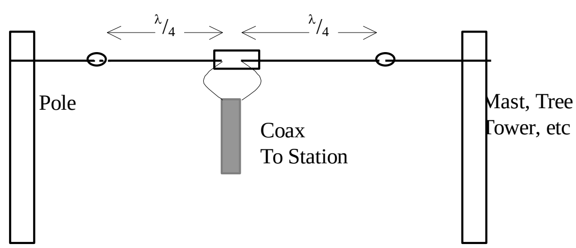
ANTENNAS

It is said that next to a good pair of ears, the antenna is the most important part of the amateur radio station. An antenna converts electrical energy from the transmitter into radio waves that can be radiated. It can also intercept radio waves that have been transmitted, which are reconverted to electrical signals and then sound.

The basic antenna that many amateur radio operations utilize is the *half-wave dipole*, which consists of two equal lengths of wire or metal tubing, cut to a specific length for the frequency of interest. It is a balanced antenna, where both sides (two quarter-wavelength sections of a dipole) are symmetrical about a 'feed point' and neither side is connected to ground. A basic half-wave dipole is to some extent a directional antenna, as it radiates at right angles to the wire lengths or legs.

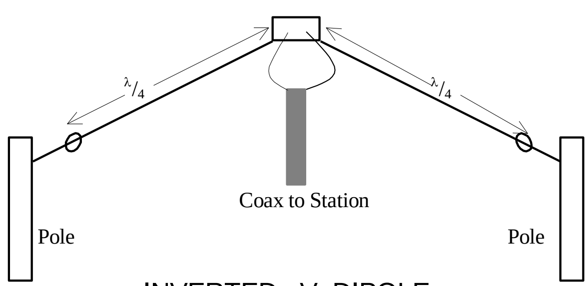
A dipole antenna can be set up using one of three basic configurations, depending on your space requirements.

- A horizontal flat-top,



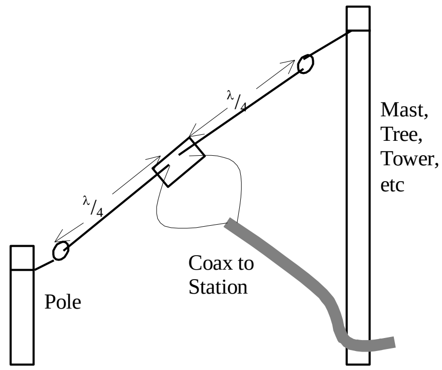
HORIZONTAL DIPOLE

- An inverted "Vee",



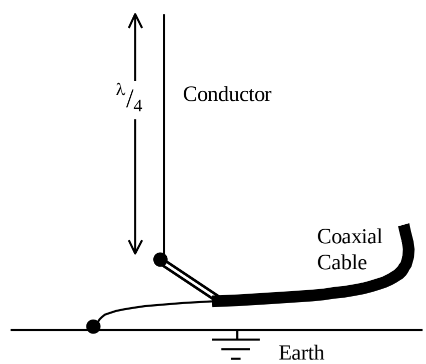
INVERTED –V DIPOLE

- A sloping (sloper) dipole.



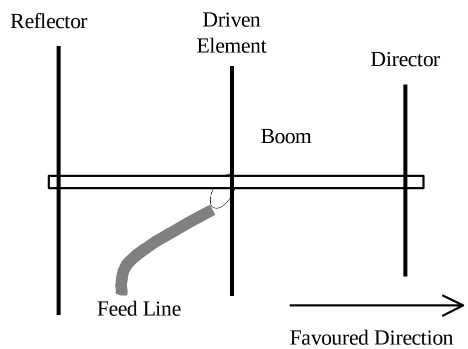
SLOPING DIPOLE

Another popular antenna configuration is the *quarter-wavelength vertical antenna*. This antenna is similar to the dipole antenna, but one of the quarter wavelength sections, is grounded and thus is considered to be *unbalanced*. Vertical antennas radiate in all directions and are considered to be non-directional or omnidirectional antennas.



QUARTER-WAVELENGTH VERTICAL ANTENNA

One of the most popular antennas is the Yagi-Uda (Yagi for short), which consists of a basic half wave dipole, called the *driven element*, with another half wave dipole separated by a multiple of a wavelength (such as $^1/_8$, ¼ or ½). The second half-wave dipole is about 5% longer than the driven element and it is called the reflector. Additional elements, called directors, can be added to increase the gain of the antenna. This antenna is sometimes referred to as a *beam antenna*, as the signal can be usually beamed in the desired direction.



THREE-ELEMENT YAGI UDA ANTENNA

Many amateur fixed-stations also have vertical antennas for HF-band use. They require very little physical space and are good low-angle radiators for DX operation. Some vertical antennas are designed for single band use, while others contain "traps," which permit them to be used on many bands. These traps serve to divorce electrically the portion of the antenna beyond (above) the trap. Dipole antennas and HF Yagi antennas can also incorporate traps to enable multiband operations.

Most vertical antennas are ¼ or $^5/_8$ of a wavelength long. They can be thought of as one half of a dipole. The missing half is in the earth and is called the *image half*. The importance of a good ground for vertical antennas cannot be stressed enough. Also, wires laid along the ground extending from the base of the antenna, called radials, help improve the antenna's performance. The number of radials may vary as per location and soil conditions, but experts agree no less than six radials should be installed. As a point to note, ¼ wave vertical antennas have no gain, while $^5/_8$ wave vertical antennas can sometimes claim gains of about 3dB over a half-wave dipole.

11.1 STANDING WAVE RATIO (SWR)

The *Standing Wave Ratio* (or *SWR*) is the efficiency (perfection) of the antenna system and feed line and is expressed as a ratio. As most amateur radio transmitters are of 50-ohm output and the transmission cables is also 50Ω and the antenna is also 50Ω, then in this case the SWR would be 1:1. This would be a perfect match, and no power would return from the antenna.

However, if the condition at the antenna were such that out of the 100 Watts coming out of the transmitter and 1 Watt was reflected, the SWR would then be 1.22 : 1, indicating that the antenna had an impedance of either

$$61\Omega \quad \left[\frac{61}{50} = 1.22\right] \qquad \text{or} \qquad 41\Omega \quad \left[\frac{50}{41} = 1.22\right].$$

Table 11.1 provides some of the readings for SWR corresponding to the listed reflected power readings for a forward (transmitting) power of 100W.

REFLECTED POWER/ W	**SWR**
1	1.22
2	1.33
3	1.42
4	1.50
5	1.58
10	1.92
20	2.62
30	3.42
40	4.44
50	5.83
60	7.87
70	11.24
80	17.94
90	37.97

Table 11.1
SWR vs. Reflected Power for Forward Power of 100 W

Most HF radios include high SWR fold back protection, which automatically reduces the output power for SWR's over 2:1. Most antennas will exhibit a low SWR when used at the design frequency, i.e. near or 50Ω at the recommended frequency. On other frequencies, the antenna impedance (resistance) will change so we deviate from the antenna's optimal performance.

It should be noted that many antennas are designed to be used on many bands and are not designed to be a perfect match to the 50Ω that the transmitter requires. They include a *transmatch* or *antenna tuner,* which is an impedance matching device that transforms the impedance of the antenna to the 50Ω that the transmitter requires. With an external transmatch or tuner in the transmitter, the only power lost is the loss in the transmission line, which, with top quality line (even under quite high SWR) is small at HF frequencies.

11.2 FEED LINES

In order to transfer the signals from the transmitter to the antenna or from the antenna to the receiver, over what may be a significant distance in the most effective manner, a *transmission line* is required to connect the antenna and the transceiver. This form of connection is often known as a *feeder* or *feed line* and may be balanced or unbalanced.

In a *balanced feed line*, both wires have an equal potential to ground, i.e. neither can be earthed. The impedance of a balanced line depends on the diameter of the wire and the spacing between the two wires. Balanced or *twin-feeder* cable is commercially available in impedances of 75Ω, 300Ω, 450Ω and 600Ω.

In the *unbalanced feed line*, one side is normally earthed. An example of the normal unbalanced feeder is coaxial cable and the commonly used impedances are 50Ω and 75Ω. Most amateur radio transceivers are designed to be fed with feed lines of 50Ω impedance. There are different types of coaxial cable used in the amateur radio operations. The small diameter cables are RG-58, RG-59 and RG-8X (also known as *mini 8*). The larger diameter cables are RG-8, RG-213 and RG-9913.

All amateur radio operators must be aware of the following when feed lines are employed.

- All feed lines incur power loss
- Certain feed lines are worse than others
- The longer the feed line, the greater the loss
- The higher the operating frequency, the higher the line losses per 100 feet of cable

Thus, it is conceivable that with certain line loss our 100-Watt signal might diminish to 40 or 30 Watts by the time it reached the antenna, especially at VHF and higher! The same loss is experienced in the receive mode. Therefore, to reduce the losses, the feed line should be kept as short as possible.

In order to match feed lines to the range of antennas available, various matching networks are employed. The most common is a *balun*, meaning balanced to unbalanced. The balun is an impedance transformer with either an air or a ferite core at the antenna’s feed point. Baluns are also employed in some antenna matchers (tuners or couplers).

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SAMPLE EXAMINATIONS QUESTIONS

1. How long (in metres) is an antenna that is 400 centimeters long?
   - (a) 0.004 metres
   - (b) 4.0 metres
   - (c) 40 metres
   - (d) 40 000 metres

2. When may an amateur operator transmit unidentified communications?
   - (a) A transmission need not be identified if it is resisted to brief tests not intended for reception by other parties.
   - (b) A transmission need not be identified when conducted on a clear frequency or “dead band” where interference will not occur.
   - (c) Never. All transmissions must be identified.
   - (d) A transmission need not be identified unless two way communications or third party communications is involved

3. When is an amateur station permitted to transmit music?
   - (a) Transmission of music is not permitted in the amateur service
   - (b) When the music played produces no dissonance or spurious emissions
   - (c) When used to jam an illegal transmission
   - (d) Only above 1280 MHz

4. An amateur licence is required to
   - (a) Transmit on public service frequencies
   - (b) Retransmit short-wave broadcasts
   - (c) Repair broadcast station equipment
   - (d) Transmit on amateur service frequencies

5. What is the pressure that forces electrons to flow through a circuit?
   - (a) Electromotive force, or inductance
   - (b) Electromotive force, or voltage
   - (c) Farad, or capacitance
   - (d) Thermal force, or heat

6. What is the basic unit of resistance?
   - (a) The Volt
   - (b) The Watt
   - (c) The ampere
   - (d) The Ohm

7. What is the name of a current that flows in only one direction?

(a) An alternating current	(c) A smooth current
(b) A direct current	(d) A bi-directional current

8. What is the name of a current that flows back and forth, first in one direction, then in the opposite direction?

(a) An alternating current	(c) A rough current
(b) A direct current	(d) A reversing current

9. What path do radio waves usually follow from a transmitter antenna to a receiving antenna at VHF and higher frequencies?
   - (a) A bent path through the ionsphere
   - (b) A straight line
   - (c) A great circle path over either the north or south poles
   - (d) A circular path going either east or west from the transmitter

10. What is coaxial cable?
    - (a) Two parallel conductors held at a fixed distance from each other by insulating rods
    - (b) Two parallel conductors encased along the edges of a flat plastic ribbon
    - (c) A centre conductor encased in insulating material which is covered by a conducting sleeve or shield.
    - (d) Two conductors twisted around a each other in double spiral

11. What is the approximate length (in feet) of a half wave length dipole antenna for 7.150 MHz?

(a) 84 feet	(c) 33 feet
(b) 42 feet	(d) 66 feet

12. What is an S-meter?
    - (a) A meter to measure sideband suppression
    - (b) A meter to measure spurious strength in a receiver
    - (c) A meter to measure relative strength in receiver
    - (d) A meter used to measure solar flux

13. What device converts sound waves to electrical energy?

(a) An antenna	(c) A speaker
(b) A microphone	(d) A rectifier

14. For safety purposes, how high should you locate all portions of your horizontal antenna?
    - (a) Above knee level
    - (b) Above electrical lines
    - (c) Higher than your electrical equipment
    - (d) High enough so that a person cannot touch them from the ground

15. What is one meaning of the Q signal "QTH"?
    - (a) My age
    - (b) My name
    - (c) My wife
    - (d) My location

16. What is the term for a failure in an electrical circuit that causes excessive high current?
    - (a) A open circuit
    - (b) A dead circuit
    - (c) A short circuit
    - (d) A closed circuit

17. If 200V is applied to a 100Ω resistor, what is the current through the resistor?
    - (a) 0.5A
    - (b) 2.0A
    - (c) 50.0A
    - (d) 20 000A

18. Write the PHONETICS for the call sign "J69IQ"

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19. What is the meaning of the Q code QRM and give at least one example

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20. Give the meaning of the following signal reports:

    a. Readability 5, Signal strength 5

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    b. Readability 1, Signal strength 1

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