Feeders and Antennas

Feeders

4A1

Recall the correct cable types to use for RF signals and that coaxial cable is the most widely used because of its screening properties.

Identify Twin Feeder and Coaxial as types of feeder.

Understand that twin feeder is balanced having equal and opposite signals in the two wires.

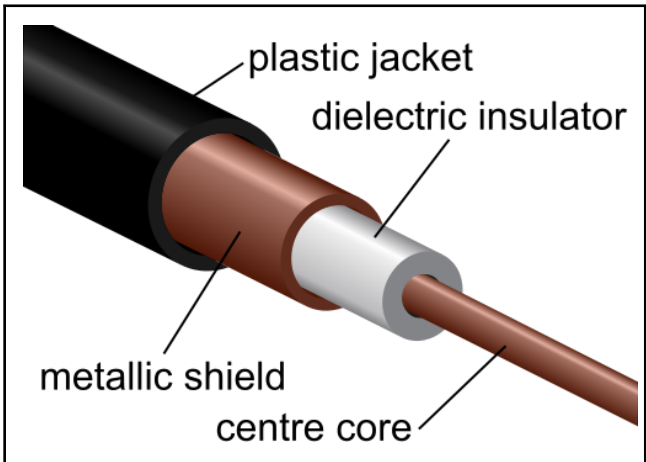
Understand that coaxial feeder is unbalanced with the signal in the centre conductor surrounded by a screen.

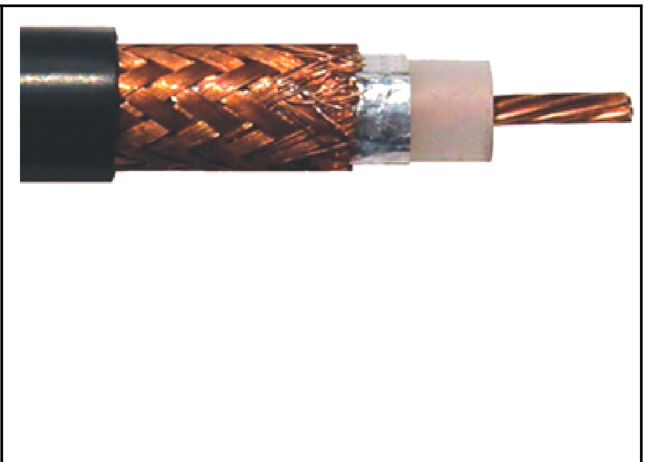
The cable that connects the transceiver to the antenna is known as the feeder. Feeders need to exhibit certain characteristics and only specifically designed and manufactured cables should be used.

There are, essentially, two types of RF feeder:

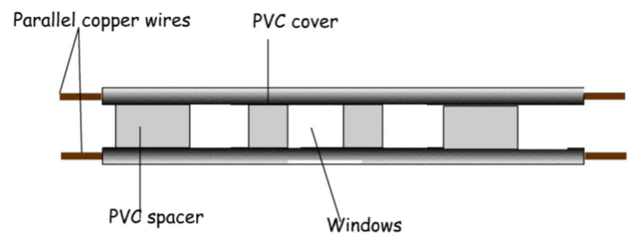
1. Coaxial cable
2. Twin feeder

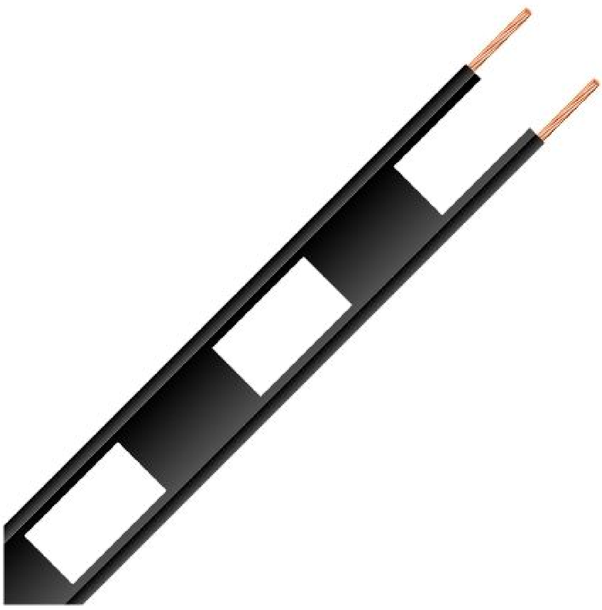
Of the 2 types, coaxial cable is probably the most common because it contains a screen that reduces the risk of interference when the signal is on the feeder.





Twin Feeder, which is sometimes referred to as "ladder line" or "balanced feeder" because the twin wires look like the stringers on a ladder and the insulating spacers look like rungs, consists of two wires running parallel to each other held a fixed distance apart by a series of insulated spacers.





It is important that a feeder does not radiate, i.e. it does not allow the transmitted signal to "leak" out before it gets to the antenna and prevents local interference from getting into the received signal.

Coaxial feeder achieves this by encasing the signal carrying centre conductor in a metallic screen. It is considered or defined as an **unbalanced** feeder, having only one signal carrying part, and is best suited to feeding unbalanced antennas such as quarter-wave, five eighths-wave and colinear antennas.

Twin feeder prevents radiation from the feeder by having two signal-carrying parts in which the signal is equal and opposite. When they are in close proximity the two signals cancel each other out outside of the twin wires avoiding radiation. Twin feeder is a **balanced** feeder, having two signal-carrying parts, and is best suited to feeding balanced antennas such as dipoles and doublets.

The radiation cancelling properties of twin feeder can be unsettled if the twin feeder is hung near metal objects such as old fashioned metal rainwater pipes, and is less well suited to being "kinked" where the direction of the wires is changed abruptly or the spacing between the wires changes.

4A2

Recall that some RF energy is converted to heat in feeders so they exhibit loss.

Recall that feeders cause loss of signal strength on both transmit and receive; the longer the cable, the greater the loss.

Recall that feeder loss increases with frequency and that low loss feeders (lowest dB per unit length) should be used at VHF and UHF.

Feeders, whether coaxial or ladder line, exhibit loss. This is caused by some of the energy in the signal being lost to heat. The longer the feeder the greater the loss, that is the loss is proportional to the length of the feeder so avoid having excess lengths of feeder that are surplus to requirements. Different qualities of feeder can have greater or lesser amounts of loss but no feeder is perfect and all of them exhibit some loss.

The loss is apparent on both transmit and receive. That is some of the power that the transmitter produces is lost to the feeder resulting in less power than is transmitted making it to the antenna. Equally, on receive, the signal that is received by the antenna is further weakened by the feeder between the antenna and the receiver.

The amount of loss is not constant, at higher frequencies the same piece of cable will exhibit a greater amount of loss than at lower frequencies. For this reason, when establishing high-performance stations for VHF and UHF it is important to select feeders that have the lowest dB of loss per unit length that can be afforded as well as keeping the feeder runs as short as possible.

As an example the stated performance of Messi and Paoloni Ultraflex 7 (similar to RG8) is as follows:

Frequency (MHz)	Loss (dB/100m)	Frequency (MHz)	Loss (dB/100m)
1.8MHz	0.6dB/100m	21MHz	2.6dB/100m
3.5MHz	0.9dB/100m	28MHz	3.0dB/100m
7.0MHz	1.2dB/100m	50MHz	4.0dB/100m
10MHz	1.6dB/100m	144MHz	6.9dB/100m
14MHz	2.1dB/100m	430MHz	12.3dB/100m

Baluns

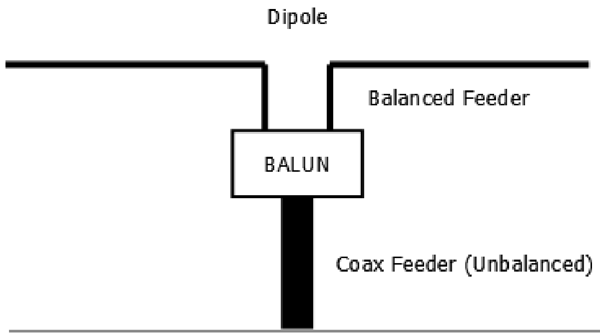
4B1

Recall the difference between balanced and unbalanced antennas and that a balun should be used when feeding a dipole with coaxial cable (which is unbalanced).

A dipole is a balanced antenna, this means that it is symmetrical around the feed point, there is an equal amount of antenna either side of the feed point. Ideally, a dipole antenna should be fed using a balanced feeder, such as ladder line.

If a balanced antenna, such as a dipole, is fed with an unbalanced feeder, such as coaxial cable, then in order to prevent RF current flowing back to the transceiver along the screen the unbalanced feeder should be passed to a **balun** (BALanced to UNbalanced transformer) which takes the signal on the single central conductor of the unbalanced feeder and converts it into 2 signals that can be fed to each arm of the dipole.

The Balun is located close to the feed point of the antenna.



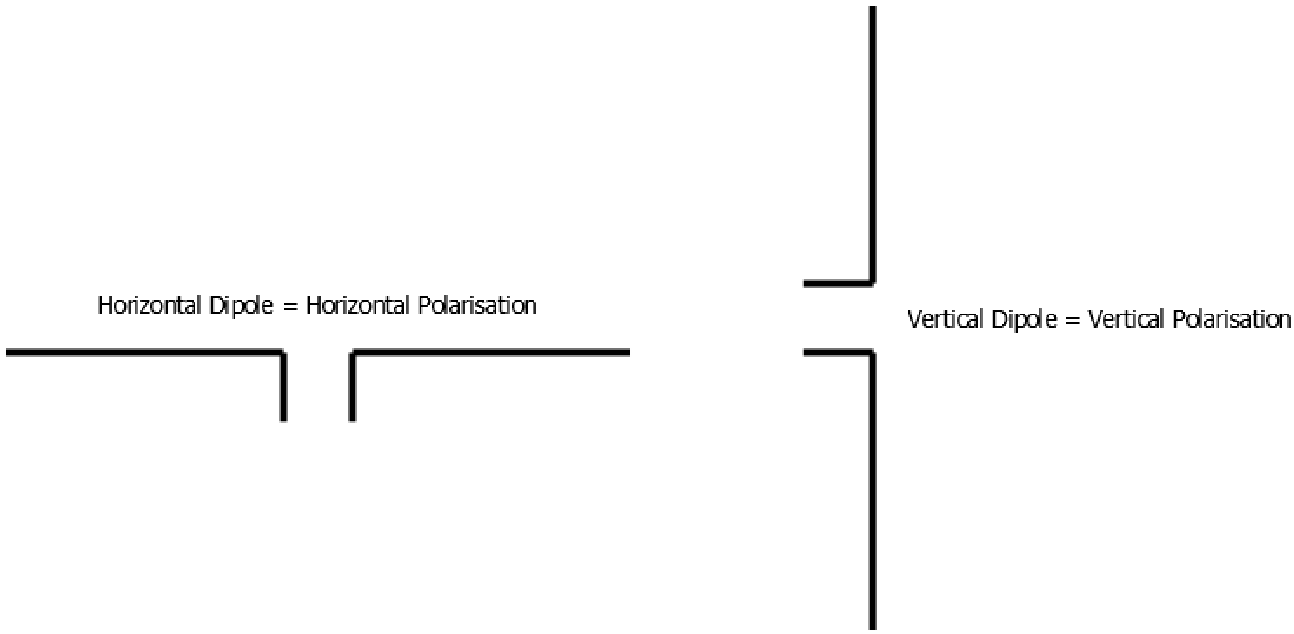
Antenna concepts

4C1

Recall that the purpose of an antenna is to convert electrical signals into radio waves (and vice-versa) and that these are polarised according to the orientation of the antenna, e.g. a horizontally oriented antenna will radiate horizontally polarised waves.

The antenna is designed to radiate the signal that is sent to it on the feeder when used with a transmitter. When used with a receiver, obviously it operates in reverse and creates an electrical signal on the feeder from the received electromagnetic wave.

The orientation or arrangement of the antenna influences or affects the signal. This is referred to as **polarisation**. A horizontal antenna creates a horizontally polarised signal while a vertical antenna creates a vertically polarised signal.



Polarisation is important at VHF/UHF but is less significant at HF where the polarisation is affected by the propagation methods. There are conventions as to which polarisation is employed where that will be discussed shortly.

4C2

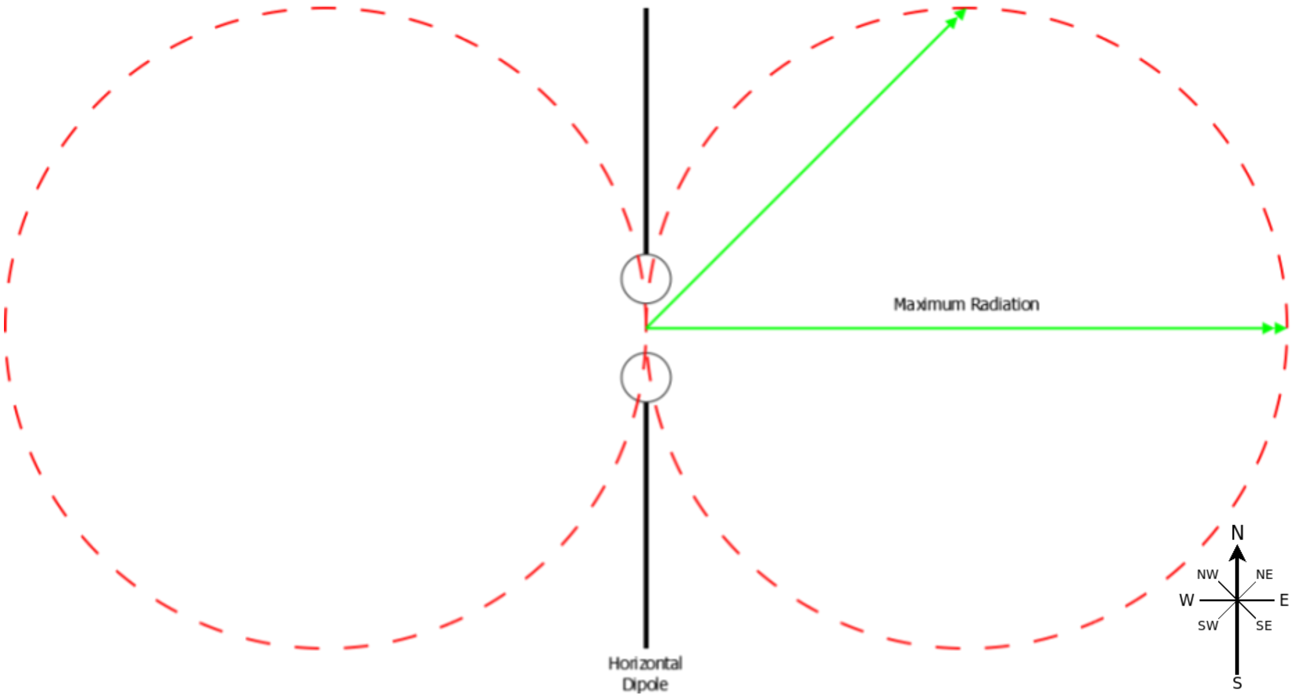
Understand the concept of an antenna radiation pattern.

Identify the polar diagrams for the half-wave dipole and Yagi antennas and identify the directions of maximum and minimum radiation.

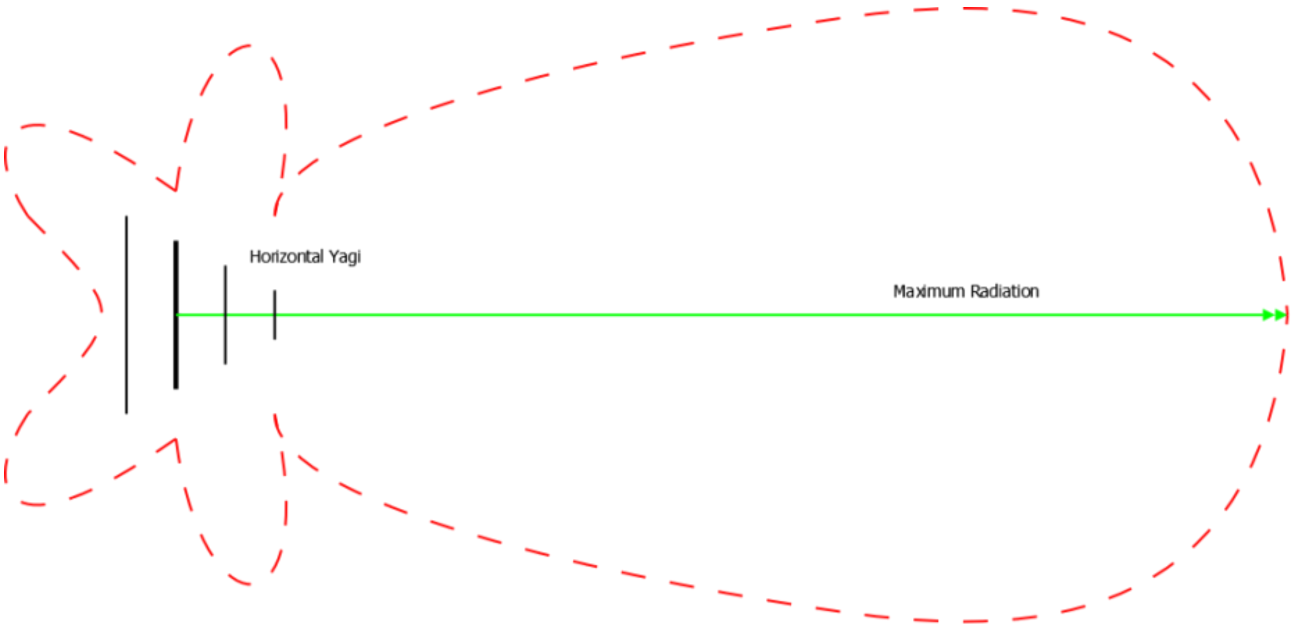
Understand that half-wave dipoles (mounted vertically), λ/4 (quarter wavelength) ground planes and 5/8 λ antennas are omnidirectional.

Note: Only dipole and Yagi antennas will be examined for radiation pattern

An antenna radiation pattern is a representation or picture of the way a signal leaves an antenna and begins to propagate through the "ether". Different antennas radiate differently and an understanding of what the radiation pattern looks like, even if only conceptually, can help when setting up a station or at least understand some of the limitations that might be present.



The radiation pattern for a horizontal dipole looks like a "figure 8" and the direction of maximum radiation is perpendicular, or at 90 degrees, to the line of the dipole. Therefore a dipole that is hung north-south will have its maximum radiation to the east and west.



The radiation pattern for a Yagi antenna shows a focussing of the radiated energy with the direction of maximum radiation being to the front of the antenna. This focussing effect comes at the expense of radiation in directions away from the direction of the antenna.

Any vertical antenna: vertical dipole, quarter-wave or five-eighths wave will have a circular or **omnidirectional** radiation pattern. These antennas radiate equally in all directions in plan.

4C3

Understand that antenna gain is due to its ability to focus radiation in a particular direction.

Recall that a Yagi antenna typically has a higher gain because of its improved focusing ability.

Recall the gain of an antenna is normally expressed relative to a half-wave dipole and measured in dB (Higher dB value is a higher gain).

Recall that the directional power is expressed as Effective Radiated Power (ERP) and that this apparent power increase is known as gain.

Recall that ERP is calculated by multiplying the power applied to the antenna feed point by the gain of the antenna.

Calculate ERP given antenna input power and antenna gain.

Note: dB conversion table (3, 6 & 10) will be provided

The ability to focus the radiation pattern to create a situation where more energy is radiated in one direction than others is referred to as gain or more accurately antenna gain.

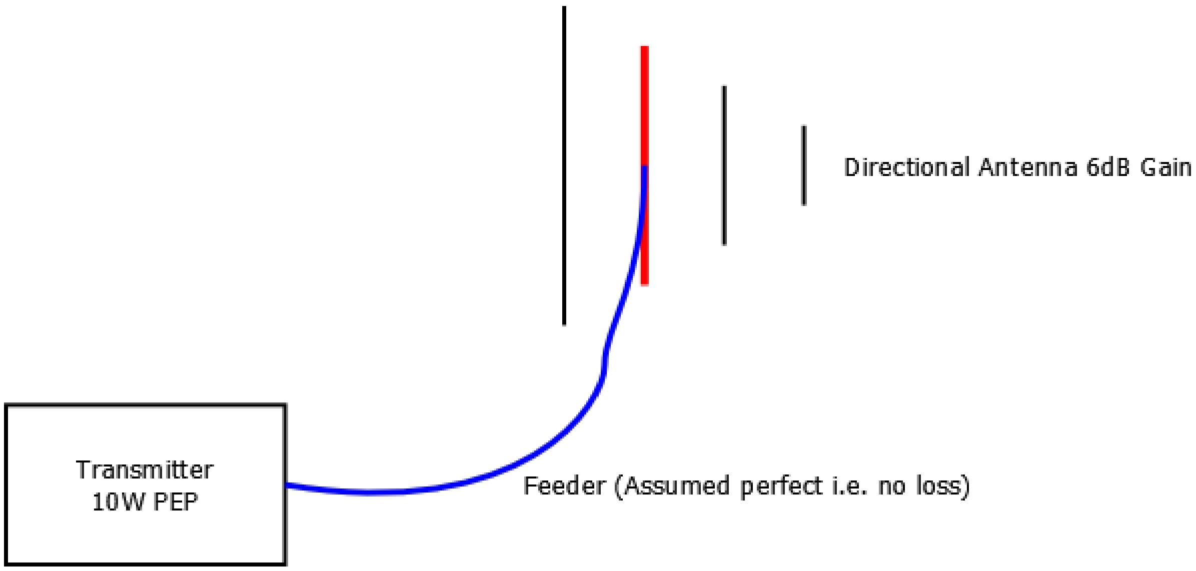
Yagi type antennas typically exhibit higher levels of gain than other types due to their superior ability to focus the radiated energy.

In order to be able to compare different antenna designs antenna, performance or antenna gain is usually compared to the performance of a half-wave dipole. A larger dB_d value represents greater gain and a more "focussed" radiation pattern.

The power that a focussed antenna emits is referred to as **effective radiated power** (ERP). ERP is calculated by multiplying the power applied to the antenna by the gain of the antenna. Gain is expressed in dBs and the following table shows typical gain values and their multiplying effect:

Gain in dB	Gain as a Multiple
3dB	x2
6dB	x4
9dB	x8
10dB	x10
12dB	x16

Consider a station with a 10W PEP transmitter that is connected to a Yagi antenna with 6dB of gain as shown below:



6dB of gain represents a power multiplication factor of 4. Therefore the Effective Radiated Power (ERP) of the above station is $10W_{PEP}$ x 4 = $40W_{ERP}$.

Had the gain been 3dB then the multiplication factor would have been 2. Similarly, if the gain had been 10dB then the multiplication factor would have been 10.

It is relatively straightforward at VHF and particularly UHF to be able to make high gain antennas that are relatively space-efficient and light. However, the size of this type of antenna at lower frequencies, such as on the HF bands, becomes much larger and the logistics and construction become much more complicated.

Note that in the example above the loss that the feeder will present has been ignored, however, this is why we employ dBs when calculating loss and gain as it makes it much easier to evaluate the complete antenna system in the real world.

4C4

Recall that antenna gain can also be expressed relative to a theoretical antenna that radiates equally in all directions and this is shown as EIRP, Effective Isotropic Radiated Power.

Recall that 10W EIRP is equivalent to 6.1W ERP

Decibels are a simple ratio of input power to output power. When it comes to evaluating antenna gain there are two common reference points:

- dB_d - Gain relative to a dipole antenna, and
- dB_i - Gain relative to a theoretical Isotropic radiator, a point radiator that radiates equally in all directions having a spherical radiation pattern

A dipole does not have a spherical radiation pattern, and as such it does "focus" some of the energy, hence a dipole has gain over an isotropic radiator. The amount of gain is not important but it means that the Effective Radiated Power from the antenna needs to be reduced from the EIRP levels stated in places such as the ICNIRP regulations.

Exposure levels, as defined in the ICNIRP regulation, are calculated based on the EFFECTIVE ISOTROPIC RADIATED POWER, however real world ERPneeds to be lower to maintain compliance levels.

10W EIRP is 6.1W ERP.

4C5

Recall that VHF and UHF signals will normally be received most effectively when the transmitter and the receiver have the same antenna polarisation and that this is less important at HF because the polarisation may change during ionospheric reflection.

A signal that is transmitted using vertical polarisation will be best received if the receiving antenna is also vertical. This is particularly important at VHF and UHF. It is also true at HF, but here because the polarisation of the signal is influenced by the propagation process there is less loss involved.

Typically FM signals on VHF/UHF adopt vertical polarisation, this is because it is simpler and more practical to equip vehicles with vertical antennas and much simplex and all repeater communication takes place using FM. SSB operation typically employs horizontal polarisation.

It is possible for Yagis and dipoles to be either horizontally or vertically polarised depending on how they are erected. Other antennas such as the quarter-wave and five-eighths antennas are always vertical.

4C6

Recall that the connection point of the feeder to the antenna is called the feed point.

Recall that at the design frequency the feed point has an impedance that should match the impedance of the feeder and the transmitter.

Recall that the feed point impedance of an antenna is related to the dimensions of the antenna and the wavelength of the applied signal.

Recall that if the feed point impedance of the antenna does not match that of the feeder, energy will be reflected back down the feeder; the proportion reflected depending upon the degree of mismatch.

The feeder is connected to the antenna at the **feed point**. For a dipole, this feed point or point of connection is at the centre of the antenna. For antennas such as the quarter-wave or five-eighths wave, the feed point is at one end (usually at the base). Yagis have a driven element that is usually the penultimate rearward element, although in some designs it can be the most rearward element.

The feed point presents a characteristic impedance that is related to a range of factors. In a good design, this feed point impedance should be similar to the impedance of the feeder and the transmitter at the design or operating frequency.

The feed point impedance is related to the length of the antenna in relation to the operating frequency, as well as the height of the antenna above the ground, the materials the antenna is made of, the surrounding terrain or buildings, the type of soil and its wetness, what the antenna is mounted on and other factors.

If the feed point impedance does not match the characteristic impedance of the feeder then some of the energy that is sent to the antenna will be reflected back down the feeder to the transmitter. If the amount of reflected energy is excessive then the transmitter may be damaged. Even if the transmitter is protected any loss in power being transferred to the antenna through reflection will reduce the effective radiated power of the signal.

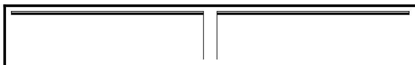
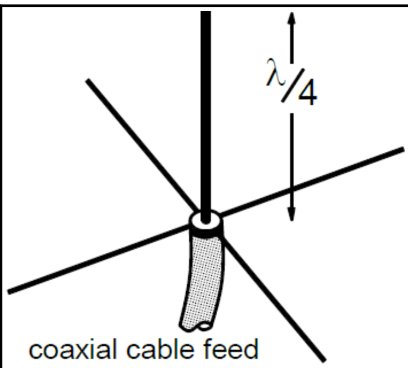
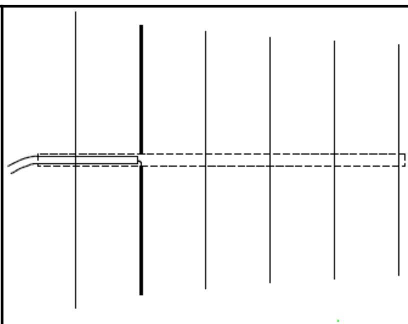
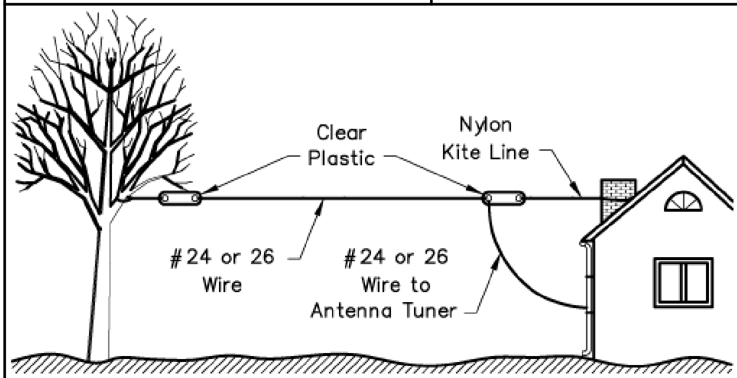
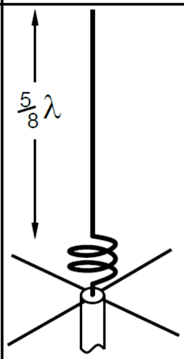
Types of antenna

4D1

Identify the half-wave dipole, λ/4 (quarter wavelength) ground plane, Yagi, end-fed wire and 5/8 λ (five-eighths wavelength) antennas.

Understand that the sizes of HF and VHF antennas are different because they are related to wavelength, though they operate on the same basic principles.

Understand that the λ/2 (half wavelength) dipole has a physical length approximately equal to a half wavelength of the correct signal.

		
Half Wave Dipole (Horizontally Polarised)	Quarter Wave Ground Plane	Yagi (Vertically Polarised)
		
End Fed Wire		Five-Eighths Ground Plane

The size or length of an antenna is directly related to the frequency or wavelength that the antenna is designed to operate on. All antennas operate in the same way, whether they are intended for use on HF, VHF or UHF it is just the size and often the construction that changes.

For example, a half-wave dipole for 2m is about 1m long. Whereas a half-wave dipole for 20m is about 10m long. Clearly, the construction of such a dipole might differ. At 1m overall length (0.5m per arm) a VHF 2m half-wave dipole can be made out of stiff metal and support its own weight. By contrast at 10m overall length (5m per arm), the HF 20m half-wave dipole needs to be supported at the end and is typically made from wire rather than rods.

Standing waves

4E1

Recall that the antenna system must be suitable for the frequency of the transmitted signal.

Recall that if an antenna is not correctly designed for the frequency it will not match the transmitter and will not work effectively.

Recall that if the antenna does not match the feeder that some power from the transmitter will be reflected back towards the transmitter causing Standing Waves.

The feed point impedance is related to the length of the antenna in relation to the operating frequency, as well as the height of the antenna above the ground, the materials the antenna is made of, the surrounding terrain or buildings, the type of soil and its wetness, what the antenna is mounted on and other factors.

If the feed point impedance does not match the characteristic impedance of the feeder then some of the energy that is sent to the antenna will be reflected back down the feeder to the transmitter. If the amount of reflected energy is excessive then the transmitter may be damaged. Even if the transmitter is protected any loss in power being transferred to the antenna through reflection will reduce the effective radiated power of the signal.

The reflected power interacts with the signal that is being sent to the antenna from the transmitter. This interaction creates standing waves on the feeder.

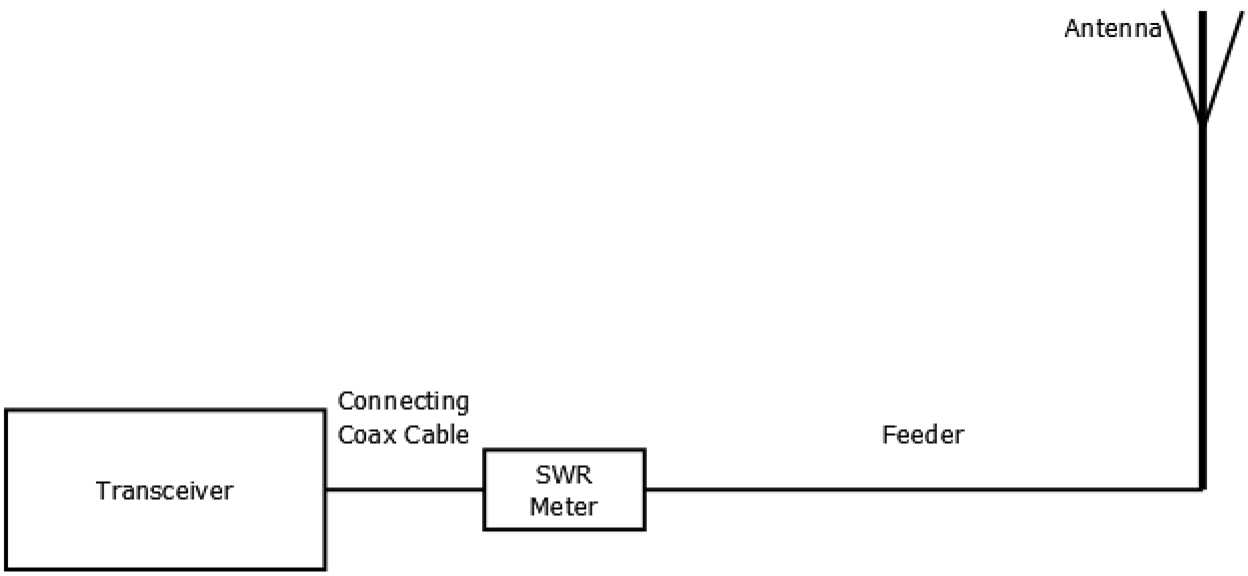
4E2

Recall that an SWR meter shows whether an antenna presents the correct match to the transmitter and is reflecting minimum power back to the transmitter.

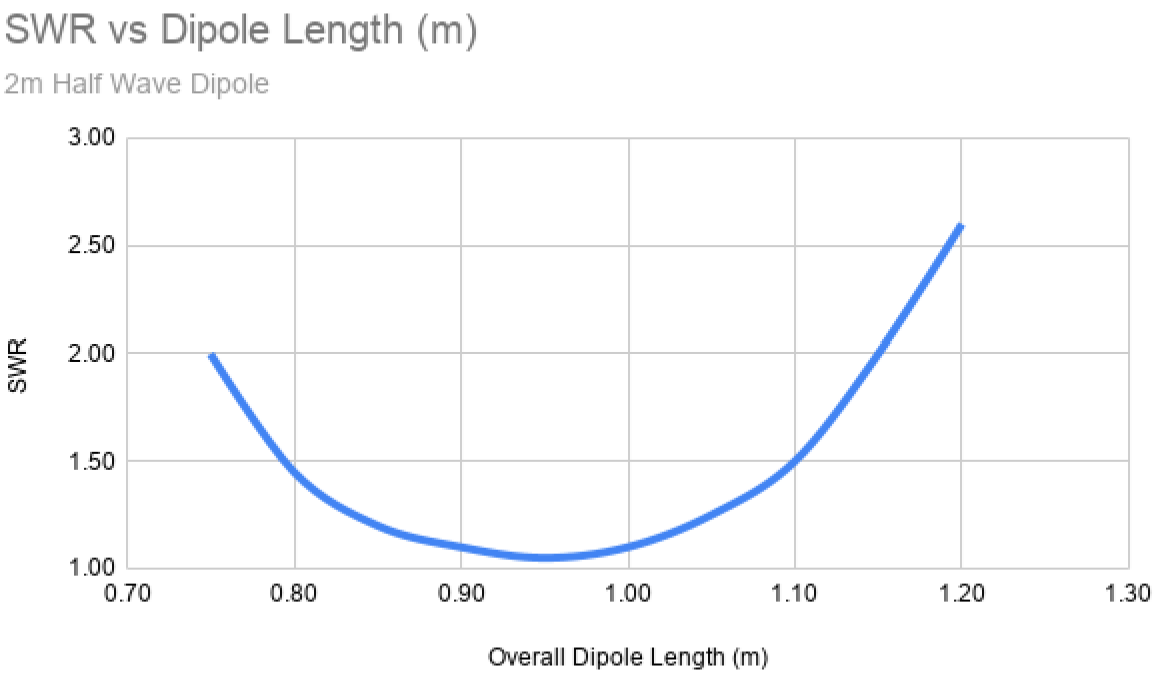
Recall that a high SWR, measured at the transmitter, is an indication of a fault in the antenna or feeder and not the transmitter.

Recall that the transmitter may be damaged in the presence of a high SWR much greater than 2:1.

It is important to monitor the transmitted and reflected power and this is achieved by a SWR meter. The lower the Standing Wave Ratio (SWR) the less power is being reflected and the more power is being radiated. Some transceivers have an internal SWR meter and in the absence of any form of outboard meter these are better than nothing but a proper SWR meter is a very desirable accessory to have in the shack.



If an antenna is being constructed to be resonant or matched to a particular band then the SWR meter can be used to determine the length that presents the lowest SWR and therefore the best match. However, if this antenna is then used on a different band then there will be a mismatch and power will be reflected back to the transmitter which could be potentially damaging to the transceiver.



Typical levels of reflection are as follows:

SWR	Reflected Power
1.5 : 1	5%
2.0 : 1	10%
3.0 : 1	25%

If the SWR is high then the fault lies in the feeder, the antenna or the overall system. A high SWR does not indicate a fault with the transmitter.

The table above shows the approximate amount of reflected power as SWR increases. Clearly, the increase is not linear and it is desirable to keep the operational SWR below 2:1 although higher levels might be tolerated in temporary situations or if a transmitter is not being operated at full power.

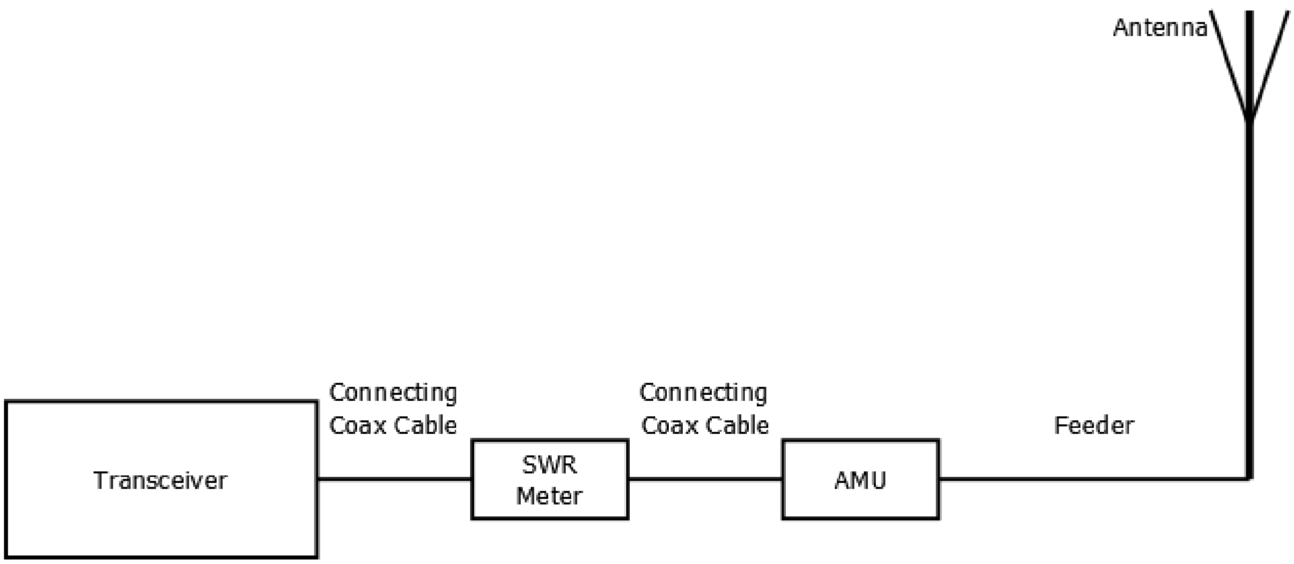
Some modern transceivers have auto foldback protection where the equipment senses a high SWR or a high level of reflected power and automatically reduces the transmitted power until the reflected power is at tolerable levels.

Antenna matching units

4F1

Recall that where an antenna has not been designed for the frequency being used, the feed resistance will change resulting in a mismatch and that an Antenna Matching Unit (AMU), also sometimes referred to as an ATU, can correct the mismatch and is used to ensure that the transmitter can supply energy to the antenna without damage to the transmitter.

A random length antenna or an antenna designed for a different band can be used where it isn't matched if an Antenna Matching Unit is employed. The typical arrangement is shown below:



An AMU is not magical, it can't fix a poorly matched antenna, it only allows the transceiver to see a good match and pass maximum power to the antenna system. Any mismatch that was present before the AMU was added will remain, the AMU just hides the mismatch from the transmitter but does allow the antenna to be used on bands it wasn't designed for.

Dummy loads

6D4

Recall that transmitting into a dummy load is a good test for any unwanted RF being conducted out of the transmitter along its power supply leads and any connected interface leads and into the mains.

Recall that a dummy load is a screened resistor of the correct value and a suitable power rating connected instead of an antenna to allow the transmitter to be operated without radiating a signal.

In the absence of a matched antenna system, a transmitter should not be operated. To allow testing, a dummy load can be employed.

A dummy load is simply a resistor capable of handling the transmitter's full output without radiating RF. It can be used to operate the transmitter without radiating a signal to test for possible EMC routes.

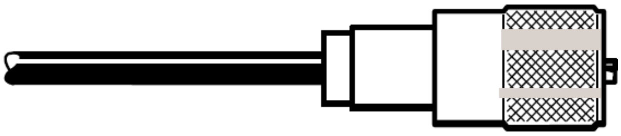
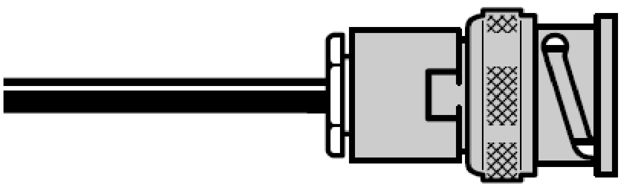
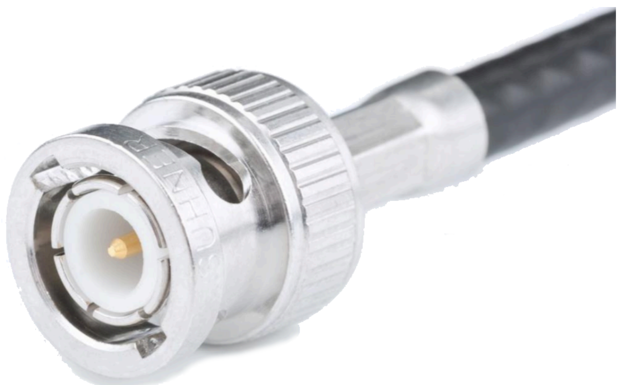
Plugs and sockets

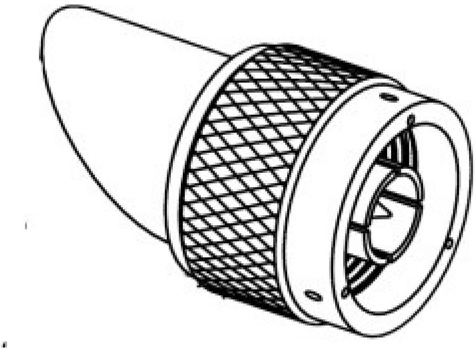
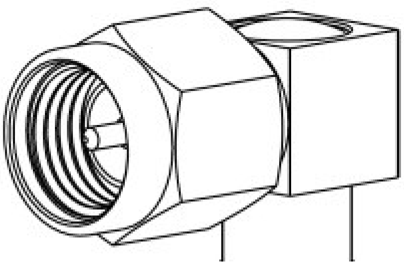
4G1

Recall that the plugs and sockets for RF should be of the correct type and that the braid of coaxial cable must be correctly connected to minimise RF signals getting into or out of the cable.

Identify BNC, N, SMA and PL259 plugs.

Feeders must be connected to equipment and other accessories. Connections should be made using suitable connectors that match each other and have the correct characteristic impedance.

	
PL259	
	

BNC	
	
N Type	
	
SMA	

Typically used with coaxial cable PL259, BNC, N Type and SMA connectors attach the centre conductor to a central pin. The outer screen of the coax must make a good connection with the outer body of the connector to ensure a continuous path for the screen between the transmitter and the antenna.

