Amateur Radio Foundation Licence Manual Instructor's Guide

by John Hislop G7OHO

In colour, with web links, activities, revision questions and answers.

Edition: July 2024

Introduction

Who is this manual for?

This manual is for Instructors running a Foundation amateur radio licence course. It gives the details of the activities and has progress questions and answers.

New Licence Conditions

I've done my best to interpret Ofcom's new licence conditions. It will take a while for things to settle down so I'm sure I will be writing updates to this manual! Check the date on the front page to see if you have the latest edition. I have not included the web links for the Ofcom documents in the Student Guide nor have I included the photos of the girls with their achievements to save space.

How can I use this manual?

Students can go to websites easily to find out more information. They should do the activities, as they will help them to learn. There are also questions and answers, which you should use to test their understanding.

Do you need to supervise them?

There are lots of activities, some of which you need to be present, such as wiring a plug. You should do a risk assessment, and take suitable precautions. You can supervise them when operating on the air.

What will they learn?

They will learn how radios work, how radio waves travel and how to operate a radio, as detailed in the specification for the Foundation licence https://rsgb.services//public/exams/specifications/syllabus_2024_v1.6.pdf Amateur radio wouldn't exist today without the pioneering work of Michael Faraday and James Clerk Maxwell. They will learn that oscillations generate waves and waves generate oscillations. Therefore the manual starts with oscillations and radio waves. Obviously, there are some difficult concepts to understand. For example, impedance is mentioned in the syllabus and we shall see what that means.

Who am I?

I am a physicist, which means I want to know how things work, such as the Universe and black holes! I got my Full Licence in 1992 and I joined the Hilderstone Radio Society G0HRS (https://www.g0hrs.org). The club is so successful, it won the National Club of the Year in 2018. I am a STEM ambassador and I do a lot of outreach in astronomy, electronics, coding and amateur radio. I helped the STEAMettes to code the BBC Micro:bit to send Morse code, as if they were Morse texting. They have given two online presentations on the topic, one at the QSO Today conference in the USA (https://vimeo.com/595487326) and one at the RSGB convention in 2021(https://www.youtube.com/watch?v=pHQsftZhogY). Together we wrote an article for RadCom, the magazine of the Radio Society of Great Britain, on Morse texting (https://rsgb.org/main/blog/publications/radcom/2021/07/23/radcom-august-2021-vol-97-no-8/).

Disclaimer

The author takes no responsibility if you have an accident. I cannot take responsibility if you fail to follow instructions or if you fail to take adequate precautions.

You can contact me at johnhislop30@gmail.com if you come across any typos or broken web links.

Latest edition

The latest edition will be available from the Hilderstone Radio Society website (https://www.g0hrs.org/) under training resources.

The front cover shows Lauren 2E0LHR, operating a Special Event Station at Cape Wrath Lighthouse, after cycling 1000 miles to get there!

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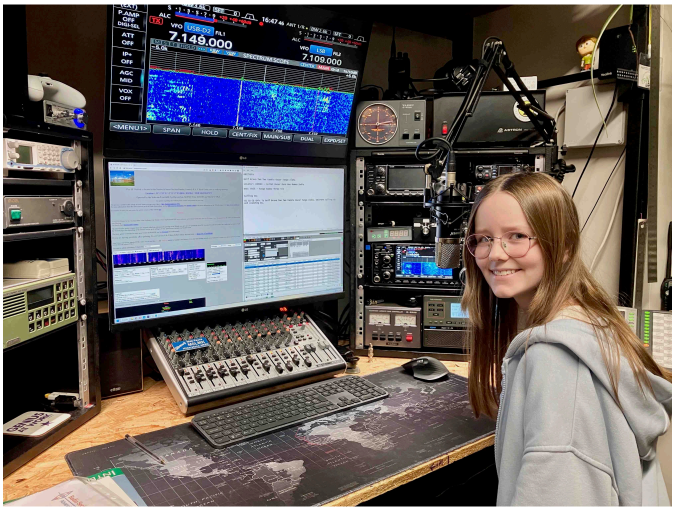
Radio waves

Amateur radio is a hobby that allows you to make friends. You can speak with them using a radio or meet them at your local radio club. They can be in your neighbourhood, on the other side of the world, or in space, orbiting Earth or, one day, the Moon.
This manual will guide you on how to get your licence.



Milly made 40 contacts all round Europe, using the special event call sign GB22YOTA, under the supervision of Matt M0LMK.

Radio waves are all around us. In the room where you are reading this, there are radio waves from hundreds of different radio broadcasting stations. We can’t see the waves but a radio will tune into the signals and you will be able to hear the music or the talking. If we had an antenna and a TV, we could pick up all the radio waves carrying TV pictures. Also there are radio waves from cell phones. GPS signals from satellites are around you! Other satellite signals are too, such as Sky, transmitted on radio waves. Your Wifi router is sending out radio waves. There are even radio waves from space - from the Sun and Jupiter. Microwaves are radio waves, so there are even signals from the beginning of time in your room - the cosmic microwave background radiation.

All waves, whether they are water, sound, light or radio, are produced by an oscillation or a vibration. A material or medium is disturbed. To set a wave into motion, water or air has to vibrate or oscillate backwards and forwards, or up and down. When we were very young we enjoyed oscillations, on a baby bouncer, or as we got older, on a swing. The number of oscillations every second is the frequency, measured in Hertz, Hz.

We can disturb water with a pencil and see what happens.

Activity 1.1 Making waves

We've seen that increasing the frequency of the oscillation makes the distance between the waves, the wavelength, shorter.

If we photograph a wave on a rope or a water wave it will look like this:

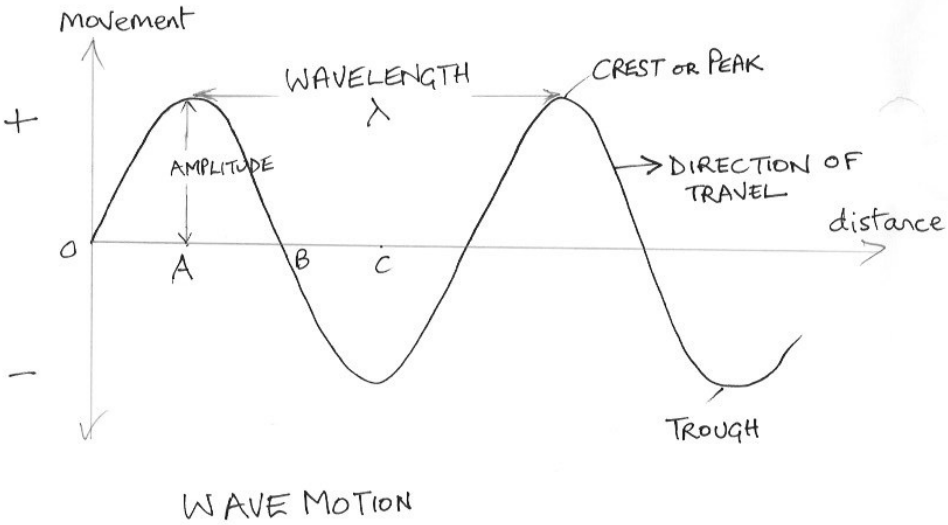
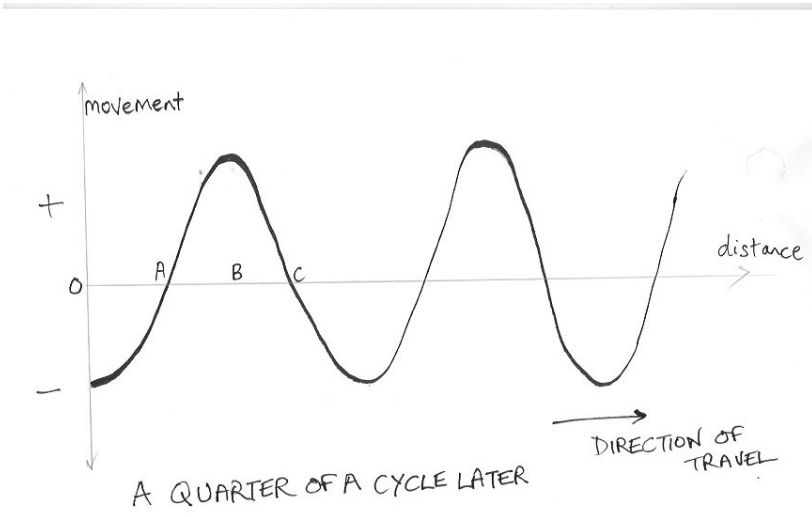


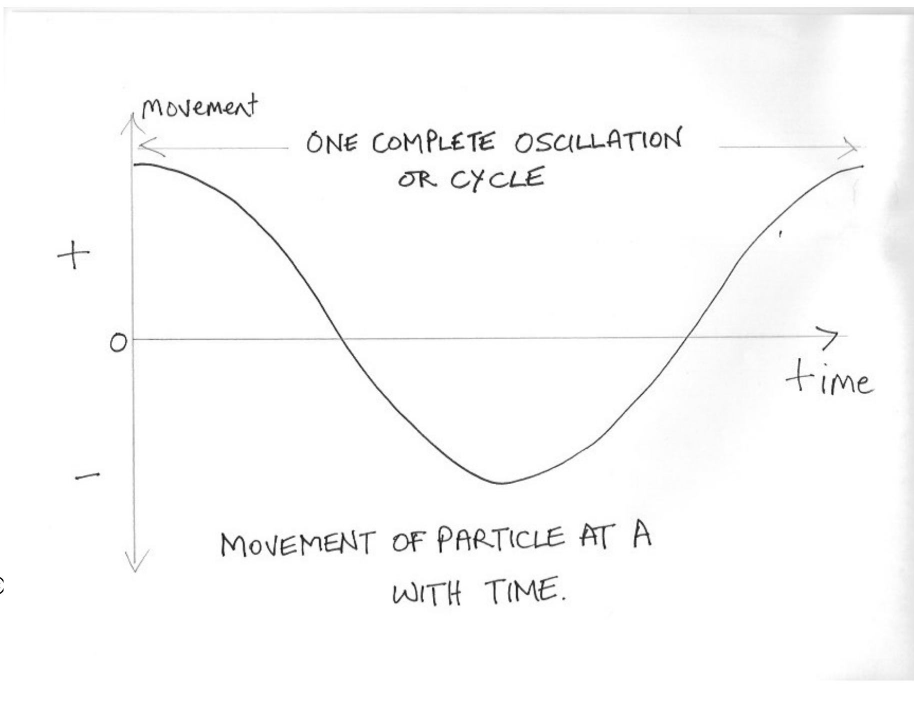
Diagram of movement against distance, and wavelength.

The shape of the wave is a sine wave and we can see that at some points, such as the peak A, the movement is at its greatest, in the positive direction, upwards. It has stopped and cannot go any further. The y-axis could be the height of the wave, the pressure of the air or even a voltage. The amplitude is the maximum height, pressure or voltage.
At points like B, the movement is zero at the moment we have taken the photograph, while at the trough C the movement is in the negative direction. The distance between two peaks is called the wavelength. In the time that point A moves down and back up again to the peak, the wave would have travelled a distance equal to the wavelength.
If the wave is going from left to right, after a quarter of a cycle later, at position A, the movement has travelled down to zero. Position B has become a peak. The particle at B, which was at zero, is now at maximum amplitude because the wave is travelling towards the right. What has happened to the particle at C? It is moving upwards and is now at zero.



Graph of the wave, a quarter of a cycle later.

How do the individual particles of the rope or water vibrate? They too vibrate in the same way, in a sinusoidal motion. The graph shows how the particle at A moves with time. It



started at the peak value. A quarter of a cycle later it is at zero. The points on the wave, whether they are water particles, air molecules or a voltage, just oscillate, moving up and down, while the wave passes.

Sound waves

We can make sound waves and hear what happens when we make changes.

Activity 1.2 Using a source of sound

Just like invisible radio waves, we cannot see the sound wave travelling through the air. Your voice causes pressure changes in the air. The air molecules bunch up or spread out. This pressure change is detected by your ear. Plucking the string of a guitar will cause it to vibrate. Those vibrations will cause the body of the guitar to vibrate and in turn, the air inside.

Travelling at the speed of sound, about 330 m/s, the vibrations reach our ear. For normal human hearing the frequencies range from as low as 20 Hz up to 15 kHz, or 15,000 times a second. This range is called the Audio Frequency range or AF. Young people can hear even higher frequencies!

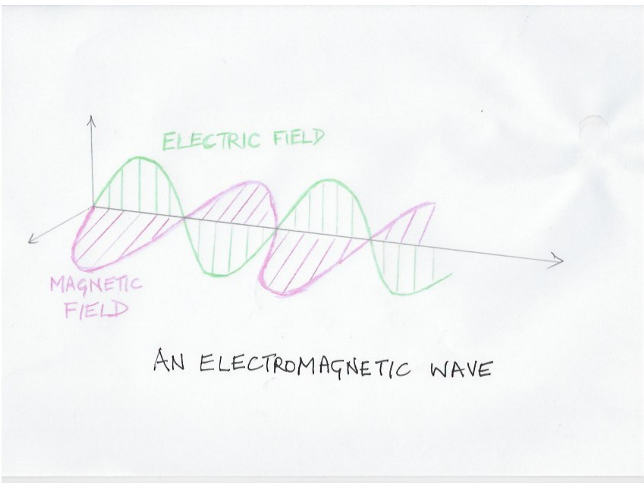
For a radio wave, the oscillations are created by a moving electron. What is an electron? It is part of an atom, as we will show in the next chapter. We are made of electrons. Every substance has electrons in them. They have an electric field around them, which means they can attract or repel. You can show this in the next activity.

Activity 1.3 Investigating electric fields

When electrons move they have a magnetic field around them. A magnetic field is where there is a magnetic force, usually caused by a magnet.

Activity 1.4 Investigating magnetic fields

An oscillating electron generates electric and magnetic fields. Michael Faraday's experiments showed the link between electricity and magnetism, contributing to the study of electromagnetism. A moving electron produces a magnetic field. Magnets have a magnetic field due to spinning electrons. James Clerk Maxwell described these phenomena in mathematical equations. If the oscillation of the electrons are at a certain frequency, the electric and magnetic fields travel out into space as radio waves. So a radio wave is an electromagnetic wave, travelling at the speed of light, 300,000 km/s.



There is a good simulation here, of an oscillating electron generating radio waves. https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves

The electric and magnetic fields jiggle like a snake as they travel through the air, out into space. The two fields always travel together. In the diagram, the electric field is vertical so we say it is polarised vertically. The polarisation is vertical. If the antenna on your handheld radio is vertical, it will send out vertically polarised waves. Amazingly, the radio wave could in theory jiggle round the Earth seven times in only one second! Some radio hams communicate by sending a radio wave from Earth to bounce off the Moon, and return to Earth, taking only 2 and a half seconds.

It's worth investigating the whole Electromagnetic Spectrum to see how radio fits in. Radio has the longest wavelengths and lowest frequencies. At the other end of the spectrum there are X rays and gamma waves, with extremely short wavelengths. Their frequencies are so high that we need to shield ourselves from them. Light is in the middle, with red having a longer wavelength than violet.

Activity 1.5 Investigate the Electromagnetic Spectrum

For more information go to https://science.nasa.gov/ems/02_anatomy
Or search 'anatomy of an electromagnetic wave'.

The frequency of a wave, f, multiplied by its wavelength, λ, gives the speed of the wave. In this case c is the speed of light, 300,000,000 m/s.

$$f \times \lambda = c$$

We can use the chart given in the exam http://rsgb.org/main/files/2020/10/EX307_Oct_2020duo.pdf to find either the frequency or wavelength. If you prefer you can use the formula

$$\lambda = 300/f \qquad \text{or} \qquad f = 300/\lambda$$

f must be in Megahertz for the formula to work. For example, if f is 150 Megahertz, we obtain

$$\lambda = 300/150 = 2 \text{ m.}$$

Activity 1.6 Try calculations of f and λ

Help with Mega to micro
The National Physical Laboratory has an awesome table, going from 10 to the power 30 to 10 to the power -30!
https://www.npl.co.uk/si-units
For the Foundation, you only need to learn Mega to micro. Don't get confused with milli. It comes from the Latin meaning a thousand, so it is not a million! Mega is a million, kilo is a thousand, milli is a thousandth and micro is a millionth. You can write them as a decimals but it is very easy to lose a zero. You should try to master standard form, and learn how to enter them into a calculator.
For example 150 MHz is 150 x 10^6 Hz.
The wavelength of green light is about 0.5 microns, or 0.5 micrometers. In standard form, that is 0.5 x 10^{-6} m.

Let's send some radio waves!

Activity 1.7 Using a Licence-Free PMR446 N.B.not a PMR radiohttps://www.ofcom.org.uk/__data/assets/pdf_file/0025/85156/ir_2009_analogue_and_digital.pdf

The range of Radio Frequencies (RF) is very large. In total it is referred to as the Radio Spectrum. For convenience, the radio spectrum is divided into different bands to give a band plan, each with a descriptive name, such as the Broadcasting band. For amateur radio, we have our own band plans http://rsgb.org/main/files/2022/02/220126_2022-Band-Plans_RadCom-web.pdf. There are three radio bands which you need to learn:

HF 3 MHz to 30 MHz
VHF 30 MHz to 300 MHz
UHF 300 MHz to 3000 MHz.

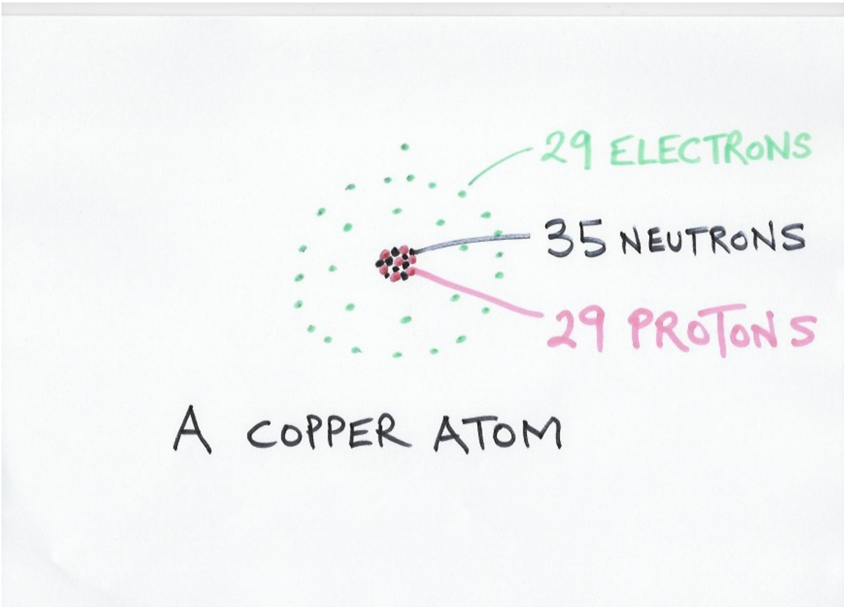
The full range of radio frequencies or RF is from 30 kHz to beyond 3000 MHz.
The PMR446 operates at a frequency of 446 MHz which is in the ultra high frequency UHF part of the radio spectrum.
Other radio users have access to the bands as well as amateur radio operators. You are provided with the table showing how frequencies are allocated https://rsgb.services//public/exams/specifications/syllabus_2024_v1.6.pdf
For example, Radio Astronomy is allocated 150.05 MHz to 152.0 MHz which is in the VHF band. FM radio is allowed 87.5 MHz to 108.0 MHz. What is the frequency of the local radio station in your area, which for us is Academy FM?

107.8 Academy fm
Thanet's Local Radio

Circuits

Free electrons

In a metal such as copper, the atoms are neutral, with a positive nucleus surrounded by negative electrons. Can you see the electron in the outer ring, all alone, far from the nucleus? That electron is able to detach itself from the atom and roam freely. Therefore in a copper wire there are many free electrons. The free electrons carry a negative charge which repels other electrons.

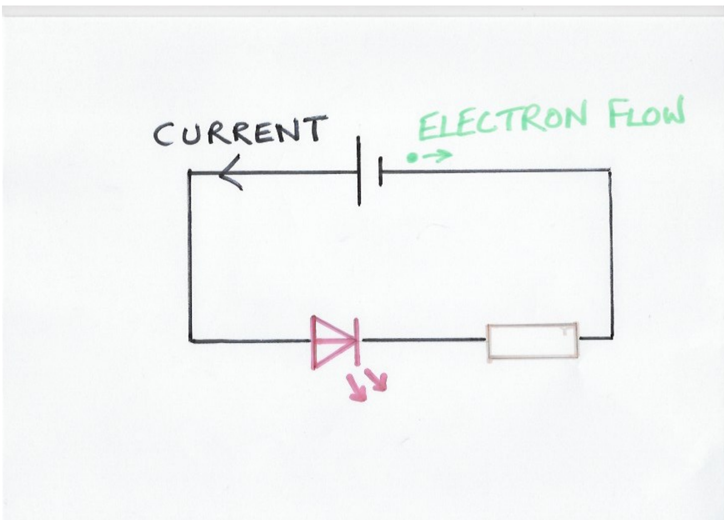


a copper atom

Activity 2.1 Investigating electric charge

Circuits

In a copper wire, the free electrons move around in random directions. If a cell is applied across the wire, the negative terminal repels the negative electrons, and they flow round to the positive terminal. Confusingly, we say there is a current flow from plus to minus! It is called the conventional current.



Activity 2.2 Making a circuit

Polarity

You will need to be careful with the polarity of some components when connecting them in circuits. For example, a diode or an LED has to be correct way round to work properly, with the longer positive pin connected to the positive terminal of the battery. Similarly, an electrolytic capacitor will have a minus on it, which should be connected to the negative terminal.

Activity 2.3 Investigating polarity

Conductors and Insulators

Metals such as silver, alloys such as brass and non-metal graphite, have free electrons so they are conductors of electricity. If a material has no free electrons or very few, it is an insulator. Examples are rubber, plastic, ceramic and wood. Water is a conductor, so current can flow through a wet insulator.

Activity 2.4 Conductors and Insulators

Electric current

The current, measured in amperes, A, is how much electric charge flows in one second. For 1 A, that corresponds to a lot of electrons. About 6 million, million, million in fact!
That is, 6,000,000,000,000,000,000. Approximately!
Current is given the symbol I.
Current is measured with an ammeter which is connected in series in the circuit.

Activity 2.5 Electric Current

Voltage

The electrons get their energy from the chemical energy of the cell. The voltage of the cell measures how much energy is given to the charge. In a circuit there can be a voltage across a component causing the electrons to flow, so this voltage is called an electrical potential difference.
Voltage is measured with a voltmeter, connected in parallel with the component we are measuring, and has the symbol V.

Activity 2.6 Potential Difference

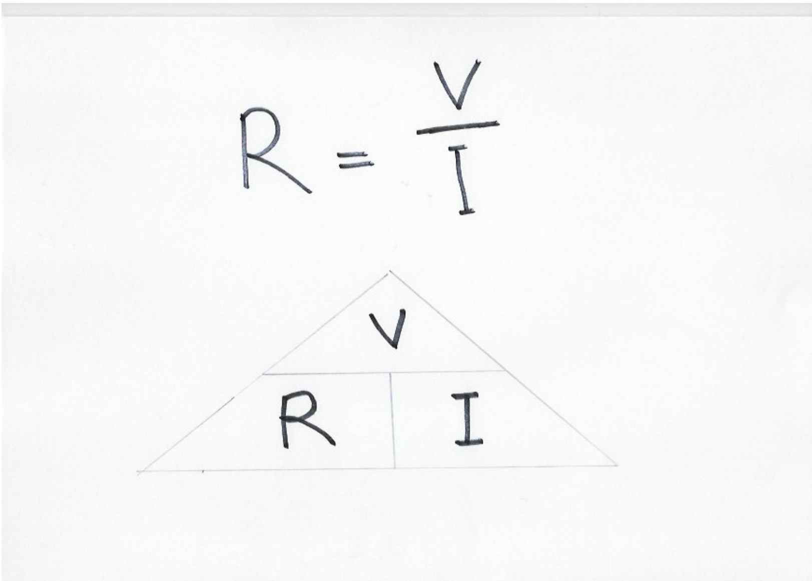
Resistance and Ohm's Law

If we want to change the current in a circuit what do we do? For example, we might want to decrease the volume of a loudspeaker, by sending less current through it. The answer is to change the resistance in the circuit. Resistance can be provided by a resistor. The current gives up some of its energy to the resistor as heat.

What is this resistance, and where does it come from? The electrons flow happily through the circuit, but they come across vibrating atoms in their path. The flow of electrons is slowed down by these vibrations. Heat the wire and the vibrations become greater, causing more resistance. Resistance can be a good thing if we want to reduce the current in a circuit. We can add more and more resistors. Better still, we can use a variable resistor. It is also called a potentiometer, as it can also vary the potential difference.

If we double the voltage, such as having two cells, then the current through a resistor will be doubled too. We find a pattern between the voltage and current. If you double one, you double the other. This means they are proportional. What doesn't change though is the resistance of the resistor, so we define resistance R as the ratio of the voltage V and the current I. The ratio doesn't change; it is a constant and we measure it in ohms, symbol Ω. This is Ohm's law.

This is the first of only two formulae in the course.



Many people are put off by maths, and it stops them from going on to the intermediate and full levels of the licence. Formulae can be mastered with practice, and they help us to understand the theory. There are two ways of getting to grips with formulae.

The Pyramid method

The first way is to learn the definition, which is not provided for you in the exam. If you learn R=V/I, then you can write down the pyramid, with V on the top. To find V, if you are given values for R and I, you multiply them.

For example, if a current of 0.5 A flows through a 100 ohm resistor, what is the voltage across it? 100 x 0.5 is 50, so the voltage is 50 v.

If you are provided with the voltage and resistance, you can find the current by placing your finger over the I, which leaves V/R.

For example, if the voltage is 6 v and the resistance is 2 ohms, then the current is V/R = 6/2 = 3 A.

For example, if a current of 2 A flows in a circuit with a 6 volt battery, what is the resistance in the circuit? To find the answer cover R with your finger, leaving V/I. Therefore the resistance is 6/2 = 3 ohms. Try another one.

If we have 6 ohms in the circuit, what will the current be? Cover I with your finger, leaving V/R, which is 6/6 = 1 A. As expected, doubling the resistance in the circuit has halved the current.

<u>The Re-arranging method</u>

The second way is to learn the formula V = I x R and rearrange it as necessary. With practice you can do this in your head. If you want to find I, you have to divide both sides by R. This becomes

$$V/R = I \times R/R$$

Which leaves $V/R = I$

You have effectively moved R to the left hand side of the equation and changed the 'times' sign to a 'divide'.

Let's say we want to make R the subject. This time we divide both sides by I, to leave R on its own.

$$V/I = I/I \times R$$

Which leaves $V/I = R$

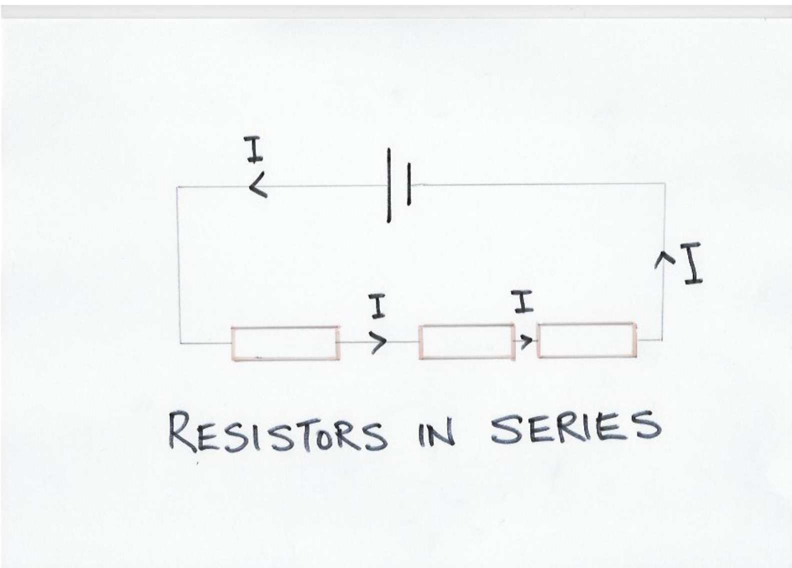
This is my favoured way of doing equations. I learn the equation and rearrange it to get the quantity I want.

<u>Activity 2.7</u> Resistance

<u>Activity 2.8</u> Ohm's Law

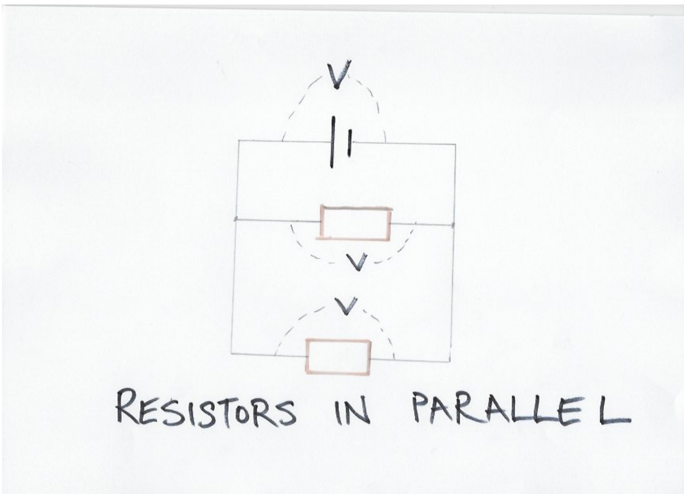
<u>Series circuits</u>

Circuits can have resistors in series, one after the other. Even if the resistors are different, the current around the circuit is the same. The resistor with more resistance must have a



bigger potential difference across it to give the same current. The potential differences in the circuit must add up to give the battery or cell voltage.
resistors in series
For example, if the cell voltage is 6 volts and in the diagram we have 1.5 v and 2.5 v across two of the resistors, then the third must have 6 - (1.5 + 2.5) = 2 v potential difference across it.

Parallel circuits
If the resistors are in parallel, they will have the same voltage as the battery or cell. If the resistances are different then the currents will be different. The one with less resistance will have more current through it. The total current through the battery is the sum of the two currents. This is the arrangement in your home for all the sockets. They are all parallel to each other.

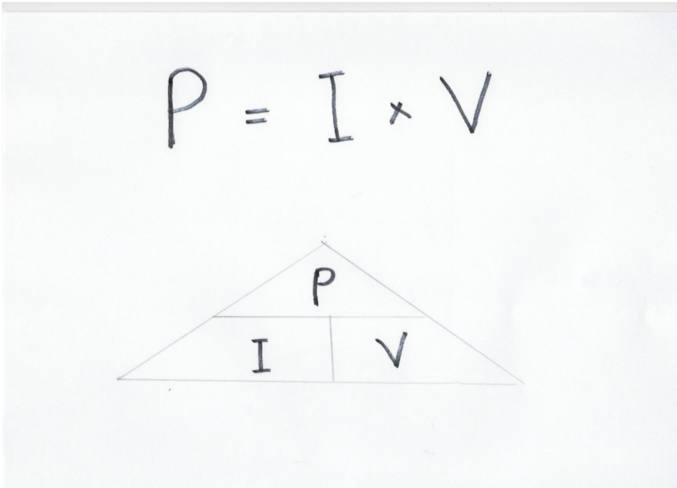


resistors in parallel
For example, the 6 volt cell is delivering 3 mA. If one of the resistors is allowing a current of 1 mA through it, then the other one must have a current of 2 mA. We know too that the second resistor must then be half the resistance of the first one, to allow twice the current.

Activity 2.9 Series and Parallel Circuits

Power
The power of a device tells us how much energy is being transformed every second. For example a 1000 watt (1 kW) hair dryer changes the electrical energy into heat, movement and sound. The current tells us how much electrical charge flows every second, while the voltage tells us how much energy is carried by the charge. Multiplying the current by the voltage will tell us how much energy there is every second, which is the power, measured in watts.
Power = Current x Voltage.
For example, if a resistor is allowing a current of 3 A to flow in a circuit with a 6 volt battery, how much power is being dissipated as heat? The power is I x V, which is 3 x 6 = 18 W.
If the current was only 10 mA, we could convert it to amperes, but we could leave it as mA and remember the power will be in mW. For example, if the battery is still 6 volts, we have 10 x 6 = 60 mW.

Activity 2.10 Electrical Power



Cells and Power Supplies

A battery is a combination of cells. They are usually in series, such as three 1.5 v cells to make a 4.5 v battery. They convert stored chemical energy to electrical energy.

Once a non-rechargeable (primary) battery is depleted it must be properly disposed of. A rechargeable battery (secondary) can be recharged because the chemical process is reversible.

Alternating Current and Voltage

So far, we have been using a battery and the current has gone in one direction, from positive to negative, which we call Direct Current or DC. In our homes, all the electrical appliances, such as a kettle and the lights, use alternating current, AC, meaning that the current changes direction. It oscillates 50 times a second or 50 Hz. You won't be surprised to learn that the change in current with time is a sine graph. The voltage of mains electricity is 230 volts, which also oscillates at 50 Hz.

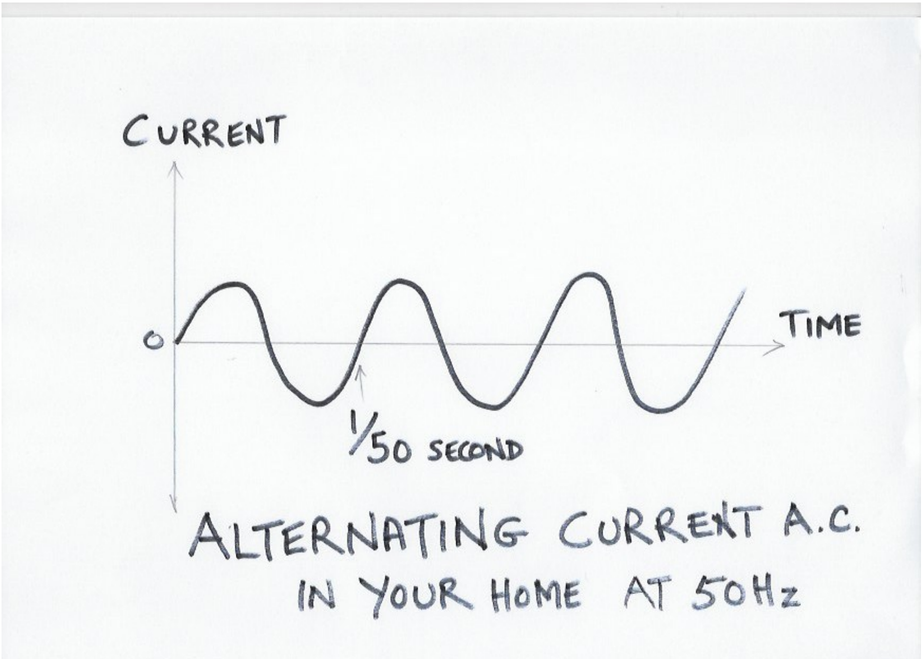
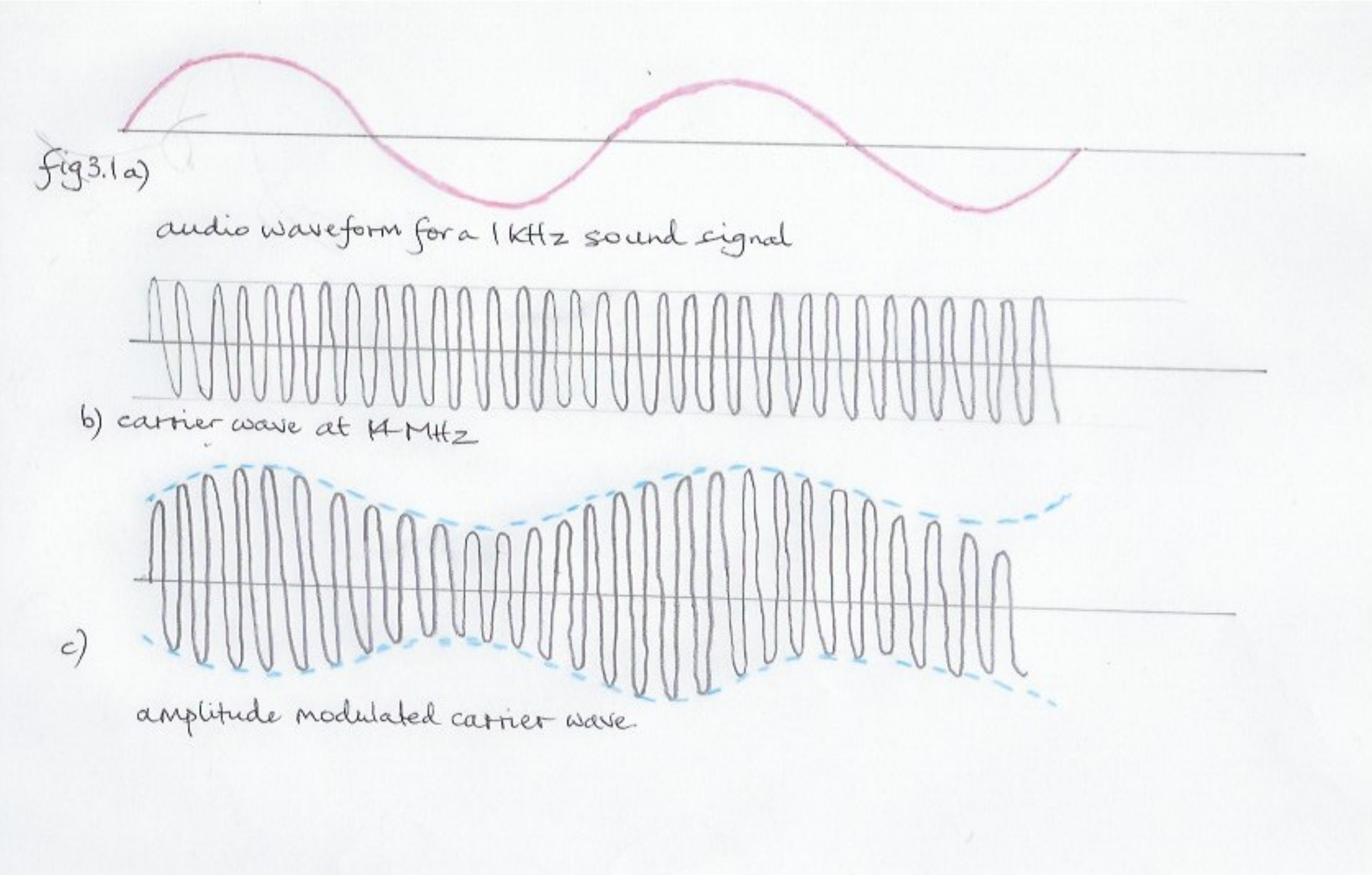


Diagram of current against time

Activity 2.11 Look at the power ratings of devices in your home.

Modulation

How does a radio wave transmit your voice or data?
The pressure waves from your voice are converted into electrical signals in the microphone. For example, if you make a sound wave at 1 kHz, perhaps by whistling or from a signal generator and loudspeaker, the microphone converts the sound into an alternating current, also oscillating at 1 kHz, as in fig 3.1 a).



Amplitude Modulation, AM
If you have chosen to transmit at a frequency of 14 MHz, the oscillator in the radio will generate a carrier wave, as in fig 3.1 b).

Your audio sound signal at 1 kHz will change or modulate the amplitude of the carrier wave, when the two waves mix. When the audio signal is positive, the amplitude of the carrier wave is greater. When the audio signal is negative, the amplitude is reduced. Therefore the amplitude of the carrier changes to match the sound as shown in fig 3.1c)

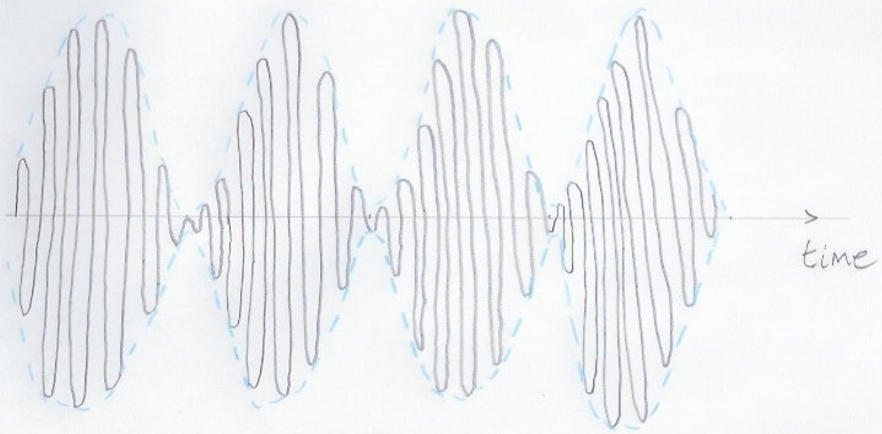


fig 3.2 amplitude modulated waveform for a loud signal.

When the amplitude modulated wave reaches the receiver, the circuitry extracts just the audio signal and feeds it to the headphones or loudspeaker. This is called demodulation.
When we speak there is a whole range of frequencies and we have a complicated audio signal. The amplitude of the carrier will still change to match the audio signal. However at all times the carrier wave frequency is unchanged, in our case, 14 MHz.
If you make a louder sound the amplitude of the carrier wave will be increased a lot on the positive cycle of the sound and reduced a lot on the negative cycle, as we can see in the diagram

We are now close to the noise levels and it can be difficult to understand the sound. If we speak really loud, or have the microphone level too high, it will be over-modulated, and the wave can be distorted. You could then be transmitting outside the band, and cause interference to other users.

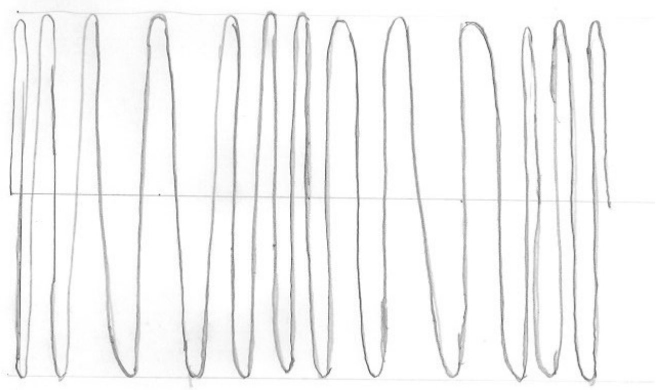


fig 3.3 frequency modulated waveform

<u>Activity 3.1</u> Observing AM on an SDR waterfall

<u>Activity 3.2</u> Speaking in an AM voice!

Frequency Modulation FM

For frequency modulation, the frequency of the radio waves changes as you speak. The frequency of the carrier wave is usually much higher than HF such as 145.500 MHz, so it would be the same as fig 3.2 but with10 times more waves. If we take the sound wave of 1 kHz from fig 3.1, how does that change the frequency? The frequency of the carrier wave will change one thousand times a second.

The frequency will change by an amount governed by the loudness of the sound. The louder the sound, the bigger the change in frequency. Just as with AM, this change in frequency can cause your signal to be outside the permitted band.

In the receiver the demodulator does the job of converting the changes in frequency into the original sound wave.

The advantage of FM is that the amplitude of the carrier wave remains constant, giving a strong signal at all times.

A demonstration of AM and FM is given by Izzy M6TZI on YouTube (https://www.youtube.com/watch?v=yo6_ZuDEzAc&t=32s)

Wiki has a nice animation showing AM and FM (https://en.wikipedia.org/wiki/Amplitude_modulation)

Activity 3.3 Observing FM on an SDR waterfall

Activity 3.4 Speaking in an FM voice!

Morse code

Morse code or Continuous Wave, CW, consists of dots and dashes. To send a dot, the carrier wave is transmitted for a short period of time. To send a dash, the carrier wave is

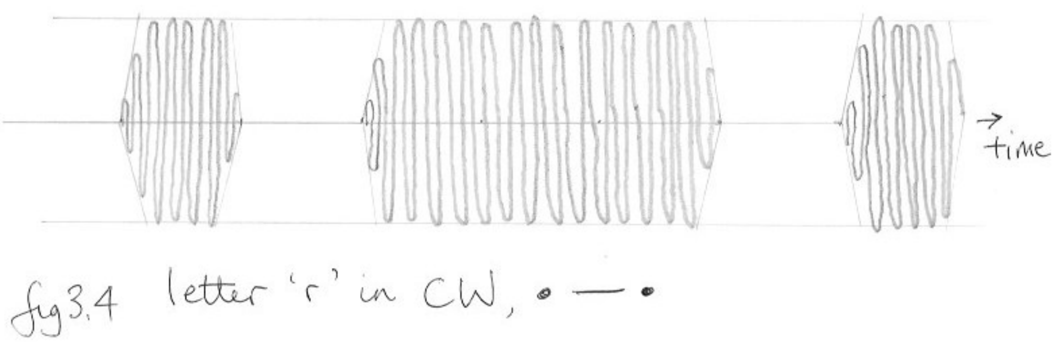


Fig 3.4 Diagram of CW wave

transmitted for a period three times longer than for dot.
The advantage of CW is that the duration of Morse code dots and dashes can be distinguished, even if there is much noise.

Activity 3.5 Observing CW on an SDR waterfall

Activity 3.6 Speaking in Morse code!

Digital Signals

So far, we have looked at analogue signals, where the amplitude or frequency changes continuously. Analogue means that they can take any value. However, Digital Data comes in the form of binary, either 1 or 0. No other value! The 1 can be represented by 5 volts for example and 0 will be 0 volts.

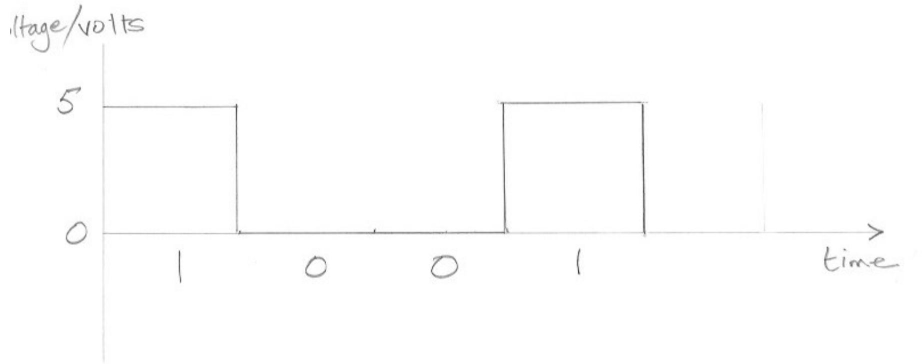


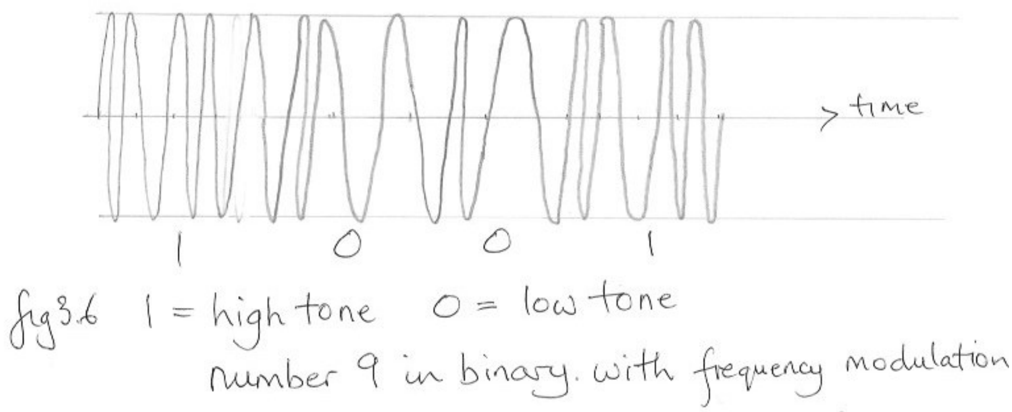
fig 3.5 The number 9 in binary

Fig 3.5 Diagram of 1’s and 0’s with a graph of 5v for the number 9

The digital signal is therefore a stream of definite values, 1’s and 0’s. They are separated by a specific time interval. This is all carried out by the computer software. There are several ways to transmit digital signals.

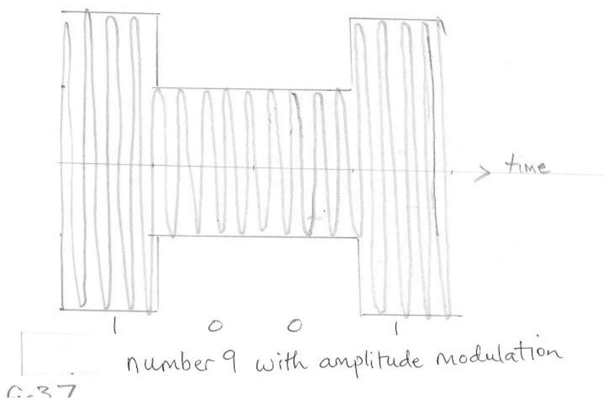
Frequency Modulation

For frequency modulation, data is sent as two audio tones or frequencies. One frequency for 1’s and a different frequency for 0’s. For example, we could have 800 Hz for 1 and 1000 Hz for 0. The amplitude would be same for both. This is the case for Frequency Shift Keying or FSK, FT8, Radioteletype or RTTY, and packet radio. This operation is carried out by an audio interface such as your computer sound card. To make the transmission



even faster, we could have a frequency of 600 Hz for a 1 followed by another 1, and 900Hz for a 0 followed by another 0.

Fig 3.6 Diagram of 1’s and 0’s as two frequencies for the number 9



Amplitude Modulation

We can also send digital data by changing the amplitude of the carrier wave. Amplitude Shift Keying, ASK, does just that. A zero could be represented by one amplitude of the carrier wave, while the 1 is represented by a different amplitude.

Fig 3. 7 Diagram of 1’s and 0’s as two amplitudes for the number 9

Sampling

How is an analogue audio signal, such as fig 3.1 or fig 3.4 with continuously changing values of amplitude and frequency, converted into a digital signal with only two values? The signal is sampled at certain intervals of time to give a series of voltages. Those voltages are converted into binary. For example 3 volts would be 11 in binary and 5 volts would be 101.

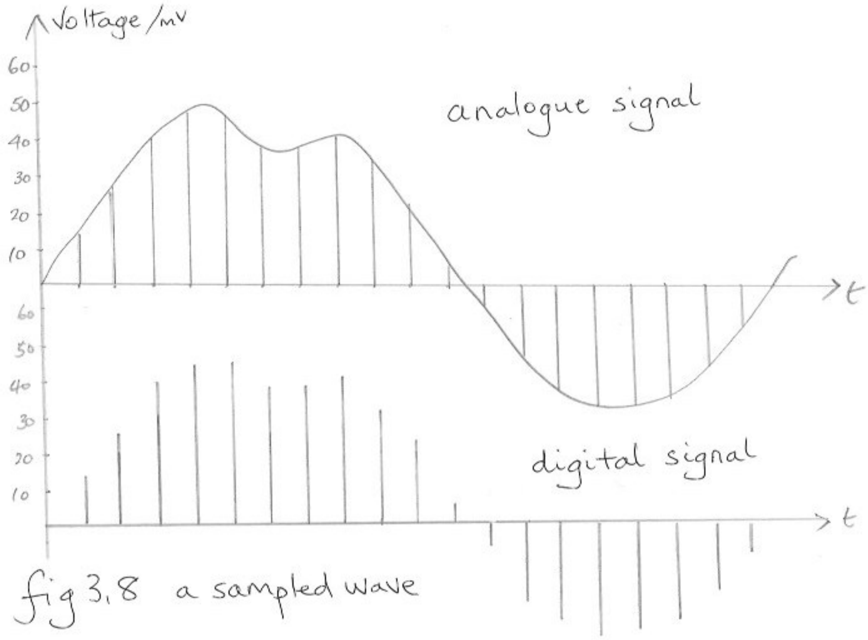


Fig 3. 8 Diagram of a sampled wave

Activity 3.7 Sample a wave exercise

To get a more faithful copy of the original wave, the sampling needs to be done at very short time intervals, that is, at a high frequency.

Single Sideband

When an audio signal is mixed with a carrier wave we get an amplitude modulated wave. However, we get three signals, the carrier wave and two sidebands. We show this on a diagram with frequency along the x axis. The signal is analysed into all its frequencies, and plotted to give a frequency spectrum, centred on the carrier wave frequency.

Only one sideband is needed as the two sidebands are duplicates. Therefore we send only a single sideband, SSB. All the information on the sound or data is contained in the sideband. Below 10 MHz we use the lower sideband and above 10 MHz we use the upper sideband. In both cases we are sending an SSB modulated signal. An AM modulated signal would send both sidebands.

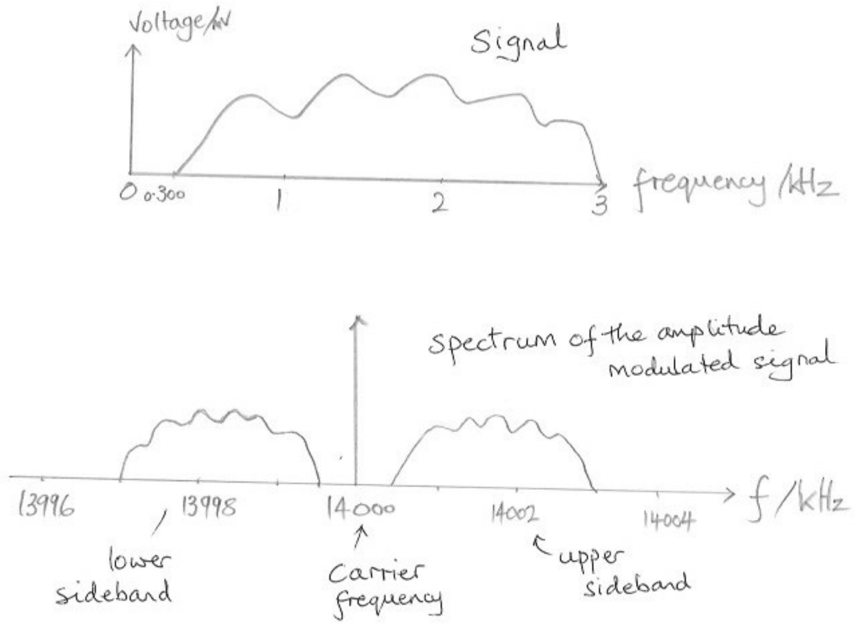


fig 3.9

Transmitters and Receivers

Transmitter

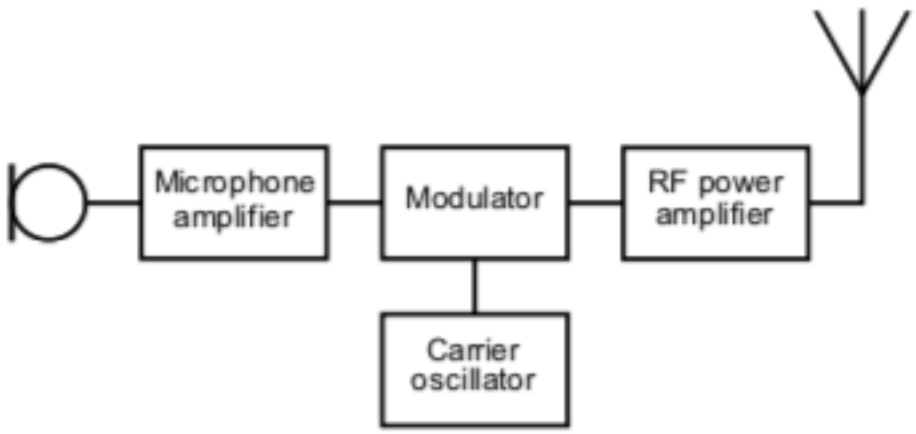
Whether it is a handheld or a base station radio, a transmitter can look quite daunting at first, with all its controls and buttons. With practice, you will soon become a confident radio operator.

The Icom IC-7300 transceiver

Other radio manufacturers include Kenwood https://www.kenwood.eu/comm/amateur/hf_all_mode/ and Yaesu https://www.yaesu.com

All transmitters need a wave carrier, which is produced by an oscillator. It makes the electrons oscillate at the required frequency. When you speak into a microphone it produces an audio signal. The microphone amplifier has two jobs. Firstly, it needs to amplify the signal from the microphone so that it can drive the modulator in the next stage. Secondly, it limits the range of audio frequencies to the range 300 Hz to 3 kHz. The modulator mixes the audio signal with the wave carrier frequency. The output can be amplitude modulated or frequency modulated. The modulated signal is amplified by the radio frequency amplifier before being sent to the antenna.

As we will see in the chapter ‘Setting up a Radio Station’ the signal has to be matched to the antenna. If there is a mis-match, such as using the wrong antenna, the transmitter can be damaged.
A transmitter can be represented by a block diagram.

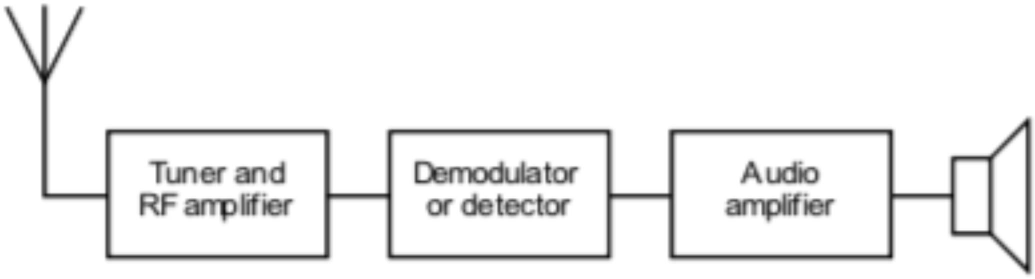


Activity 4.1 identify the controls on a transmitter

Receiver
An antenna will receive every radio wave that’s out there. The electrons in the wire will be made to oscillate by absorbing the energy of the waves by electromagnetic induction. The signal will be very weak, so the first job is to amplify it. But how do we select the wave we want? It is similar to a child’s swing which will swing freely at only one frequency, which we call the natural frequency. Let’s say it takes 3 seconds for one swing, backwards and forwards. If we push the swing at this frequency the oscillations will build up. It will resonate. If we push every 2 seconds or 4 seconds, the swing won’t go very far!

Inside the receiver is a tuning circuit, which is designed to oscillate at the required frequency, just like the swing. Incoming signals are like the person pushing the swing. Signals at frequencies below or above that frequency will have little effect on the electrons in the circuit. However a signal at the same frequency as the frequency of the tuning circuit will drive the electrons to oscillate. We say the receiver is tuned. The phenomenon is called Resonance.

Once the required frequency is tuned, it needs to be demodulated to extract the audio information. This is performed by the demodulator, also known as the detector. We now have an audio signal which is amplified, and then sent to the loudspeaker or headphones.



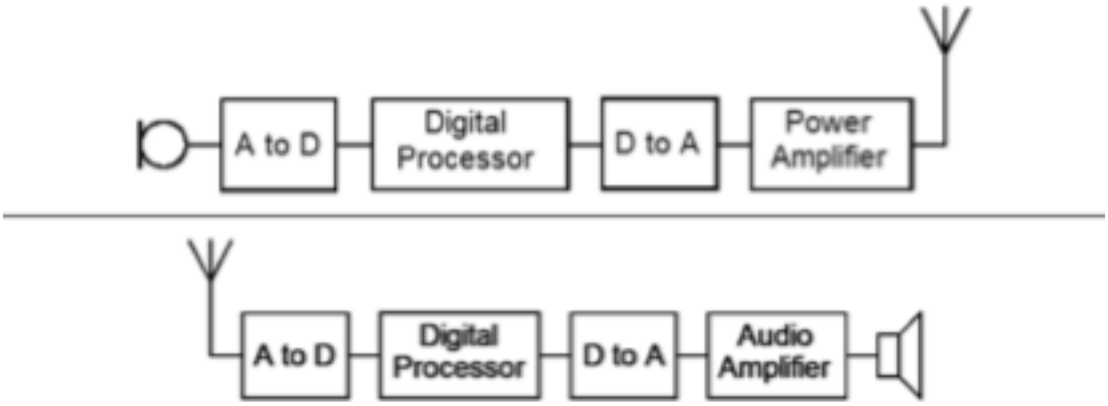
Block diagram of a receiver

Activity 4.2 identify the controls of a receiver

Software Defined Radio
The SDR receiver comes in the form of a dongle, which plugs into a computer.

A FUNcube dongle

It takes in ALL electromagnetic signals from the antenna and converts these analog signals into digital form using an analog to digital converter (ADC). They can then be processed in computer software. The different frequencies are separated out using a mathematical operation. The software does the job of selecting the frequency you want.
Even the demodulation is carried out in software! The digital audio or data signal is converted back into analog form by a digital to analog converter (DAC). The signal can now be sent to the loudspeaker or headphones.



An SDR transmitter has the same block structure as the receiver but has a power amplifier to send the analog signal to the antenna.

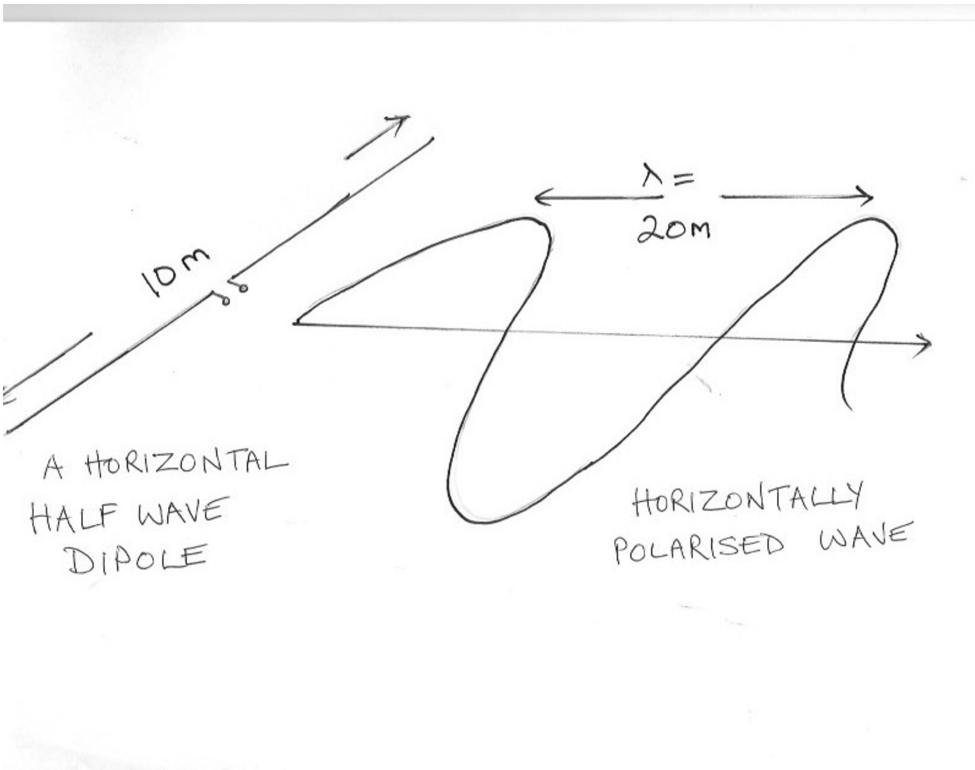
Activity 4.3 Look at the waterfall of an SDR

Antennas and Feeders

How antennas work

When a wire antenna receives a radio signal, the electromagnetic energy of the wave causes the free electrons in the wire to oscillate at the same frequency. The signal is then fed along the cable to the radio receiver.

To transmit a radio wave at the required frequency, you need to send an oscillating signal



to the antenna. This will cause the free electrons in the antenna to oscillate at that frequency. These oscillations will send out an electromagnetic wave at that frequency.

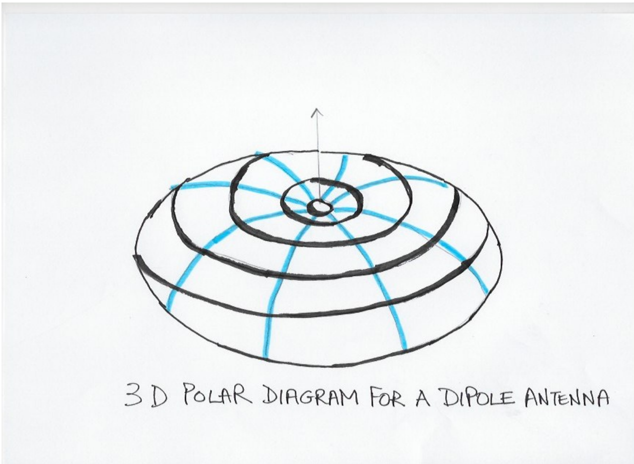
The radiation pattern of an antenna

The most common type of antenna is the half-wave dipole. Its length is approximately half the wavelength of the radio wave. For example, to transmit on 20 m, the antenna will be approximately 10 m in length.

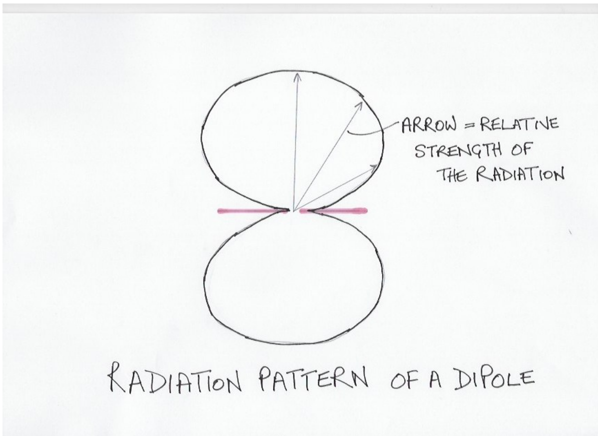
If the dipole is mounted horizontally, the radio waves will be horizontally polarised with the electric field oscillations in a horizontal direction. Similarly, if the dipole is vertical, the polarisation will also be vertical. To receive horizontally polarised radio waves, your antenna needs to be horizontal. If the antenna is vertical, the reception will not be so good! This is certainly the case for VHF and UHF signals but is less important at HF, as we will see in the chapter on Propagation.

Activity 5.1 investigate the effect of changing orientation of antennas

A vertical antenna will radiate horizontally in all directions, and we say it is omni-directional. The polar diagram for an antenna shows how much energy is radiated in different directions. A 3D diagram can be used, or two diagrams, one looking from above giving a horizontal view, and the other looking from the side giving a vertical view.
In 3 dimensions the pattern looks like a donut! Why is it called a 'polar' diagram? Because polar spherical coordinates are used instead of the normal Cartesian x and y coordinates.



Polar Diagram in 3d



Polar diagram in 2d

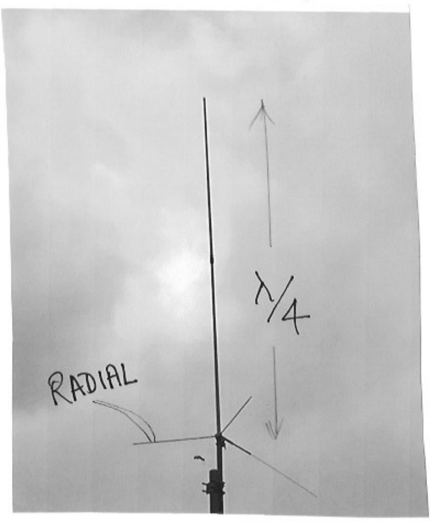
We can see that the radiation is mostly in a horizontal direction with very little in the vertical direction.

<u>Activity 5.2</u> make a half-wave dipole

If the dipole is mounted horizontally in the north-south direction, the donut pattern will be like a vertical donut with energy radiated horizontally in the east-west direction, as well as upwards and downwards.
<u>Other types of antenna</u>
The half wave dipole antenna is balanced, because each half has an equal and opposite signal. The signal is taken at the midpoint.

The 1/4 ground plane antenna

The quarter wave ground plane antenna is a dipole with the bottom half removed. The vertical antenna will have a length equal to a quarter of the wavelength. So for 20 m its length will be 5 m. However it will need four radials to act as the ground plane.



Alternatively if it is on a car roof, the roof itself will be the ground plane.

The 5/8 wavelength antenna

The 5/8 ground plane antenna has a coil at its base. It too is omnidirectional.

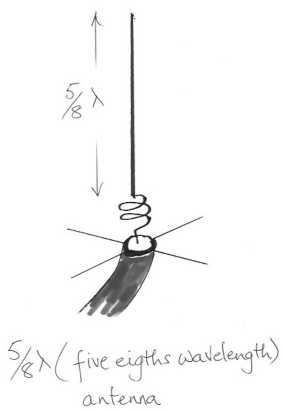


Diagram of 5/8

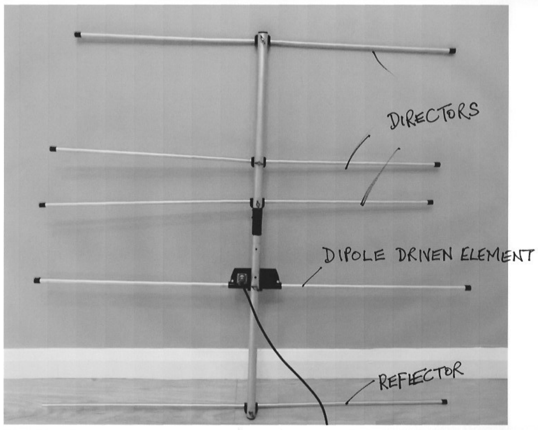
The end-fed antenna

The end-fed antenna is usually a long horizontal length of wire attached to a pole at the end of your garden. What could be simpler?! You would need an Antenna Matching Unit, which we discuss in the chapter 'Setting up a Radio Station
'.
You can find out more here:
https://www.electronics-notes.com/articles/antennas-propagation/end-fed-wire-antenna/end-fed-long-wire-antenna-basics.php

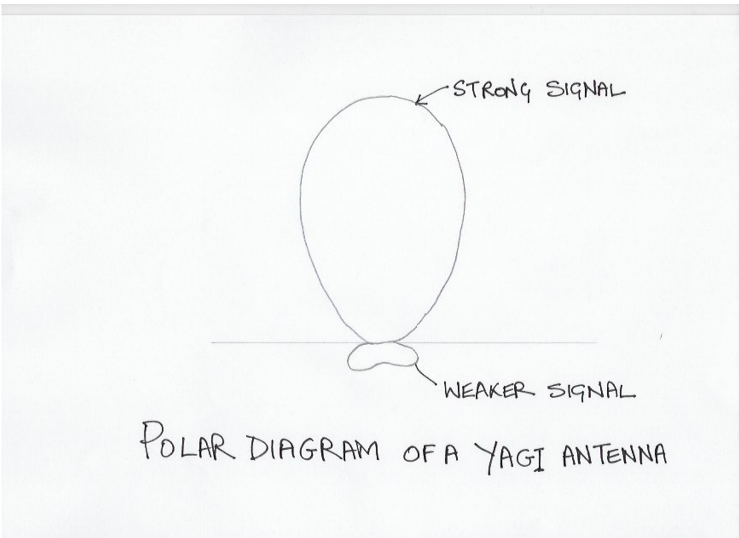
Also, it's fine for listening to stations, but it could present interference problems on transmitting, as discussed in the chapter 'Electromagnetic Compatibility'.

The Yagi-Uda

If you want to transmit in a particular direction, such as across the channel, rather than in all directions, you can use a Yagi antenna, similar to a television antenna. It has a dipole, which is the active element and several director elements. Behind the dipole is the reflector element.



The energy will be focussed in the direction of the elements. We can see the difference in the polar diagram, which looks like a fish. Most of the energy goes in one direction.



Activity 5.3 make a Yagi antenna.

Using a Yagi to talk to Robert Deschodt F1FXN in France

Antenna gain

The Yagi antenna has effectively provided you with increased power, by focussing the energy in one direction. The output power is still the same, but to get the same strength from a vertical antenna, you would have to increase the amount of power to the antenna. The antenna has given you an apparent gain in power, which we measure in dB. We can talk about the Effective Radiated Power, ERP, as being the product of the power applied to the antenna multiplied by the antenna gain. For example, let's say you send 10 W to the antenna which has a gain of 3 dB. Looking at the table provided in the exam we see that 3 dB means a power ratio of two, so the Effective Radiated Power is 20 W.

dB	multiplier
3	x2
6	x4
9	x8
10	x10

ERP is mentioned in the licence schedule so you need to be cautious as to how much power you send to the antenna.

ERP = Power x Gain measured with respect to a dipole antenna.

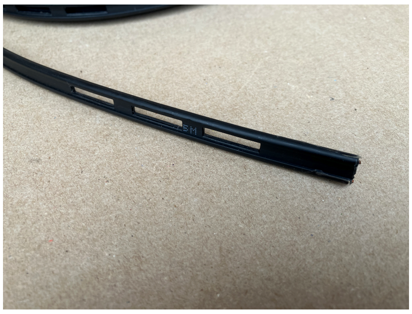
Another way of expressing the gain of an antenna is to use the Effective Isotropic Radiated Power, EIRP, where you compare the gain of the antenna to that of an antenna that radiates equally in all directions.

EIRP = Power x Gain measured with respect to an isotropic antenna.

No such antenna exists; it is purely hypothetical. Therefore the gain of an antenna could be quoted as 10 dB EIRP. It works out that 10 W EIRP is equivalent to 6.1 W ERP.

The feed point
To connect the antenna to the radio, you will need feeder cable designed especially for radio frequencies. The most popular is coaxial cable with its useful screening properties, meaning that the signal stays within the conductor, and does not radiate outwards.

Another type is twin feeder cable. It has two conductors with the signal going in opposite directions in each conductor. This makes twin feeder cable a balanced feeder, whereas coaxial feeder is unbalanced.



twin feeder

Connectors
There are various kinds of plugs and sockets, the most common being the PL259. It is important that the braid of the coaxial cable is connected to the body of the connector plug. This helps to minimise the RF signals that can get in or out of the cable.

PL259 connector

Activity 5.4 Connect a PL259 to a cable

Other kinds are BNC, N and SMA, which your instructor will show you. Can they tell you what the initials BNC stand for?! You can see them here:
https://uk.rs-online.com/web/c/connectors/rf-coaxial-connectors-adapters/coaxial-connectors/

https://uk.rs-online.com/web/c/connectors/rf-coaxial-connectors-adapters/coaxial-connectors/?applied-dimensions=4291130301

https://uk.rs-online.com/web/c/connectors/rf-coaxial-connectors-adapters/coaxial-connectors/?applied-dimensions=4291130302

From the RSGB specification, we have these diagrams:

<u>Feeder loss or attenuation</u>

As the signal is passed down the feeder cable, there will a loss of energy due to some of it being converted to heat. This will be the case whether you are transmitting or receiving. Making the cable shorter will reduce the loss. The signal loses strength the longer the cable distance it has to travel. As the frequency increases, so does the loss. Therefore, at VHF and UHF it is best to use low loss feeder. The loss will be quoted in so many dB for every metre, such as 0.5 per metre, so for 6 m it will be -3 dB, which is half the signal strength.

<u>Activity 5.5</u> identify connectors

Setting up a radio station

You've bought a transceiver, a long length of cable, connectors, antenna, a balun, an Antenna Matching Unit and a dummy load. You have everything you need, so how do you set it all up? Why do you need all those extra parts? Can't you just connect the wire to the radio and start transmitting? Not if you want to damage your radio!

Matching

It is all about oscillating waves going from one medium to another. Before you were born, your mother saw you inside her womb using ultrasound. To enable the ultrasound waves to penetrate the skin, the nurse applied some gel. Without the gel, the waves would have just reflected back.

You have to match one medium with another. The inner workings of the human ear also help the sounds waves transfer from the air to the bones. A megaphone helps to match your vocal chords to the air, allowing more sound to be transmitted.

Matching impedances

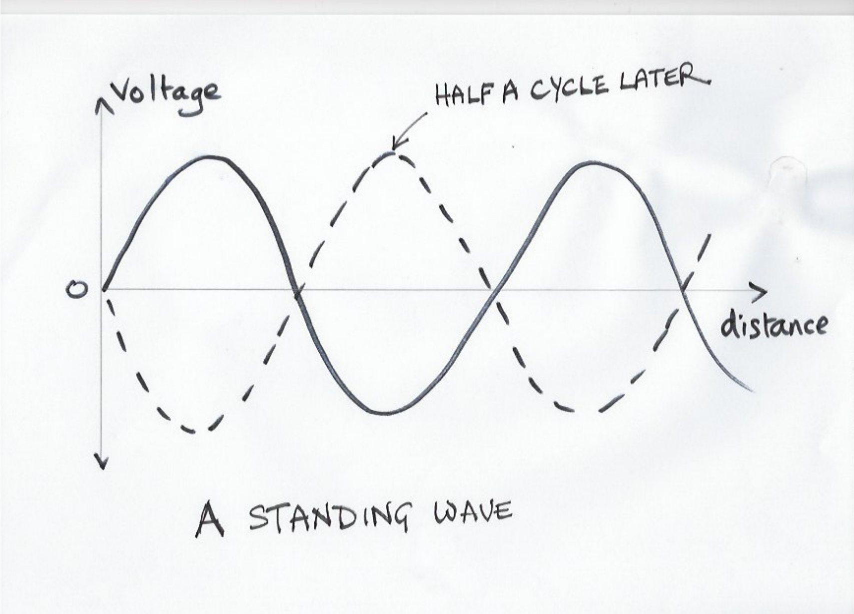
The medium could be a coaxial cable, an optical fibre or even the axon that transfers your nerve impulses. The ability of a medium to carry oscillating signals is measured by its impedance. The impedance will depend on the frequency of the signal. If the impedances of the different media do not match, then energy will be reflected back to the source. If all the media do match, no energy will be reflected and everything will be fine! That's the ideal!

Activity 6.1 show reflection if there is no matching

Standing waves

In practice energy will be reflected. A reflected wave will meet the incident wave, interference will occur and a standing wave pattern will be produced. This can be shown with a slinky or a long rope. If you make waves at one end, they will be reflected back when they reach the end. A build up of oscillations can be seen if the rope or slinky is shaken at the right frequency.

Activity 6.2 Standing waves with a slinky or rope



Antenna Matching Unit
When setting up the radio we need to include the Antenna Matching Unit (AMU), or Antenna Tuning Unit (ATU) as it is sometimes called, so that the transmitter is matched to the antenna. If it's not matched, currents will be reflected which could damage the radio.
Antenna Matching Unit

The AMU can measure the incident and reflected energy or power. The Voltage Standing Wave Ratio (VSWR or SWR) is the ratio of the maximum voltage to the minimum voltage

and gives an indication of how well the radio is matched to the antenna. Ideally, we want a ratio of 1:1 but 1.5:1 is acceptable.

SWR meter

Activity 6.3 Plot a graph of SWR against length

Let's imagine we want to transmit on 40 m and that our half wave dipole is the right length. Unfortunately the SWR meter is reading 3:1. We can adjust the controls on the Antenna Matching Unit to reduce the SWR. If we are lucky enough to have a radio with a built in automatic AMU we can just press a button!

Activity 6.4 Correctly connect up a station

Balun
Why do we need a balun ? Our dipole is balanced in the sense that a maximum of voltage or current on one side will balance the opposite maximum on the other side. However, coaxial cable is not balanced and a signal in the braid could transmit unwanted signals. Therefore the balun (balanced - unbalanced) is inserted at the dipole.

A Balun

<u>Dummy Load</u>

In order to test our set-up we should also use a dummy load in place of the antenna, so that no radio waves are transmitted. It is a resistor of 50 ohms, capable of taking high power, to turn the energy into heat. If a problem persists, even with the dummy load, then we can eliminate the antenna and feeder. Similarly if the problem disappears with the dummy load, it can point to the antenna and feeder as the source of the problem.

Propagation

Amateur radio operators love to communicate, whether it is with a friend in the next town or to make new friends on the other side of the world. How they do so depends on many factors - the radio frequency or band, the antenna, the year, season, day or night and even the weather.

Radio waves behave in much the same way as light, but with some important differences in the way they interact with matter. However, they both travel at the speed of light, 300,000 km per second, through the vacuum of space.

Attenuation
Attenuation is the decrease in signal strength. For example, when you drop a stone in a pond the ripples get smaller in amplitude as they travel outwards. Similarly radio waves get weaker and weaker as they travel from a vertical or horizontal dipole antenna.

Activity 7.1 Finding the range of a PMR446 radio

Reflection
Just like light waves, radio waves are reflected from metal surfaces. This property is used in RADAR on ships and by air traffic control.

Activity 7.2 Reflection experiments

Absorption
When electromagnetic waves meet substances, the energy can be absorbed. The energy of the wave is attenuated or reduced. A VHF signal can penetrate a building but obviously it will become weaker.

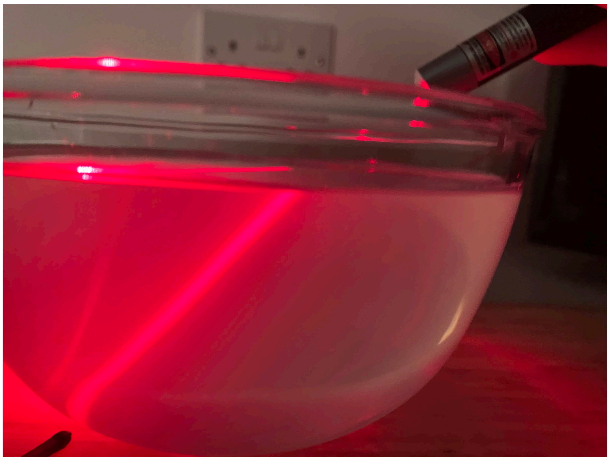
Heavy rain, hailstones or falling snow can attenuate UHF and higher frequencies. Similarly, vegetation, such as tall trees, and areas with lots of buildings can make VHF and UHF communication difficult.

Activity 7.3 Testing a brick wall for absorption

Line of sight
If you can see someone in the distance you should be able to contact them by radio on 2 metres VHF and 70 cm UHF. You could contact your friend on a 2 m simplex channel. Simplex means that you communicate with each other directly, on the same frequency. https://www.hamradioschool.com/post/simplex-duplex-offset-and-split for some useful diagrams. However as the frequency increases, the range decreases, so on 70cm UHF you might not be able to make contact. Instead you can always call up the local repeater to extend the range.

Activity 7.4 Under supervision, use a handheld radio to investigate VHF Propagation.

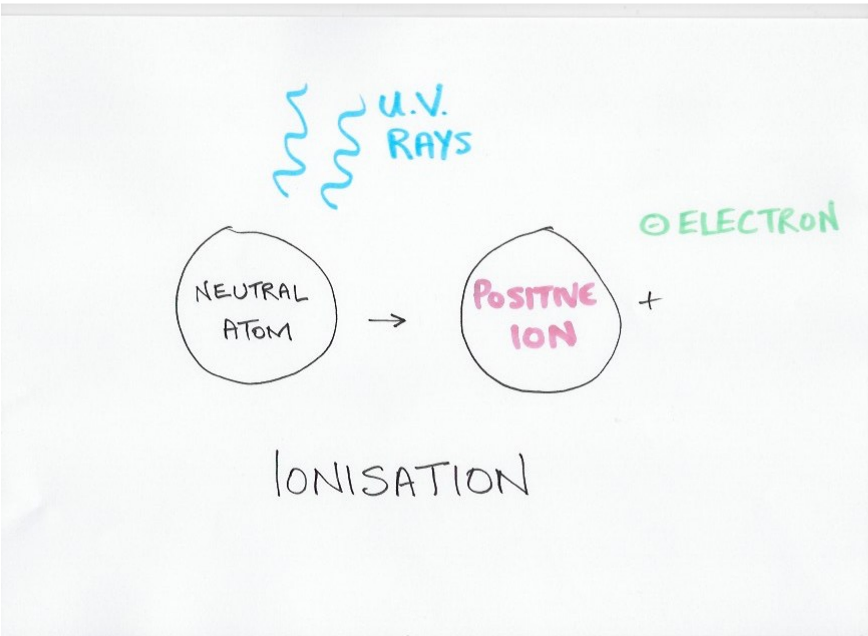
<u>Refraction</u>
To contact a friend in another continent, you need to resort to HF and make use of the refraction of radio waves. We are used to seeing a straw bent in a glass of water, but how do radio waves refract?



<u>Activity 7.5</u> Refraction experiments

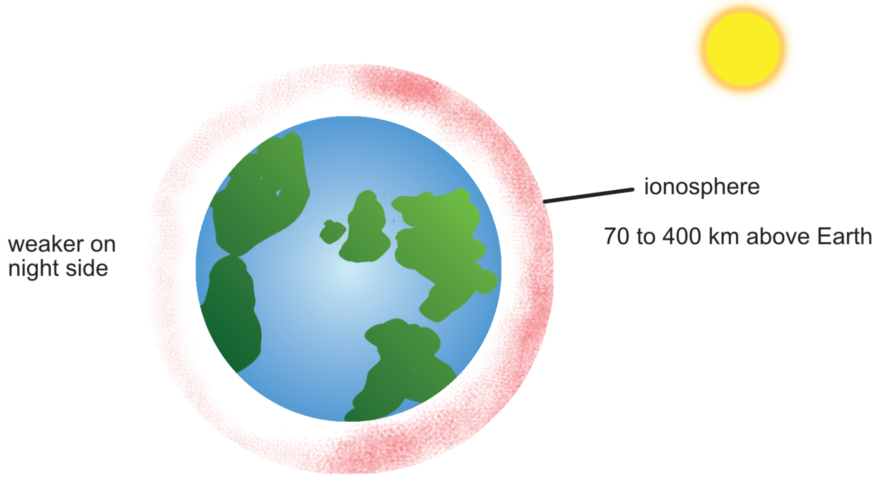
The light changes direction when it enters the water because it slows down. This bending of light is called refraction.

Ultra-violet electromagnetic waves from the Sun have frequencies much higher than radio. They oscillate at an incredible 30,000 THz! They have enough energy to break apart molecules, such as oxygen, in the upper atmosphere into an ion and a free electron.

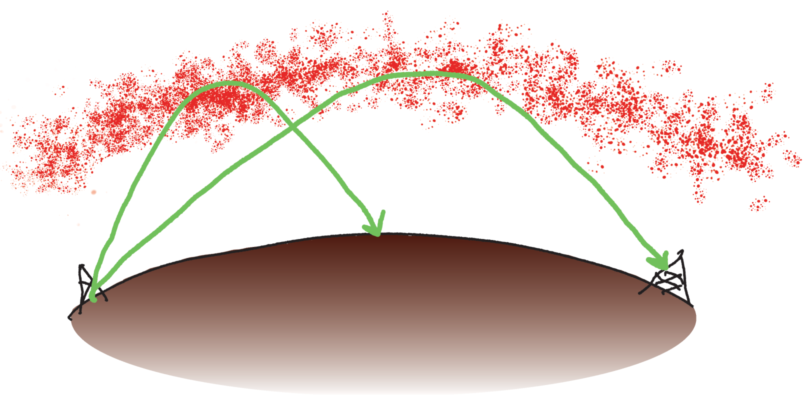


An ionised atom

So all round the Earth, more so on the Sun's side, there is a sphere of ions which is called the ionosphere. The ionosphere extends from 400 km down to 70 km. That is high up when you think that planes fly at about 10 km and the International Space Station is 400 km up.
The ionosphere



The density of ions increases as you go higher up, so the ionisation is greatest at the top of the ionosphere. When you transmit on HF, the waves go through the ionosphere.
They refract when they travel from one region of ions to another. They change direction as they travel upwards. Eventually they refract so much that they come back down to earth. It would appear that the ionosphere reflected the radio waves, like a mirror, but it was all due to refraction. This kind of propagation is called skywave propagation.



A skywave returning to earth

So how do hams communicate with Australia if the sky wave comes back down at about only 4000 km? The answer is the waves bounce off the Earth. They hop! They can do this several times.

The propagation of signals is affected by the frequency. As the frequency of the HF waves increases, they find it more difficult to refract back down to earth. Higher frequencies are refracted less. In fact at VHF and UHF frequencies and beyond, they pass through the ionosphere. We say a particular band is 'open' when signals are able to propagate.

The propagation is also affected by the season and time of day, with more ionisation in the daylight and summer. At night some of the ions join with the electrons again and go back to being molecules, so there is less ionisation.
The polarisation of the HF wave will change during its path through the ionosphere. Therefore it is not critical to have the same orientation of the antenna for reception as for transmission.

Activity 7.6 Under supervision, have a QSO using HF

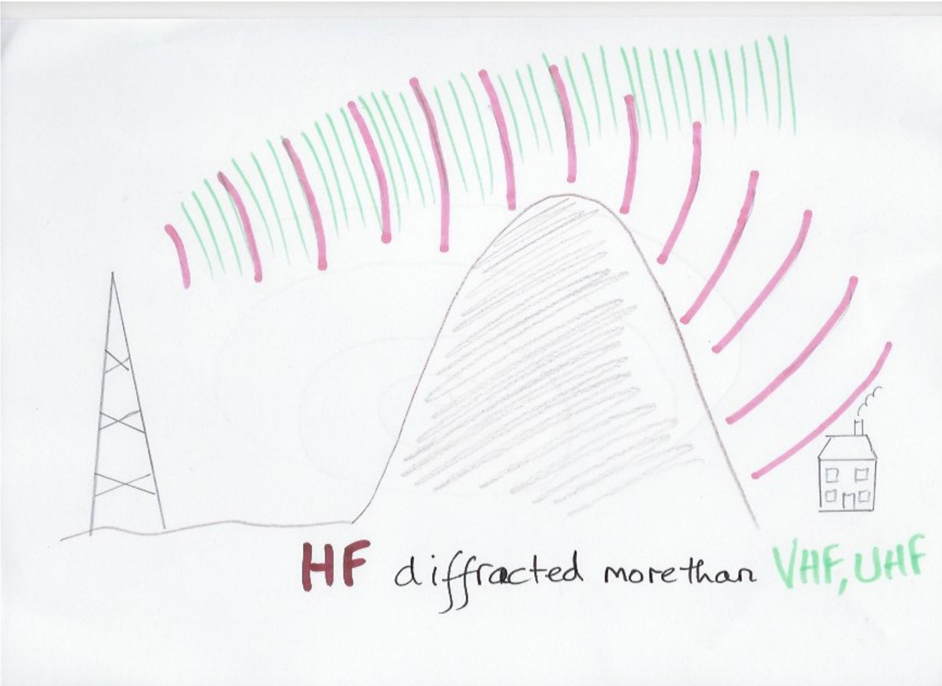
Solar Cycle
The Sun goes through a cycle of activity with an increased number of sunspots, rising to a maximum every 11 years. Why it does this, no-one knows! It makes a big difference to the ionosphere, increasing the production of ions. At the peak of the cycle, HF signals as high as 50 MHz and more may be refracted back to earth, causing much excitement in the ham community!

Satellites and space craft
Only VHF, UHF and microwaves can penetrate the ionosphere. Therefore, you can communicate with satellites and the International Space Station with these wavelengths on your handheld radio. Amazing! The STEAMettes are downloading a fitter message from the FUNcube satellite.

Activity 7.7 Under supervision, communicate with a satellite

Diffraction

Water waves can diffract when they come into a harbour, meaning that they go round a corner or edge. Radio waves can also go round corners, depending on their wavelength. For example a hill can block VHF and UHF signals but HF signals, with their longer wavelength, can pass into the valley.



Diffraction of radio waves for HF and VHF

Activity 7.8 Diffraction investigations

Sporadic E

The ionosphere has a particular layer of ions, called the E layer, and occasionally its level of ionisation is very high. This can allow VHF and UHF waves to reflect back down to earth, meaning a much greater range than normal for these bands.

Ducting

VHF and UHF waves can also travel longer distances when the right atmospheric conditions trap the waves. This happens in the troposphere, which is below the ionosphere, from just above the earth's surface to 10km, and generally occurs when we have regions of high pressure.

Range

If we want to send or receive signals over greater distances, we can do a number of things. We can raise the antenna and use more power. However, it is preferable to have a higher antenna rather than more power, as it will improve both transmit and receive performance. An antenna outdoors will also perform better than one indoors, perhaps having it mounted on the roof, so that the signal can have a clear path above the trees and buildings. Also we can use a directional Yagi antenna to focus the energy.

Licence Schedule

When you operate a radio, there are some rules or guidelines you will need to follow so that you do not cause inconvenience or interference to other radio users.

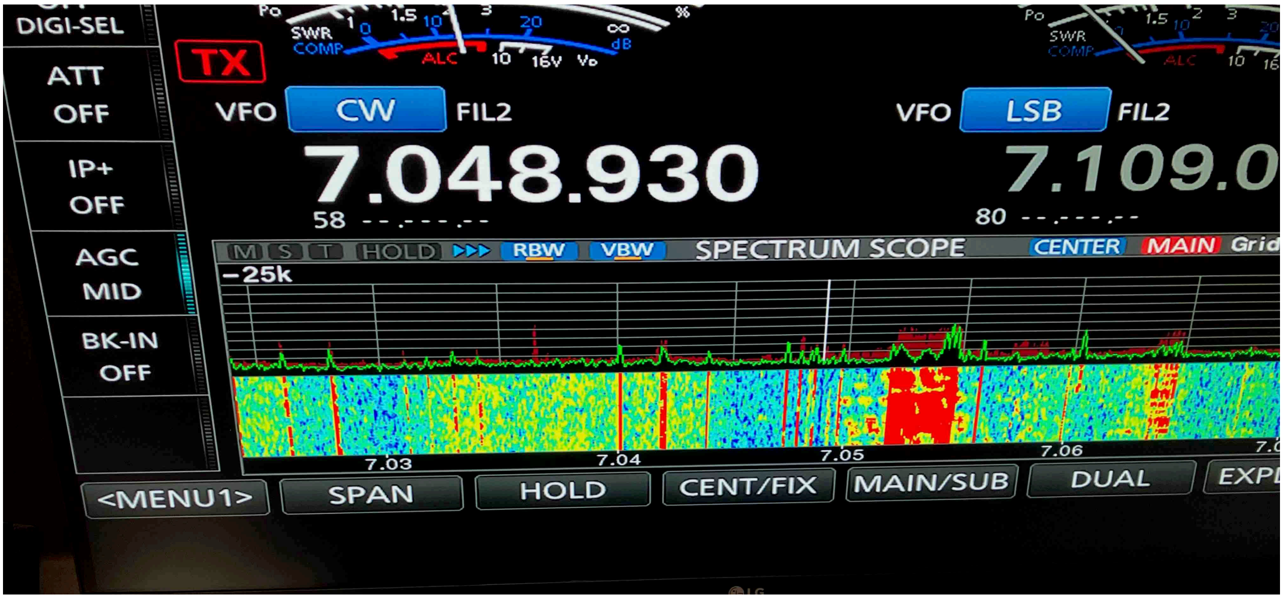
In this chapter we will find out where on the radio spectrum you are allowed to operate, such as using the calling channel.

Have a look at the 'Foundation Licence Parameters' in the RSGB reference data for the exam. http://rsgb.org/main/files/2020/10/EX307_Oct_2020duo.pdf This tells us what frequency bands we are allowed to transmit on and the power levels. The 2 m band is expanded in more detail. For example, this tells us where we can find the calling frequency, FM calling, at 145.500 MHz when we transmit a CQ. Also we need to be careful that we don't transmit on a frequency that is allocated to a beacon!

The lowest frequency band is 0.1357 to 0.1378 MHz. What is that in kHz? It is 135 to 137.8 kHz. What radio band is that in? In the chapter on 'Radio Waves' you learned the three main bands. The other bands are:
LF 30 to 300 kHz
MF 300 kHz to 3 MHz
So the lowest frequency you can use is in the LF band.
What is the highest frequency you can use? From 10450 to 10475 MHz at 1 W on a secondary status. What band is that in? The band is
SHF 3000 MHz to 30000 MHz (30 GHz).
So you are allowed to transmit in the microwave band.

Bandwidth
In the 'Notes to the bandplans' in the schedule, there is reference to 'necessary bandwidth' and 'Narrowband Modes'.
Mobile phone companies pay billions of pounds to Ofcom to be allowed to use a part of the radio spectrum. Amateur radio users do not have to pay anything! However, they are limited to how much of the spectrum they can use.

The term bandwidth is how much of the spectrum you are using. Look at the band plan for 144 MHz in the reference data and the column ‘Necessary Bandwidth’. If you are sending telegraphy, CW, at 144.025 MHz you are allowed 500 Hz of the spectrum. We can see the small amount of bandwidth used by CW compared to telephony with this image of a waterfall.



The big red section, above ‘MAIN/SUB’, is a QSO using telephony while the red stripes to the left of it are CW contacts, occupying very little bandwidth in comparison.

Here’s a little calculation for you! How many operators can use the region 144.025 to 144.100 MHz? The width is 144,100 kHz minus 144,025 kHz which equals 75 kHz or 75000 Hz. 75000 divided by 500 equals 150, meaning 150 CW operators can use that width of radio spectrum. Narrow bands such as CW are at the lower end of most of the band plans.

To limit the amount of bandwidth and allow more radio frequencies to be used on a band, radios limit your audio signal to the range 300 Hz to 3 kHz, which is a difference of 2.7 kHz. Look at the reference data for 14 MHz (20 m). So long as you don’t shout into the microphone or turn up the gain too much, you will use 2.7 kHz of RF spectrum. This is the case for Single Sideband, SSB, which we met in the chapter on Modulation.

For normal speaking on FM, the allowed bandwidth is 12 kHz. For 144.500 to 14.794 MHz you can use a bigger bandwidth of up to 20 kHz.

Activity 8.1 find out what you are allowed or not allowed in the Licence Schedule

EMF restrictions

A requirement in your licence is to check that you are compliant with Electromagnetic Field, EMF, exposure limits. You are required to calculate the ‘compliance distance’ that people need to be from your antennas. See Ofcom’s guidance https://www.ofcom.org.uk/__data/assets/pdf_file/0025/214459/guidance-emf-compliance-enforcement.pdf The RSGB have provided a calculator for you. https://rsgb.org/main/technical/emc/emf-exposure/

In effect, you are working out the EMF Exclusion Zone for your station. No member of the family, or the general public, should be allowed within that zone, while you are transmitting! You need to keep a written record of the assessments that you carry out.

The rules apply to any transmitter operating with more than 10 W EIRP, which is the same as 6.1 W ERP. Therefore you must do an assessment as your permitted power could be more than 6 W ERP, taking into account the gain of your antenna. Record your results for all your radios. Your 5 W handheld will be exempt in normal use but if you add a Yagi you would need to carry out an assessment.

Operating

In this chapter we will learn how to operate a radio, learn the phonetic alphabet, understand the RST system and some Q codes.

You can find the phonetic alphabet here:
https://www.sarcnet.org/international-radio-alphabet.html
The RST system:
https://www.sarcnet.org/amateur-radio-rst-codes.html
And Q codes:
https://www.sarcnet.org/amateur-radio-q-codes.html

VHF
If you want to find out if any of your friends are listening on the radio, you can make a call on the calling channel. On 2 m, it is 145.500 MHz. If anyone replies, you should ask them to move to another frequency, first checking it is not in use. This allows the calling frequency to be used by someone else.
https://www.sarcnet.org/amateur-radio-operating-procedures.html
The 'centre of activity' is where you find initial contacts, such as using SSB to call CQ on or around 144.300 MHz.

There is plenty of advice on operating from the RSGB website https://rsgb.org/main/operating/band-plans/vhf-uhf/144 MHz-band/
Essex ham have some useful hints https://www.essexham.co.uk/operating

Activity 9.1 Demonstrate the ability to make a contact using FM simplex.

Repeaters
Repeaters extend the range of your signal by receiving it and re-broadcasting it. A repeater is waiting for your tone to switch it on. This tone is called a CTCSS tone, which stands for Continuous Tone-Coded Squelch System. When you press the transmit button, the radio transmits a sub-audible tone, which you cannot hear, to activate the repeater. For example, for our local repeater in Margate, it is 103.5 Hz. So as not to activate several repeaters, each one has a specific CTCSS tone.

A repeater receives your signal on one frequency and retransmits it on a different frequency, which is duplex operation https://www.hamradioschool.com/post/simplex-duplex-offset-and-split There is a frequency offset. It would be a bit silly if the repeater transmitted your signal on the same frequency as it would come straight back at you, causing feedback! When programming your handheld radio, you therefore need to enter the repeater frequency and the offset frequency, bearing in mind it can be positive or negative. How do you find out this information? The RSGB call book has details for all the repeaters in the UK. https://rsgb.org/main/operating/beacons-and-repeaters/

There is a time out facility, meaning that the repeater will cease operating after a certain time. Leave a break after you have spoken, as it allows the timer on the repeater to reset. It will also allow other stations to call in.
You can only operate duplex on a repeater, never simplex.
You can find out more about using repeaters in this article from RadCom

https://ukrepeater.net/doc_files/getting_started.pdf

Activity 9.2 Use the local repeater to make a contact

HF

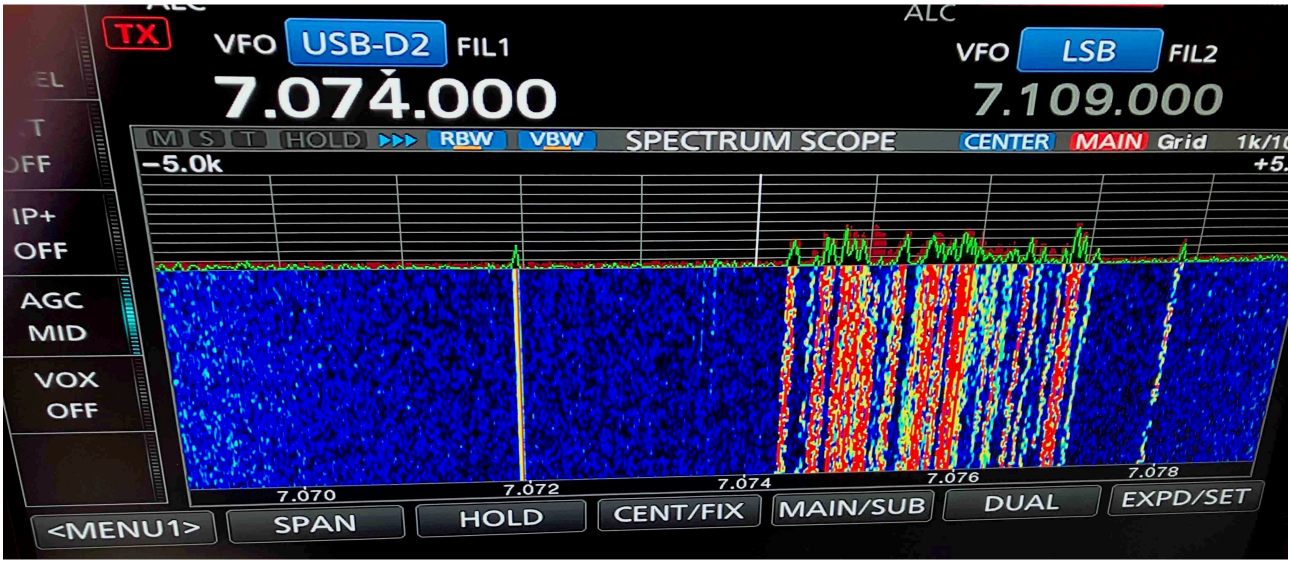
There is no set calling channel for telephony on the HF bands. You should listen before making any contact, as there may be a conversation, and the other operator is out of your range. You must ask if your chosen frequency is free.

You should be using the supplied microphone for the transmitter. If you are using a different microphone, the PTT line must be operated correctly and you should check that the audio signal levels are correct too.

Activity 9.3 Demonstrate the ability to make a contact using SSB.

Computer Digital Modes

You can send digital voice, DV, signals as well as digital data, DD, such as images. Digital Radios using the Digital Mobile Radio DMR mode are becoming increasingly popular. The STEAMettes used DMR to speak to pupils at the Estes Park Middle School in Colorado. The girls were sitting indoors in the warm on the handheld radio, while the pupils in the US had to be outside in the cold, in order to pick up their repeater!
Be aware that there is a variety of modes, which are not all compatible. Also, you need the appropriate radio equipment for each mode. D-star does not work on all radios, for example. Some repeaters, such as Folkestone GB3FK, have two modes, FM and Fusion Digital Mode, which does not require a CTCSS tone.
FT8 is a digital mode that occupies very little bandwidth as can be seen from this waterfall, where each stripe is a station.

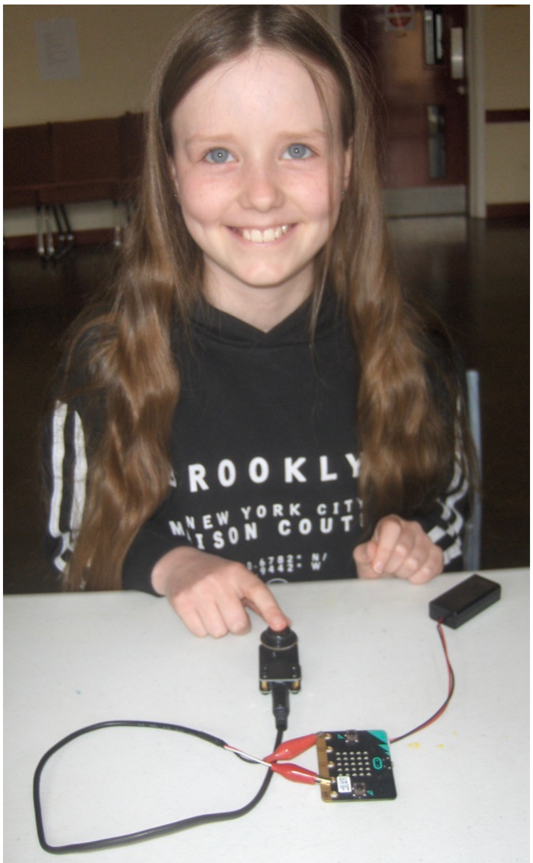


Another problem that could arise is that if you borrow a digital radio, it may be pre-programmed for another user's call sign.

Activity 9.4 Demonstrate the ability to make a contact using a mode other than telephony.

Morse Code
The STEAMettes learnt Morse Code with the help of the Long Island CW Club, https://longislandcwclub.org. They built a Snail Morse key which is easy to make (https://rsgb.services/public/publications/snail-morse-key-kit/the_snail_practice_morse_key.pdf)

Also they made their own proper Morse key from a kit by PhoenixKitsonline (https://www.phoenixkitsonline.co.uk/ourshop/prod_7540104-The-NanoKey.html)



The girls even sent Morse using their BBC Micro:bits! They gave a presentation on 'Morse Texting' to the QSOToday conference, which you can see here: https://www.youtube.com/watch?v=PoIgWJeXGwk

Activity 9.5 Demonstrate the ability to send correctly by hand, and to receive correctly by ear, text in Morse Code.

Satellites

Why not try making a QSO via a passing satellite?! You will need to know the passes of amateur radio satellites which you can find here:
https://www.heavens-above.com
The satellite will have allocated frequencies for the uplink, where you transmit, and downlink, the frequency for the satellite. Satellite frequencies cannot be used for terrestrial operation on the ground.
You can always try the International Space Station! https://www.ariss.org/contact-the-iss.html?fbclid=IwAR2MMa21WVvOY27hksRDTTpaAoAEse4ITW0rNNvo4Blci5iR9XDxQOyjVis

Keeping a log

In the chapter on 'Electromagnetic Compatibility', we will see the importance of keeping a log of your contacts. You should record the date and time in UTC, so that there is no confusion with time zones. UTC stands for Universal Coordinated Time and is basically Greenwich Mean Time, GMT. Also, you need the mode you are using, not necessarily the frequency and most important of all, the call sign of the station you have contacted. This information is needed to confirm the contact for a QSL card or electronic version. Also contests will require this information too.

Finally, remember you cannot transmit music, make offensive or threatening remarks. If you do hear such language, do not engage with the person, just move on.
You will make lots of friends around the world. There is a code of ethics for amateur radio, available here, which is worth reading.
https://www.iaru-r1.org/wp-content/uploads/2021/01/Eth-operating-IARU-ENGLISH-version3-2010-amended-2021.pdf

Ofcom's rules

You will need to know the rules and regulations laid down by Ofcom. These are some of the documents you need to read.
Ofcom has explained the new licence rules in this document, Amateur Radio Guidance
https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/amateur/amateur_radio_licence_guidance_for_licensees.pdf

and the Amateur Radio Wireless Telegraphy Licence Conditions Booklet
https://www.ofcom.org.uk/siteassets/resources/documents/spectrum/emf/emf-amateur-licence-terms-and-conditions.pdf

and the Notice of Coordination
https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/amateur/notice-of-coordination-procedures

and the Guidance on EMF Compliance and Enforcement
https://www.ofcom.org.uk/siteassets/resources/documents/spectrum/emf/guidance-emf-compliance-enforcement.pdf

And your licence document
https://www.ofcom.org.uk/spectrum/radio-equipment/amateur-radio-info

Your Licence

When you get your Foundation Amateur Radio Licence, what does this licence permit you to do? It permits you to learn about radio communications, by using your radio equipment to transmit to and receive from other radio stations. It does not permit you to use it for business use or commercial advertising. You can't sell stuff, like on eBay.

Regional Secondary Locators RSL and optional suffixes

You can use your radio anywhere in the UK, but you must change your call sign to indicate where you are operating from. If you live in Scotland your call sign would be MM7ABC, with the Regional Secondary Locator equal to M for Scotland, but if you operate in England it is omitted to give M7ABC.
For Northern Ireland, it changes to MI7ABC.
For the Isle of Man, to MD7ABC.
For Wales, to MW7ABC.
For Jersey, to MJ7ABC.
For Guernsey, to MU7ABC.
The same is true for full licence holders, whose call sign would be MM0ABC in Scotland, changing to M0ABC in England.
Just to confuse you - intermediate licence holders in England have E added. For example, if you were in Scotland your call sign would be 2M0ABC, which would change to 2E0ABC in England.

Activity 10.1 Imagine touring the UK, changing your call sign.

The group that administers European licences is the European Conference of Postal and Telecommunication Administrations or CEPT. Unfortunately, you have to get special permission to operate a radio with your Foundation Licence in other countries as the licence is not normally recognised. However, there is nothing stopping you communicating with people in Europe and elsewhere.

Activity 10.2 Find out the prefixes for other countries.

Activity 10.3 Log on to a webSDR site to hear some real call signs.

Suffixes
You can add a suffix, but it is not compulsory. You can add /A, /P and /M.
/A, alternative, if you are at a location which has a post code, such as a friend's house,
/P, portable, if you are somewhere without a post code, such as camping in a field,
/M, mobile if you are on the move, such as in a car or walking.
So you would say 'my call sign is M7ABC stroke mobile'.

/MM, maritime mobile, which is for licence holders out at sea
You can indicate where you are by adding something helpful such as M0ABC/Beach! However Ofcom is quite strict in your use of a suffix because it becomes a 'core' call sign. You need to be aware that an inappropriate suffix would contravene the Wireless Telegraphy (Content of Transmission) Regulations, 1988 and it would become a police matter.

If you are airborne the aircraft must be registered in the United Kingdom, the Channel Islands or the Isle of Man. Also you are restricted to 500 mW EIRP in primary amateur radio bands only. (Schedule 1, page 15, Table C)
ERP is 2.15 dB less than EIRP. In terms of watts, EIRP = 1.64 ERP. Therefore the limit is 305 mW ERP. There is a discrepancy in the Ofcom guidance as it says 500 mW ERP, which is wrong! The schedule is the legal requirement.
Similarly you can operate from a ship but it is limited to ships registered in the United Kingdom, the Channel Islands or the Isle of Man, in international waters. It goes without saying that you have sought permission from the captain of the vessel or aircraft beforehand.
This sounds very tempting, to take your radio on a cruise or on a ferry across the channel. However, if your cruise is from Dover on one of Fred's ships, you will find they are registered in the Bahamas. P&O Ferries? Cyprus and the Bahamas. In those cases, you would need to get authorisation from the administration of the country of registration for the ship or aircraft, bearing in mind that some countries do not allow airborne amateur radio use.

Station Identification
You must give your call sign when you change frequency and when you change mode on the radio to identify yourself. The mode button is used to change to Frequency Modulation, Amplitude Modulation, Single Sideband, Continuous Wave (Morse Code) or a DATA mode, such as PSK, RTTY, WSPR and FT8.

Also you need to give your call sign if there is a change in supervisor, and if you change your regional locator.
When you make a CQ call you are not addressing any particular individual. This is one occasion when you make a general reception message. The main intention is to communicate with another licensee. When you are in a net of several amateurs, it is fine to say something for the general reception of the group, such as 'bye everyone!' This is allowed because you have identified yourself at the beginning of the net.

You must give your unique call sign as a means of identification. Another exception to general reception is for a Beacon or a Data Station which would automatically transmit a call sign.

<u>More rules!</u>

If you change your name, address or mailing address, you must notify Ofcom immediately.
You need to re-validate your licence every five years by logging on to the Ofcom website.
If you fail to do so, or breach your licence conditions, Ofcom can revoke your licence.

<u>No secret codes!</u>

It's OK to send Morse code, but you are not allowed to send any secret codes, 'except under very specific circumstances'.

<u>Your Radio Equipment</u>

There's nothing stopping you making your own receiver but you must ensure you do not cause interference.
Your licence will mention your radio equipment as the equipment which you use in your home. If you are visited by a UK licensed amateur friend, he or she can use your equipment. They can use your call sign, with the limitations of the Foundation Licence, or they can use their own, adding /A.
Anyone can use your radio under your supervision provided they are aware of the limitations of your licence and you are able to take back control if needed.

You can allow your radio equipment to be used by a member of a User Service, such as the Police or Emergency Services.

You have to carry out tests from time to time, to ensure that your station is not causing undue interference to other radio users.

A person authorised by Ofcom has the right to inspect your Radio Equipment. They can require you to modify it by turning down the power, for example. They can even close you down or restrict your use of it. They could require you to keep a log of your operating, if they think you are causing interference.

Your equipment is subject to Electromagnetic Field, EMF, restrictions and you need to keep a written record of assessments carried out. We will explain this in more detail in the Safety chapter.

<u>Messages</u>

You can only send messages to other amateurs.
You might arrange a 'Net' or 'Network' with your licensed friends but each person must identify themselves with their call sign.
When you make a CQ call, you are transmitting to anybody who may be listening. That is the only time you are allowed to transmit generally. You can't transmit on the radio and say 'hey, everybody, I passed my exam!'
When you make a CQ call you are not addressing any particular individual. This is one occasion when you make a general reception message. The main intention is to communicate with another licensee. When you are in a net of several amateurs, it is fine to say something for the general reception of the group, such as 'bye everyone!' This is allowed because you have identified yourself at the beginning of the net.
You must give your unique call sign as a means of identification.

Permitted power levels
At Foundation level, you are permitted 25 W 13.98 dBW PEP in the primary bands.
If you operate above 10 W EIRP (6.1 W ERP) you need to have assessed your EMF compliance.

It's interesting to see why at Foundation the power is quoted as 25 W 13.98 dBW PEP.
The conversion is 10 log(25/1) = 10 x 1.39794 = 14 dBW to two significant figures. If you want to quote to four significant figures, you need to be consistent. Working backwards, the power is 25.00 W. Embarrassing!

Unattended and remote control operation
Amateur Radio Direction Finding competitions are great fun, and they enable non-licensed persons to use amateur radio equipment. You are now allowed to hide a transmitter, a beacon, which will transmit its call sign every so often, for the competitors to find. The power of the transmitter must be no greater than 5 W ERP.
You need to ensure that the Radio Beacon does not cause undue interference. Ofcom may request evidence that you have done this. If Ofcom wants you to close down the Radio Beacon Station, you have two hours in which to do so.
You cannot operate a Radio Beacons at a greater power.
You can find out about events and how to borrow equipment here https://rsgb.org/main/about-us/committees/ardf-committee/

You can remotely control your radio. Why would you want to do that? There might be a lot of RF noise in your area or you might live in a confined spot. However, the Remote Control link must be by radio in an amateur band, limited to 500 mW pep e.r.p. maximum transmit power. It should be above 30 MHz. It must be failsafe, to avoid unintended transmissions. Also, it must be adequately secure, to ensure the station remains compliant with the terms of the Licence. Your remote control operation is for your use only, and not for general use by other amateurs. Also the Licence Number must be displayed on or next to the radio equipment.

Gateway and Data Station operation
Your radio equipment can be used as a Gateway or a Data Station but not as a repeater. It may be operated by other radio amateurs without supervision. However the same restrictions apply as for Radio Beacons.

Electromagnetic Compatibility

When you speak on a radio, you are sending out electromagnetic radio energy into the environment. Just like unwanted light pollution, radio energy can get into places it shouldn't. Similarly, your radio needs to be able to work properly in today's environment with radio energy everywhere.

Electromagnetic Compatibility ensures both - that the radio doesn't emit electromagnetic interference, and that it works as intended in the presence of electromagnetic phenomena.

EMC performance can mean the difference between life and death! Planes and cars can be affected. The navigation system on a plane can be affected by radio emissions from faulty laptops and other electronic devices. Electromagnetic Interference can even fry integrated circuits!

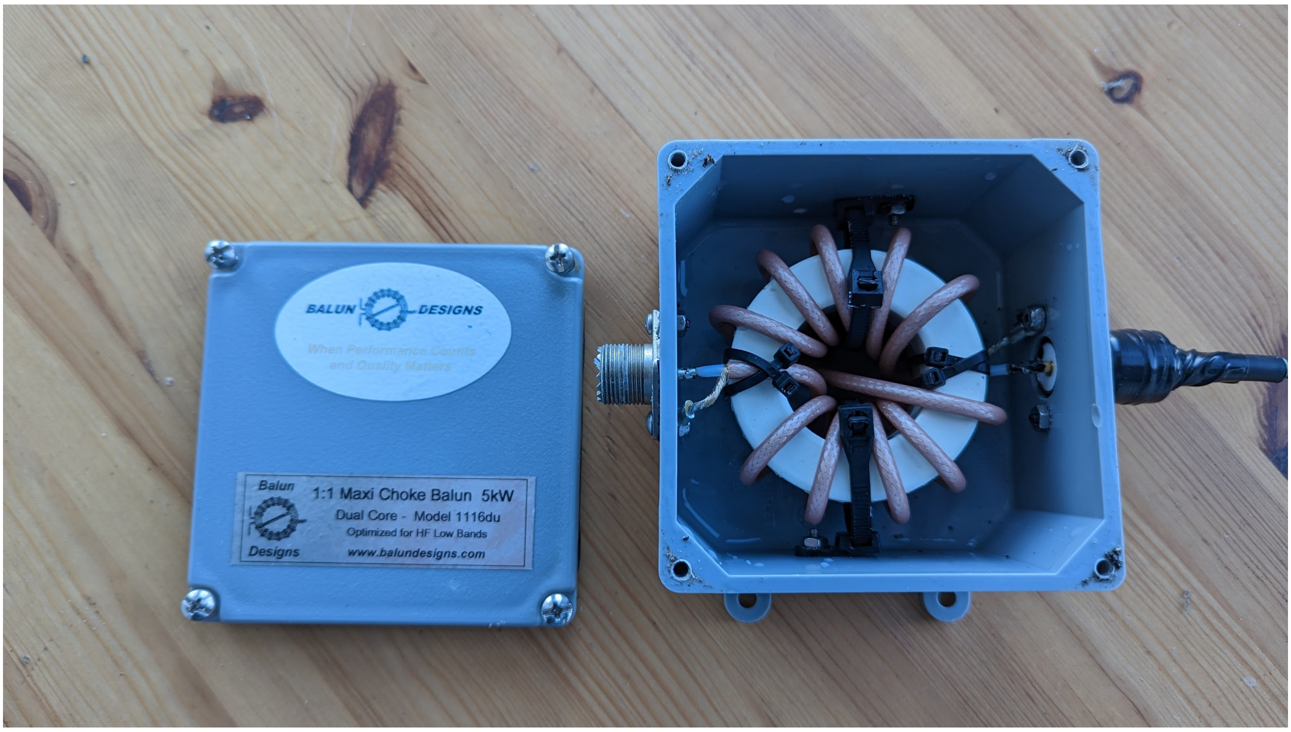
Don't be a nuisance!
What could possibly go wrong? You are happily transmitting from your shack. However, your electromagnetic radio energy can be picked up by any metal surface or wire, by electromagnetic induction. We hope that electronic devices we have bought, possibly on eBay, have been tested to be immune from electromagnetic waves, but we cannot be certain. The mains wiring around your house, the wires in a radio, TV or telephone can all potentially pick up your signals.
Of course, you are sending signals from your antenna. Are they being received by nearby telephone wires in the street? Are they being received by the down-lead of the TV antenna? AM and SSB modes are the most likely to cause problems, while FM and some of the HF data modes are least likely to do so.
Your rig could be leaking RF energy along the transmitter's mains cable, which would then enter electronic devices in your home. VHF and UHF transmissions can be picked up directly by the circuits inside your home equipment.

When you operate on a particular frequency, you need to be sure that you are not transmitting on other frequencies in the electromagnetic spectrum.

Activity 11.1 Be a nuisance!

What to do about it
The obvious answer is to reduce the amount of radiant energy, that is, the electric field strength of your signal. Turn down the power. The more power you use, the more likely you will cause interference.
Have your antenna as high and away from houses as possible. You could move your antenna to the far end of your garden, away from your neighbours. You could mount your antenna high up on a pole.

To prevent RF signals entering the power cable, you could add suitable external chokes or filters. A choke is a ferrite ring with windings, so that RF oscillations are filtered out.



A choke

Any affected device could also have a filter fitted on the leads, making sure it is fitted as close to the affected device as possible. It is important to have a separate RF earth as well as the mains earth. This is simply a copper rod in the ground. This allows any RF currents to a path to ground, and not into the mains earth system. However, you may still need to add filters to the RF and mains earths.

Are you using the best antenna? A balanced horizontal HF antenna would be preferable, whereas end-fed antennas can present problems.
Think about what mode you are using, as AM and SSB are most likely to cause problems.

You should test that your radio equipment is not causing any problems, by transmitting into a dummy load instead of the antenna. As we saw in the chapter on Setting Up, this is a screened resistor which absorbs the power of your signal. You can then check for any leakage of RF from the power supply lead and other cables.

At the end of the day, you can call upon help and information from the RSGB's dedicated EMC team. Ask experienced local amateur radio club members for help.

<u>Who did that?</u>
What should you do about unwanted signals entering your equipment? Where are they likely to be coming from? How immune is your radio from electrical interference? Does it meet the EMC regulations set by the European EMC Directive?

The most likely sources of interference on your radio are devices that have switching circuits. Some power supplies, called switched mode power supplies, have switching circuits inside. While some meet regulation EMC standards, many don't!
Many hams suffer from a lot of RF noise in their environment, so much so, that they find it impossible to operate.

What to do about it

If you are receiving interference you could use clip-on ferrite rings attached to mains leads. You can use a balanced antenna or even a directional antenna, pointing away from the source of the noise.

Activity 11.2 Cause interference!

Activity 11.3 Search for culprits

Disgruntled neighbours

You definitely do not want to annoy your neighbours! If you do get a complaint from a neighbour that you are causing interference, you will need to find out the cause of the problem, and perhaps help them by fitting filters on the affected device. You can get information leaflets from the RSGB, and advice is available from the RSGB EMC Committee. As a last resort, Ofcom will help with the matter.

If you think you have not caused the problem, you will need to show them your log and compare it to the times when they experienced interference. You need to be co-operative at all times. If your neighbour is not satisfied with your efforts, both sides can call upon the RSGB or Ofcom.

Fitting a mobile radio in a car

One day you will study for your driving licence. When you get your car, you might want a professional installer to fit a mobile radio. You will need to ensure that the installation is compatible with the vehicles electrical and management systems, and does not affect the safety of the car. When you come to test it, the car must be stationary with its electronic systems operating. Only then can you test it on the road. You might find that the car's ignition and battery charging systems cause interference on your radio. Also, you should inform your insurance company.

Safety

Amateur radio is a comparatively safe hobby, but you must be aware of any hazards from electricity, using tools and operating with radio frequency energy. While a lot of advice is common sense, you must treat radio transmitters and receivers with respect.

Electricity

High voltages and currents

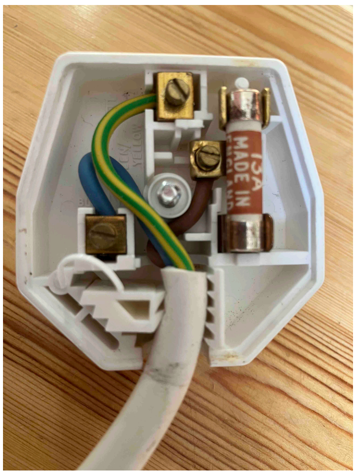
You don't have to actually touch a high voltage to be electrocuted; simply being close to the source can kill. Where would you come across such a high voltage? The source can be inside a transmitter, so don't remove the cover. Capacitors can retain their voltage even when the device is switched off.

Activity 12.1 Charging and discharging a capacitor

A low voltage source, such as a battery, can produce a high current if it is short circuited, carrying the risk of overheating and a fire.
When charging a battery you must follow the manufacturer's instructions. Lithium batteries can cause a fire and an explosion, if they are not treated properly. There are many different types of battery, each requiring different charge techniques and you must use the correct type of charger.

Earthing

Just like any electrical device, a mains radio will have an earth wire and a fuse. Obviously, the earth wire must not be removed. Note you can get electrocuted by contacting either the live or neutral wires.

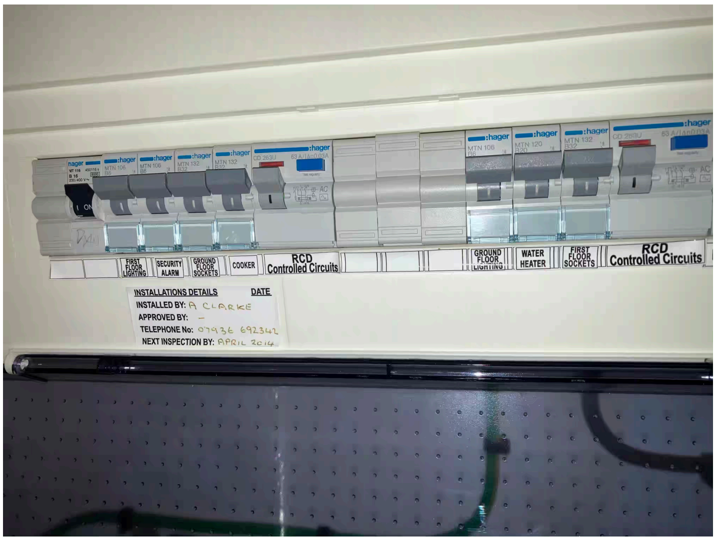


Activity 12.2 Wiring a plug

The earth wire protects you from an electric shock. If there is a fault inside the radio, the metal casing could be live. If you touch the casing, the electricity will go through you. The electricity will flow to earth, causing the fuse to blow. The thin wire inside melts and breaks the circuit. The cause of the blown fuse must be investigated.

Activity 12.3 Blowing a fuse

A circuit breaker will be fitted in your mains unit. The RCBO stands for Residual Current Circuit Breaker with Over-current protection. It detects currents as small as 30 mA going to earth, unlike a fuse which requires several amperes to blow.



Your set-up should have a master switch, which should be clearly marked and made known to everyone in your home or club.
In the event of an accident or fire involving electricity, the first thing you must do is to switch off the power. Don't touch the casualty until the power has been switched off.

Using tools
When using a drill, wear eye protection to prevent eye damage from small metal particles, called swarf.
All power tools are hazardous. Handle with care and take appropriate precautions.
Wear eye protection when soldering to prevent solder or flux entering the eyes.
Use a soldering stand to avoid skin contact with the hot part of the iron.
Make sure there is adequate ventilation to avoid inhalation of fumes, which can cause breathing problems, particularly to asthmatics.

Working at height
Have someone to help you when erecting an antenna.
At least one adult needs to be present to call for help.
Use a ladder at the correct angle with the 4:1 ratio, 4 m up a wall, 1m away on the ground.
Make sure the ladder is secured at the base to prevent slipping.
Don't over reach! Move the ladder.
A tool belt should be worn to prevent falling tools.
Wear a hard hat on the ladder or when helping on the ground.

Working with RF

There are health and safety issues to consider when operating. As we have seen in the Licence Schedule you are required to do a risk assessment. The main health effect of exposure to radio frequency electromagnetic fields is heating of body tissue. Your eyes too are particularly susceptible to damage. The UK Health Security Agency gives guidance (https://www.gov.uk/government/publications/5g-technologies-radio-waves-and-health/5g-technologies-radio-waves-and-health) as does the the International Commission on Non-Ionising Radiation Protection, ICNIRP, https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html
Therefore, you should be aware and not stand close to, or in front of, high gain antennas. Also, you need to know what a microwave frequency waveguide looks like - do a Google search now - as it would be somewhat unwise to look down it!
Antenna elements, and any other conductors carrying RF, should not be touched while you are transmitting. Therefore, you should mount your antenna in a position where unsuspecting people will not come into contact with them. Handheld radios are fine, just like your mobile phone.

Lightning
High antennas may need special protection against lightning.
The local authority building department may be able to offer advice.
You might need planning permission to erect a large antenna.

Working mobile and portable
Be careful to avoid siting your antenna near overhead cables.
Guy ropes, masts and antennas must be suitably located, and secured so that there is no danger to the public.
Overhead lines can kill. Be careful with antennas and ladders.
Watch out for trailing cables and any other trip hazards. Also check the insulation is not frayed.
Make sure you have a RCBO at the power sources and the correct fuses.
Damp ground will increase the effects of electric shock.
Be careful when wearing headphones, as excessive volume can damage your hearing.
In your own shack, or operating station, you need to make visitors aware of any dangers, and point out the master switch.
Risk assessments are the responsibility of everyone involved! Ask if you are not sure, such as at a special event station. You need to warn others, and report the matter to an appropriate person.

Activities

KIT REQUIRED

A bowl of water and pencil
A skipping rope, a slinky
Balloon for static experiments
1.5 volt cell and holder, 3 volt battery and battery holder, two LEDs, two resistors 550 ohms or any suitable limiting resistors, croc to croc connectors.
Multimeter.
A piece of ceramic.
Small motor
Two PMR446 radios
Kitchen aluminium foil
a guitar or a signal generator and loudspeaker or a tuning fork
A one Farad capacitor
A 3 pin plug and 3 core cable.
A variety of connectors
Of course, access to a radio station.

Radio waves

Activity 1.1 Making Waves

Apparatus

A bowl of water, a skipping rope, a slinky.

Get a large bowl such as for washing up and add water to a depth of about 2cm.
Using a pencil or pen, hit the surface of the water in the centre of the bowl.
A circular wave is produced. Waves are produced by oscillations. (The word ‘undulation’ is an old fashioned word, used by James Clerk Maxwell in his studies of waves around 1860!)
Now move the pencil up and down about once a second, and observe the distance between the waves, which we call the wavelength. The frequency, measured in Hertz, Hz, is the number of oscillations every second.
Repeat twice as fast, doubling the frequency. What happens to the wavelength?
As the frequency of the oscillation increases, so the wavelength decreases.

How can we make the waves travel faster through the water?
By doing the oscillation even faster? No! The speed stays the same.
The only way is to change the depth of the water. Note the waves for 2 cm and then repeat for 4 cm or deeper, and compare.

Using a skipping rope or a long length of rope, make a sideways motion to send waves down the rope.
Again, see the effect on the wavelength of the waves as you increase the frequency.
As the frequency increases, the wavelength decreases.
How do we make the waves go faster?
This time we increase the tension in the rope by stretching it more. The speed of the wave increases.
Investigate waves with a slinky if you have one.

Have a look at these simulations:
Introduction to waves
https://phet.colorado.edu/en/simulation/waves-intro

Waves on a string
https://phet.colorado.edu/en/simulation/wave-on-a-string

Activity 1.2 Using a source of sound
Apparatus
a guitar, a signal generator and loudspeaker, tuning fork

If you have a guitar or violin, you can show that shortening the string, and the therefore the wavelength, will increase the frequency.
To change the speed of the wave in the string, you have to increase the tension.

Turn on the signal generator and loudspeaker. Increase the frequency to find the highest frequency you can hear.
Take the frequency down to low frequencies, so that you can see the movement of the loudspeaker diaphragm. It helps to put some rice grains on it. It moves in and out, pushing and pulling the air.
You can't see the movement of the air, but as you increase the frequency of the sound, the wavelength of the waves decreases.

Investigate the tuning fork. Hit the fork gently on a surface without damaging the surface! The prongs push and pull the air as they vibrate. Put the stem of the fork on a table to make more air vibrate. Get a cup of water and gently place the vibrating prongs in the water!

Activity 1.3 Investigating electric fields
Rub an inflated balloon on your jumper. It is now electrically charged with lots of electrons. See how an electric field can attract, bring the balloon close to some tiny bits of paper. They will jump up to the balloon! There are more electric field activities in Activity 2.1.

Activity 1.4 Investigating magnetic fields
Using a magnet, see how far its magnetic field extends by gradually bringing a paper clip up close to it. Find out what materials are magnetic.

Activity 1.5 Investigate the Electromagnetic Spectrum

A radio wave consists of oscillations of an electric field and a magnetic field.
https://www.walter-fendt.de/html5/phen/electromagneticwave_en.htm
Of course the simulation is slowed down a lot! The frequency of the local radio station Academy FM is 107.8 MHz which means the waves oscillate at 107 million times a second!
https://upload.wikimedia.org/wikipedia/commons/4/4c/Electromagneticwave3D.gif
Radio waves vary in frequency from below 30 kHz to beyond 3000 MHz.

A radio wave is produced by an oscillator.
We can make electrons oscillate in an electrical circuit called an oscillator. You can build a sort of oscillator using two switching transistors to make two LEDs flash on and off. We will use a radio transmitter which contains an oscillator in the next activity. In this activity we look at other waves produced by oscillating electrons. The faster the movement, the higher the frequency of the waves.

https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves

This website explains which waves reach earth.
https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html

The energy of the waves or photons in the electromagnetic spectrum varies. Have a look at the diagram in this website, ignoring the mathematics.
https://courses.lumenlearning.com/physics/chapter/29-3-photon-energies-and-the-electromagnetic-spectrum/

Strike a match, or switch on an old fashioned torch, which has light bulb that gets white hot inside. It is sending out all the colours of the spectrum which combine to give white light.

Activity 1.6 Try calculations of f and λ
Practise using the graph provided or the formula. Start with a known wavelength and then find the frequency. Similarly, start with a frequency and calculate the wavelength.

Activity 1.7 Using a PMR446
You will need two handheld radios PMR446 and kitchen foil.

Investigation into the range of the radios
Set both radios to channel 1 which is often called the Children's channel. It operates on a frequency of 446.00625 MHz. Note: other people can hear your conversation!
See how far apart you can go before you lose the signal. If you operate on a beach it could be as much as a kilometre. Do you lose sight of the other radio visually? Repeat the experiment when it is raining to see if helps or hinders the range. What happens when you cover the radio with foil?

Circuits

Activity 2.1 Investigating electric charge.
Apparatus

Balloon, bits of paper, woollen jumper, access to a tap.

Method

Rub a balloon on a woollen jumper, and bring it close to some tiny bits of paper. If you don't have a woollen jumper, your cat's fur will do! The bits of paper will jump up to the balloon! Polystyrene bits work well too. The balloon can also stick to the wall. Bring the balloon close to a slow running tap without touching the water. The stream will be attracted.

Touch the balloon to discharge it, and see that the attraction will not work now. The air needs to be dry for these experiments to work properly.

Conclusions

The friction of rubbing causes electrons, which carry negative electric charge, to go from the jumper on to the balloon. This is static electricity, where the charge will stay there and not move because rubber is an insulator. If you touch the balloon, the charge will go through your body to the ground or earth. If you could insulate yourself from the ground, the electrons would go on to your body and stay there. This is what happens with the Van de Graaff generator, making your hair stand on end!

For more fun static electricity experiments search for Bruce Yeany on YouTube.

Electrons repel other electrons, as they have the same negative charge. Here is a fun activity, 'Electric field of dreams', to help you understand
https://phet.colorado.edu/sims/cheerpj/efield/latest/efield.html?simulation=efield

Keep adding electrons and see how they never touch! The arrows represent the electric field around the electron.

There are particles with a positive charge, which balance out the negative charge. When you rub the balloon on your jumper, the electrons on the jumper go on to the balloon. This simulation, 'balloons and static electricity' shows this
https://phet.colorado.edu/en/simulation/balloons-and-static-electricity
Rub the balloon on the jumper and bring it to the wall.

Static electricity can sometimes give you a shock, when you have walked on a nylon carpet and you go to touch something metal. Make John Travolta's shoes walk on the carpet and bring his hand close to the handle.
https://phet.colorado.edu/en/simulation/john-travoltage

Finally, are you ready to play electric field hockey?
https://phet.colorado.edu/sims/cheerpj/electric-hockey/latest/electric-hockey.html?simulation=electric-hockey

Activity 2.2 Making a circuit
Apparatus

3 volt Battery and battery holder, LED, limiting resistor 550 ohms or any suitable value, croc to croc connectors, multimeter, toy motor.

Method

Current electricity is when electrons flow through a conductor. They need to be given a push or energy, which can be provided by a battery or even yourself, with a hand dynamo.

Connect the red positive terminal of the battery to the longer wire of the LED. The shorter wire of the LED goes to either end of the resistor. The other end of the resistor goes back to the negative of the battery.

Conclusion

The source of the electrical energy in the battery is chemical energy. The energy is converted into heat in the resistor and light in the LED.

The source of electrical energy does not have to be a battery, it could be you. Connect the motor to the multimeter with it set to measure volts. Turn the spindle quickly and note the reading. Turn it in the opposite direction and it will reverse polarity.

Conclusion

The motor is acting as a dynamo when it is turned. Your chemical energy in your muscles is converted into electrical energy.

<u>Activity 2.3</u> Investigating polarity

Apparatus

3 volt Battery and battery holder, LED, limiting resistor 550 ohms, croc to croc connectors.

Method

Reverse the LED in task 2 and it will not come on. Put the LED back the correct way to check that it has not been damaged in this case.

Conclusion

LED means light emitting diode, and diodes allow electricity to flow in one direction only. They are useful to change alternating current into direct current.

<u>Activity 2.4</u> Conductors and Insulators

Apparatus

3 volt Battery and battery holder, LED, limiting resistor 550 ohms, croc to croc connectors, coin, ceramic.

Method

Make a circuit for the LED and resistor as in task 2. Now break the circuit anywhere and try different materials such as the piece of ceramic to see if they conduct. The test is not very sensitive because if you put yourself in the circuit the LED goes off, but you are a conductor!

Results

Conductors:

Insulators:

Conclusions

A conductor, such as copper, has electrons moving freely inside it. In an insulator, the electrons are attached firmly to the atoms.

Activity 2.5 Electric Current

Apparatus

3 volt Battery and battery holder, resistor 550 ohms, LED, croc to croc connectors, multimeter.

Method

We set up the circuit to light the LED, but include the multimeter reading DC current so that it becomes an ammeter. The positive of the multimeter should be connected to the positive of the battery. Start with the dial on 2 A and then go to smaller values.

Results

The current is in milliamperes or mA.

Current in the circuit =

Conclusions

The current shows the amount of charge flowing every second. For a current of 1 mA there are about 6 000 000 000 000 000 electrons flowing through the LED every second!

Activity 2.6 Potential Difference

Apparatus

1.5 volt cell and holder, 3 volt battery and battery holder, LED, limiting resistor 550 ohm, croc to croc connectors.

Method

Connect the circuit with the 3 volt battery to make the LED light. Replace the battery with the 1.5 volt cell. The LED is not bright at all. Current is flowing but there is not enough energy.

Conclusion

The voltage tells you how much energy is available to the electrons, to the charge flowing. We use the word potential because it means what is available. For example a girl might have the potential to be a great footballer.

Activity 2.7 Resistance

Apparatus

3 volt Battery and battery holder, resistor 550 ohms, LED, croc to croc connectors, multimeter.

Method

To find the resistance we need the potential difference or voltage across the component and the current flowing through it. Connect as in task 6 to measure the current through the LED. Remove the multimeter and change its setting to DC volts. Connect it in parallel with the resistor and measure the voltage. When working out the resistance, the current in mA needs to be converted to amperes. For example, if the current is 5 mA, this is 0.005 A.

Results

Current =

Voltage =

Resistance = voltage/ current = ohms

Conclusion

We can read the resistance of the resistor from the colour bands. Green, green, brown translates to 5, 5, and one zero. There is a tolerance which means the resistance could be 5% greater or lower than 550. Is our measured value within that tolerance?

Activity 2.8 Ohm’s Law

Apparatus

1.5 cell and holder, 3 volt battery and battery holder, resistor 550 ohms, croc to croc connectors, multimeter.

Method

Make a circuit with the 1.5 volt cell, resistor and multimeter set to DC current. Note the current. Replace the 1.5 volt cell with the 3 volt battery and note the new current.

Results

Voltage = 1.5 v Current =

Voltage = 3 v Current =

Conclusion

We have doubled the voltage and we find the current has doubled too. George Ohm noticed this pattern and gave it his law! Ohm’s law states that the current is directly proportional to the potential difference. What doesn’t change is the resistance of the resistor, provided the temperature stays the same. If we did the same experiment with the LED, we would find it does not obey the law!

Activity 2.9 Series and Parallel Circuits

Apparatus

3 volt Battery and battery holder, two LEDs, two resistors 550 ohms, croc to croc connectors, multimeter.

Method

Our first circuit is with just one resistor and a multimeter, set to DC current. Note the current. We have two ways of adding a second resistor. Hold the second resistor parallel to the first one and note the new current. To add the second resistor in series we need to break the circuit. Note the reduced current now.

Results

One Resistor, current =
Resistors parallel, current =
Resistors in series, current =

All the connections in our home are parallel and to see why we will use the LED. Make a circuit with just one LED and limiting resistor. Using the croc to croc connectors, add a second LED in parallel, with its own limiting resistor. The LEDs are both bright. You can disconnect one and the other stays on, so they are independent. Now put the LEDs in series with just one resistor for both of them. Do they light or are they very dim?

Conclusion

Adding the second resistor parallel to the first one provides another pathway for the current, so more current flows. It's like having a dual carriageway instead of a single lane. Effectively there is less resistance in the circuit than before! If the resistors are identical the current is double. Adding the second resistor in series doubles the resistance, so the current is halved.

In our homes, with parallel connections, switching on a device means more current comes from the supply. The only situation where we would find a series connection is in some Christmas tree lights, where one bulb blows they all go out.

<u>Activity 2.10</u> Electrical Power

Apparatus

3 volt Battery and battery holder, LED, resistor 550 ohms, croc to croc connectors, multimeter.

Method

We light the LED and measure the current. To make our measurements of power really accurate we can measure the voltage with the multimeter too. Remove the multimeter and change the settings to DC volts as well as the sockets for V. Place the multimeter, which is now acting as a voltmeter, parallel to the resistor. This measures the potential difference or voltage across it.

To measure the power of the LED we can connect the multimeter across the LED.

Results

Don't forget to change the current to amperes!

Current =
voltage across R =
Therefore Power in R = current x voltage =

voltage across LED =
Therefore power of LED =

You can express your answer in watts or milliwatts.

Conclusion

The chemical energy in the battery is converted into electrical energy in the circuit. For the resistor that electrical energy is converted into heat energy while for the LED it is converted to mostly light. The power tells you how much energy is being converted every second.

<u>Activity 2.11</u> Look at the power ratings of devices

Find the rating plates of various devices in your home. Which are the most powerful and energy hungry?

Modulation

Activity 3.1 Observing AM on an SDR waterfall
A good introduction to understanding SDR waterfalls is given by David Casier
https://www.youtube.com/watch?v=91XtLZNIyK8

Go to the WebSDR site in Enschede, the Netherlands, http://websdr.ewi.utwente.nl:8901
Click on SSB and see how the waterfall changes with the person's voice.

Activity 3.2 Speaking in an AM voice!
Speak at a monotone but vary your loudness.

Activity 3.3 Observing FM on an SDR waterfall
As for activity 1, note the waterfall for FM stations.

Activity 3.4 Speaking in an FM voice!
Keep the loudness of your voice unchanged, but change the frequency from high to low pitch.

Activity 3.5 Observing CW on an SDR waterfall
As for activity 1, note the waterfall for Morse code.

Activity 3.6 Speaking in Morse code!
You will need a copy of the Morse code. You can only speak one letter at a time. So 'hi' would be di di di dit pause di dit.

Activity 3.7 Sample a wave exercise
Look at the exercise here (https://cs.wellesley.edu/~cs110/reading/sound-files/#a2d) 'Converting Analog to Digital'.

Transmitters and Receivers

Activity 4.1 identify the controls on a transmitter
The Icom-7300 is a great radio to operate. With the help of an instructor or the User Manual, see how to change bands and how to choose a station to listen to.

Activity 4.2 identify the controls of a receiver
Start with a band such as 40 m. Tune in to the CW end and listen to some Morse code. Move around the band until you find a station. Change bands and repeat.

Activity 4.3 Look at the waterfall of an SDR
Move along a particular band and match what you hear with what you see on the waterfall. A bright waterfall will indicate a strong signal.

Antennas and Feeders

Activity 5.1 investigate the effect of changing orientation of antennas
Using two PMR446 radios, see how much difference it makes if the two antennas are at 90 degrees to each other.

Activity 5.2 make a half-wave dipole
All you need are two lengths of wire! If you are making a dipole for 433 MHz, calculate how long they should be. To detect a signal you can use a diode and a moving coil meter or an LED.

Activity 5.3 make a Yagi antenna.
https://www.youtube.com/watch?v=ff5sZUkdLac

Activity 5.4 Connect a PL259 to a cable
There are lots of YouTube videos to show you how, such as https://www.youtube.com/watch?v=ERRfexK9w1E

Activity 5.5 identify connectors
Given a collection of different connectors, identify each one.

Setting up a radio station

Activity 6.1 show reflection if there is no matching
Two slinkies of different material, such as one plastic and one steel.
Connect them in series, with pieces of wire, so you have one long slinky. Send a pulse along the plastic slinky. The wave will reflect with little energy continuing along the steel one. Now send the pulse from the steel one. Compare the result.

Activity 6.2 Standing waves with a slinky or rope
Hold one end of a slinky still. Send continuous waves from the other end at the right frequency to set up standing waves.

Activity 6.3 Plot a graph of SWR against length
Connect an SWR meter to a telescopic antenna. Measure the SWR as you go through resonance. An antenna analyser displaying SWR may be used. Adjust the physical length of the antenna for the lowest SWR.

Activity 6.4 Correctly connect up a station.
To include as a minimum, mains PSU, amateur radio transmitter/receiver or transceiver, microphone or PC interface, external item (e.g. VSWR/Power meter, AMU, filter), feeder

and antenna. Other accessories can be included as appropriate to local circumstances (e.g. external speaker). Match the antenna system for lowest SWR in at least two bands using a (manual) antenna matching unit.

Propagation

Activity 7.1 Finding the range of a PMR446 radio
Using two PMR446 radios, see how far apart you need to go before losing a signal.

Activity 7.2 Reflection experiments
Tune a transistor radio to a broadcasting station. Cover the radio in kitchen aluminium foil. Can you still receive the station?

Activity 7.3 Testing a brick wall for absorption

Using two PMR446s, have each one on either side of a brick wall, such as inside and outside a house. Can you still receive a signal?
See if buildings can reflect your signal. You will need a Yagi antenna to direct your signal towards a wall. Can your friend still receive the signal by reflection only?

Activity 7.4 Under supervision, use a handheld radio to investigate VHF Propagation.
Select a free simplex frequency on 70 cm. Have a QSO under supervision.
Now communicate using Duplex, where transmit and receive are on different frequencies. Select the frequency for your local repeater, having entered the CTCSS tone and offset frequency. Have a QSO under supervision.

Activity 7.5 Refraction experiments
Place a straw of pencil in a glass of water. Alternatively, point a beam of light at the water from a laser, or a phone, and look at its path.

Activity 7.6 Under supervision, have a QSO using HF
Your instructor will find a suitable frequency. Put out a CQ, having first asked if the frequency is free. Your voice will have travelled up to the ionosphere and back!

Activity 7.7 Under supervision, communicate with a satellite
Decide on a suitable satellite, such as one recommended by AMSAT (https://www.amsat.org/two-way-satellites/). Set your radio to the allocated uplink frequency and listen for any contacts on the downlink frequency, remembering to limit your power.

Activity 7.8 Diffraction investigations
Stand behind a wall, while your friend transmits, making sure that there is no possibility of reflection of the signal from surfaces, only by diffraction.

You can show diffraction of light easily by making a small hole with your fingers and look at an LED. The light will be spread out.

Licence Schedule

Activity 8.1 find out what you are allowed or not allowed in the Licence Schedule.

Study the Licence Schedule and make sure you understand what it means.

Operating

Activity 9.1 Demonstrate the ability to make a contact using FM simplex.
The contact must be made on air and include as a minimum:
• setting the radio to the correct calling frequency;
• selecting the correct mode;
• correct setting of the squelch control;
• make a CQ call;
• vacate the calling frequency after establishing the initial contact;
• check if the new (working) frequency is in use;
• the two-way exchange must include call sign, signal report and location;
• ending the contact;
• recording all the details of the contact in a log.

Activity 9.2 Use the local repeater to make a contact

Activity 9.3 Demonstrate the ability to make a contact using SSB.
The contact must be made on air and include as a minimum:
• tuning the radio to the correct frequency, or section of the band;
• selecting the correct mode;
• setting the radio microphone gain to the correct level;
• check if the frequency is in use and make a CQ call;
• vacate the calling frequency if appropriate after establishing the initial contact;
• the two-way exchange must include call sign, signal report and location;
• ending the contact;
• recording all details of the contact in a log.

Activity 9.4 Demonstrate the ability to make a contact using a mode other than telephony.
This contact must be made on air and include as a minimum:
• Tuning the radio and/or the computer system to the correct frequency,
• Selecting the correct mode,
• Setting the radio microphone gain and/or computer audio interface to correct levels and,
• Two-way exchange of call sign, signal report, location.
Where data modes are used, the candidate must type and send all information in real time.

Activity 9.5 Demonstrate ability to send correctly by hand, and to receive correctly by ear, text in Morse Code.
You may choose the character speed and spacing.
You will be provided with a copy of the Morse Code both in code and alphabetical sequence during the assessment. Sufficient correct code must be exchanged for the content of the message to be understood.
Receiving test:
You may, if desired, write down the dots and dashes for subsequent transcription and proceed one letter at a time. The tutor may re-send characters if required.
Sending test:
You are permitted to make any necessary preparations prior to sending, including writing the Morse code for each character to be sent.

Ofcom’s rules

Activity 10.1
Imagine you live in Douglas on the Isle of Man and your call sign is MD7DOG. You are driving to Jersey for a holiday, via the ferries to Holyhead and from Poole in Dorset. How does your call sign change, starting with MD7DOG? Are you allowed to transmit while crossing on the ferry, and if so, how does your call sign change?

Imagine you are licensed in Belfast with the call sign MI7CAT and you are flying to Edinburgh. How does your call sign change? Are you allowed to transmit to your mate, sitting at the back of the plane, and if so, how does your call sign change? You go across the border to Newcastle. What does your call sign become now?

Try some other situations with Intermediate and Full call signs.

Activity 10.2
You will need the RSGB Prefix Guide or the RSGB Call Book.
What are the prefixes for some of the countries in Europe?
You hear a VK call sign. Where are they from?

Activity 10.3
A good webSDR site is in Enschede, the Netherlands, http://websdr.ewi.utwente.nl:8901
Listen in to some conversations and pick up their call signs. What country are they from?

Electromagnetic Compatibility

Activity 11.1 Be a nuisance!
Test the immunity of your computer or television. Operate a PMR446 radio close to the device and see if it is affected.

Activity 11.2 Cause interference!
Use an electric tooth brush or a piezo gas lighter. Bring it close to a radio and listen for the static when you switch the electric tooth brush on.

Activity 11.3 Search for culprits
Use a spectrum analyser to investigate devices around the home to see how much RF noise they are producing.

Safety

Activity 12.1 Charging and discharging a capacitor
Charge a 1 Farad capacitor and leave it for say, 30 minutes. See if it still holds its charge by connecting it to an LED.

Activity 12.2 Wiring a plug

For safety, bend the earth pin so that it cannot be put into a socket. Simply wire the plug with 3 core cable and have it checked by your instructor.

Revision

Table of contents

Licensing

1. What are the 3 types of UK licence?

2. You make contact with the following - where are they from and what level of licence do they have?
a) MI0ABC
b) 2U0XYZ (the 2# series will be discontinued soon and be replaced by M8 and M9)
c) MJ6JKL
3. Lauren 2E0HLR is on holiday in Wales. What does her call sign become?
4. A Scottish lady MM6XYZ comes to Broadstairs - how does her call sign change?
5. Give two examples of people who can use your radio equipment.
6. Give two examples of messages you cannot send.
7. Give two cases of when you must give your call sign.
8. What four powers does Ofcom have over your radio equipment?
9. Under what circumstances would you add /A to your call sign?
10. You have stopped off at a service station drinking a coffee and put out a call. What suffix do you add to your call sign?
11 a) What does the amateur licence permit you to do?
b) What does the amateur licence NOT permit you to do?
12. You design your own transmitting apparatus. Are you allowed to use it on-air?
13. a) Does the Foundation Licence permit operation from a vessel at sea?
b) Does the Intermediate Licence permit operation from a vessel at sea?
c) Does any level of Amateur Licence permit airborne operation within the UK?
14. When do you have to tell Ofcom of any change to your name, main station address or mailing address?
15. How often do you have to confirm your details on Ofcom's website?
16. If you are being supervised by a full licence holder, whose call sign do you use, yours or theirs?
17. You haven't got your licence yet, as you are on a Foundation Training Course. Who can supervise you - an Intermediate or a Full licence holder or either?
18. Who can you send messages to?
19. What is a Net?
20. What do you understand by a 'secret code'?
21. How often should you carry out tests to ensure that your station is not causing undue interference to other radio users?
22 Why would a person authorised by Ofcom require you to keep a log of transmissions?
23 Can you use your Foundation Licence in foreign countries?

<u>Waves</u>

(you are allowed the wavelength/frequency graph and the table of bands)

1. What is the range of frequencies for normal hearing?

2. What range of audio frequencies are used for audio communication such as speech for the telephone and amateur radio communications?
3. What does the abbreviation RF stand for?
4. Which band is 1.830 MHz in?
5. What is the frequency range for HF?
6. Which band is 433 MHz in?
7. What is the frequency range for VHF?
8. What is the wavelength of 50 MHz?
9. What is the wavelength of 3.5 MHz?
10. What is the frequency of 0.7 m?
11. What is the frequency of 80 m?
12. What is meant by an analogue wave?
13. What is meant by a digital signal?
14. Explain how an Analogue to Digital converter (ADC) works.
15. What is the function of a Digital to Analogue (DAC) converter?
16. Give an advantage of using digital signals.
17. Describe a sine wave.
18. What is the mains supply frequency?
19. What is the range of radio frequencies?
20. What does the abbreviation AF stand for?

CIRCUITS

1. A 12 volt battery is connected to a 24 Ω lamp. How much current will flow?
2. What is the power of the lamp?

3. A 2k ohm resistor is connected to a cell and the current is noted. The 2k ohm is replaced with a 5k ohm resistor. What will happen to the current now.
4. The 2k ohm resistor is connected in series with the 5k ohm resistor.
a) Draw the circuit b) Without doing any calculations, how does the current in the 2k ohm resistor compare to that in the 5k ohm?
c) Without doing any calculations, how does the potential difference across the 2k ohm resistor compare to that across the 5k ohm resistor?
5. The resistors are now placed in parallel.
a) Draw the circuit.
b) What will happen to the current coming from the cell compared to when they were in series - will it increase, stay the same or decrease?
c) How does the potential difference across the 2k ohm resistor compare to that across the 5k ohm resistor?
d) How does the current in the 2k ohm resistor compare to that in the 5k ohm?
6. A 6 volt battery is connected to a resistor causing a current of 1 mA to flow. What is the resistance of the resistor?
7. If 1 mA flows through a 1kΩ resistor what is the potential difference?
8. A 12 volt battery is connected to two resistors in series A and B causing a current flow of 2 mA.
a) If the potential difference across resistor A is 4 v what is the potential difference across resistor B?
b) What is the resistance of resistor B?
9. Explain the difference between direct current and alternating current.
10. Give 3 examples of an insulator.
11. What can be said about the current in a series circuit?
12. What can be said about the current in a parallel circuit?
13. What can be said about the potential difference across items in parallel?
14. What can be said about the potential difference across items in series?
15. What happens to electrical energy when current passes through a resistor?
16. The current I through a resistor R is proportional to the voltage V across that resistor. Explain what that means.
17. What is meant by the polarity of a circuit and why is this important?
18. What is a battery?
19. Where does the electrical energy of a battery come from?
20. What is the difference between a non-rechargeable (primary) battery and a rechargeable (secondary) battery when they become discharge?

Transmitters and Receivers

1. Draw a block diagram of a transmitter.
2. In a transmitter what is the function of the a) microphone and audio amplifier, b) modulator, c) frequency generator (oscillator),
d) RF power amplifier?
3. Draw a block diagram of a receiver.
4. In a receiver what is the function of the a) tuning and RF amplifier b) demodulator (detector) c) audio amplifier d) loudspeaker?
5. Explain with diagrams how a signal is transmitted using the technique of Amplitude Modulation.
6. Explain with diagrams how a signal is transmitted using the technique of Frequency Modulation.
7. How is it possible to over modulate for both AM and FM?
8. What two problems can result from over modulation?
9. How could you possibly transmit on a wrong frequency?
10. What could happen if your transmitter is connected to the wrong antenna?
11. How are data, such as binary 1's and 0's, transmitted?
12. Amplitude modulation produces two sidebands and the carrier. Why do radio amateurs transmit using only one single sideband?
13. Explain with a diagram what the radio signal for the letter 'a' would look like for CW.
14. What is the function of the software in a software defined radio SDR transmitter.
15. What is the function of the software in a software defined radio SDR receiver.
16. What is the function of a radio transmitter?
17. What is meant by modulation?
18. Explain how data are transmitted.
19. What is the difference between amplitude modulated signals and SSB modulated signals?
20. What could happen if your oscillator was incorrectly set?
21. The microphone gain control needs to be correctly adjusted. Why is this important?
22. In an SDR, how is the required signal selected?

Feeders

1. What is the advantage of coaxial cable for RF signals?
2. What is the advantage of twin feeder cable?
3. How must the braid of coaxial cable be connected to minimise RF signals getting in or out of the cable?
4. How is a horizontal polarised wave produced?
5. What would happen if a VHF antenna was erected vertically and the incoming signal is horizontal?
6. Draw labelled diagrams of these antennas: a) a half wave dipole b) quarter wave dipole c) yagi d) 5/8 ground plane e) end fed.
7. What is the total length of a half wave dipole for 20 m?
8. How is a yagi antenna able to be directional?
9. What is the purpose of an ATU (antenna tuning unit) or AMU (antenna matching unit)?
10. What is the purpose of an SWR (standing wave ratio) meter?
11. What is the purpose of a dummy load?
12. A half wave dipole antenna is a balanced antenna but the coaxial cable is not balanced. How do we rectify this.
13. Draw and explain the polar diagram for a half wave dipole.
14. The gain of an antenna is 3 dB and the power applied to the antenna feed point is 5W. What is the Effective Radiated Power (ERP)?
15. How do feeders exhibit loss of energy?
16. Why should you use a short length of cable?
17. How is feeder loss dependent on frequency?
18. Which antennas are omnidirectional?
19. How is the gain of an antenna normally expressed?
20. Antenna gain can also be expressed relative to a theoretical antenna that radiates equally in all directions. What is this called, and how is it related to ERP?
21. Where is the feed point?
22. For a given frequency, when can we say about the impedance of the feed point and the impedance of the feeder and the transmitter?
23. What affects the feed point impedance of an antenna?
24. What will happen if the feed point impedance of the antenna does not match that of the feeder?
25. How is a standing wave produced in a feeder?
26. What does a high SWR, measured at the transmitter, indicate?
27. What could happen if the SWR reading is greater than 2:1?
28. Why is it important to correctly connect the braid of a coaxial cable?

Propagation

1. What happens to the energy of radio waves as they spread out?
2. How do radio waves, especially UHF and VHF, normally travel?
3. What does the ionosphere comprise of and what causes it?
4. What is the lower height of the ionosphere and the upper height?
5. The range achieved at both VHF and UHF depends on what 3 factors?
6. An HF wave is ‘reflected’ by the ionosphere. The place where it returns to Earth, its range, depends on what 3 factors?
7. On which of the following bands do signals travel mainly by line of sight propagation
 a) 1.8 MHz, b) 14 MHz, c) 144 MHz or d) 198 kHz?
8. In the shadow of a hill which frequency or frequencies will give the best reception - HF, VHF or UHF?
9. Which frequency or frequencies are best to communicate with satellites or the ISS?
10. What does the Maximum Useable Frequency indicate to an operator?
11. Which of the following has the greatest effect on the reflecting properties of the ionosphere - a) solar radiation b) atmospheric pressure c) temperature d) high winds?
12 Very long distances are generally worked on the HF bands. The most reliable band is
 a) 3.5 MHz, b) 7 MHz, c) 14 MHz, d) 28 MHz.
13. VHF signals could be generally considered as
 a) worldwide, b) European, c) Local, d) intercontinental?
14. On which of the following bands would a station in America be most likely to be connected during the afternoon?
 a) 160 m b) 80 m c) 40 m or d) 20 m?
15. What sort of weather conditions can attenuate UHF signals?
16. What is meant by sporadic-E?
17. What is meant by atmospheric ducting?
18. VHF and UHF signals cannot use the ionosphere for propagation, so where do they propagate?
19. What does it mean what a band is said to be ‘open’?
20. What 4 factors affect the range achieved by VHF and UHF?
21. Why is a higher antenna preferable to higher power?
22. Which will perform better - an outdoor antenna or an indoor antenna?

EMC

1. What is electromagnetic compatibility (EMC)?
2. What is RF immunity in terms of electrical equipment?
3. Give 4 places in the home where your radio transmissions could cause interference to your TV, radio or telephone.
4. Give 3 ways to minimise electromagnetic interference (EMI) problems in your radio station design.
5. Give one way how you can minimise EMI when you operate.
6. Where should external chokes and filters be fitted in an affected device?
7. Why is it important to fit an RF earth connection in an HF amateur station?
8. When installing a radio in your car what are the safety implications?
9. If you have a dispute with your neighbour about interference what should both of you do?
10. Also, what help as a radio amateur can you get?
11. Which modes are less likely to cause interference?
12. Why should you do a test of transmitting into a dummy load.
13. What is a dummy load?
14. What is its purpose?

Operating Procedures and Practices

1. Why should you listen before calling CQ and then ask if the frequency is in use?
2. Why is a CQ call on HF longer than one on VHF/UHF?
3. On VHF/UHF why should you move off the calling channel once a contact is made?
4. How should you respond to inappropriate language?
5. What is the purpose of repeaters?
6. Why is a CTCSS continuous tone-coded squelch system important for repeaters?
7. For repeaters, why is a frequency offset needed between transmit and receive?
8. Why is keeping a log advisable and what should you record?
9. What is Q in the phonetic alphabet?
10. Sierra is the proper phonetic term for the letter S. What variation might you hear?
11. What does UTC mean and why is it preferable to British Summer Time?
12. Why is it important to know the allocated amateur radio frequency bands?
13. Which are the narrow modes?
14. When would you use the lower side band?
15. What is the meaning of the RST code?
16. When using a friend's digital radio what must you be aware of?
17. What is meant by the Centre of Activity on 2 m SSB?
18. A fellow amateur gives you a signal report of 4 and 8. What does this signify?
19. What band is used by aeronautical radio-navigation stations?
20. Why may different repeaters have different tones?
21. Why may repeaters have a 'reset' tone and a time-out facility?
22. Is simplex operation allowed on repeater frequencies?
23. What should you check if you use a different microphone to the one that was supplied to the transmitter?
24. For Morse code, what is the best report you could give for a perfect tone?
25. Digital voice (DV) and Digital Date (DD) modes are available now, but what issues are there?
26. When using digital voice, what should you check first?
27. You want to operate a satellite. What should you be aware of?
28. Are you allowed to operate terrestrially on a satellite frequency?

Safety

1. Why are high voltages dangerous?
2. Why are high currents dangerous?
3. Why is an RCBO (Residual Current Circuit Breaker with Overcurrent protection) better than a fuse?
4. A 13 A fuse is fitted to equipment requiring a 3 A fuse. What could happen?
5. What is the first action in the event of an accident with electricity?
6. Give 2 reasons why wires should not be trailed across the floor.7. Give 5 precautions when erecting an antenna on a roof.
8. Why should wires not be run under carpets, out the way?
9. What are the hazards that could be met by a) your ears b) your eyes and c) your skin?
10. What safety points should you consider when charging a battery?
11. Who should be consulted before making changes to your earthing arrangements such as an RF earth.
12. What are the colours of the wires for a 3-pin plug?
13. A fuse blows. What should you do before replacing it?
14. What should you do when working or servicing inside equipment?
15. Name 3 precautions when soldering.
16. What is the main health effect of exposure to electromagnetic radiation?
17. Where can you get guidance on the safe levels of RF radiation?
18. What is a waveguide and how can it be dangerous?
19. What precautions should be taken with antenna elements carrying RF.
20. What precautions need to be taken with lightning?
21. When setting up a station outside with a tall mast, what precautions need to be taken?
22. When you are operating outdoors or in temporary premises, what new hazards can there be and what should you do about them?
23. Whose responsibility is safety, when operating outside?

Licensing

1. The 3 types of UK licence are foundation, intermediate and full.
2. a) MI0ABC is a full licence holder living in Northern Island.
b) 2U0XYZ is an intermediate licence holder living in Guernsey.
c) MJ6JKL is a foundation licence holder living in Jersey.
3. Lauren 2E0HLR is on holiday in Wales. Her call sign becomes 2W0HLR.
4. A Scottish lady MM6XYZ comes to Broadstairs. Her call sign changes to M6XYZ
5. Two examples of people who can use your radio equipment are a member of the User service or a visiting UK licensed amateur.
6. Two examples of messages you cannot send are secret codes and calls of a business or commercial nature.
7. You must give your call sign when you change frequency, when you change mode or type of transmission, when the supervisor changes or when you enter a different part of the UK such as when you cross the Severn bridge!
8. A person authorised by Ofcom has the power over your radio equipment to inspect, closedown or restrict its operation or require its modification. Ofcom can revoke your licence for breaches of licence conditions.
9. You would add /A to your call sign if you are operating from an alternative main address with a postal address such as a hotel or a friend's house.
10. You have stopped off at a service station drinking a coffee and put out a call. You would add the suffix /P to your call sign.
11. The Amateur Licence permits you to train yourself in radio communications.
12. Yes, you can use your own design or modify transmitting apparatus but you must ensure it does not cause interference.
13. a) Yes, but you are limited to UK registered ships and planes. You can operate on inland waterways of course.
b) Yes c) Yes.
14. Immediately! As soon as there is a change, you need to notify Ofcom.
15. You need to log on to the Ofcom website every five years to keep your licence current.
16. You can use the call sign of the Full Licence holder, if you wish. You can use all their privileges. However, if they leave the room, you must use your Foundation call sign, and turn down the power!
17. If you haven't got your licence yet, only a Licence holder can supervise you.
18. You can only send messages to other licensed operators.
19. A Net is when a group of amateurs have a conversation. However, each person must identify themselves.
20. A secret code is a code in which only the recipient knows the key. This is not allowed. However you can use Q codes, as everyone is familiar with them.
21. You need to carry out tests from time to time.
22. A person from Ofcom would require you to keep a log of all your transmissions to assist in identifying any interference you may or may not be causing.
23. No! Your Foundation Licence is not recognised in other countries, but you can always apply, good luck!

Waves

1.The range of range of frequencies for normal hearing is 20 Hz to 15 kHz.
2. The range of audio frequencies are used for audio communication such as speech for the telephone and amateur radio communications is 300 Hz to 3 kHz.
3. The abbreviation RF stands for Radio Frequency.
4. 1.830 MHz is in the MF, medium frequency, band or medium wave band.
5. The frequency range for HF is 3 MHz to 30 MHz.
6. 433 MHz is in the UHF, ultra high frequency, band.
7. The frequency range for VHF is 30 MHz to 300 MHz.
8. The wavelength of 50 MHz is 6 m.
9. The wavelength of 3.5 MHz is about 86 m.
10. The frequency of 0.7 m is about 430 MHz.
11. The frequency of 80 m is 3.75 MHz.
12. An analogue wave is a wave which is constantly changing in amplitude or frequency or both. It is continuous.
13. A digital signal has finite values at a specific sampling interval. It is discrete.
14. An Analogue to Digital converter (ADC) works by sampling an analogue signal and converted the values to digital values.
15. A Digital to Analogue (DAC) converter represents a digital signal in an analogue format.
16. An advantage of using digital signals is that they can be processed by the software of a computer.
17. Starting at zero, a sine wave rises quickly to a maximum but begins to level off, before falling rapidly to a minimum. At the minimum it levels off before rising rapidly to zero. The cycle repeats itself.
18. The mains supply frequency is 50 Hz.
19. Radio frequencies range from below 30 kHz to beyond 3000 MHz.
20. AF stands for audio frequencies. You can audio frequencies in sound waves and radio waves too.

CIRCUITS

1.Current = V/R=12/24= 0.5 A
2. The power of the lamp = Vx I = 12 x 0.5 = 6 W
3. The current will decrease.
4. b) The current in the 2k ohm resistor will be the same as that in the 5k ohm.
c) The potential difference across the 2k ohm resistor will be less than that across the 5k ohm resistor. V= I x R and R is less.
5. b) In parallel the current in the circuit will increase as there is now less resistance in the circuit as a whole.
c) The potential difference across the 2k ohm resistor will be the same as that across the 5k ohm resistor.
d) The current in the 2k ohm resistor will be greater than that in the 5k ohm.
6. The resistance of the resistor = V/I = 6/0.001 = 6000 = 6k ohms.
7. The potential difference = I x R = 0.001 x 1000 = 1 v
8. a) The potential difference across the other resistor = 12-4 = 8v b) The resistance of the other resistor = 8/0.002 = 4000 = 4k ohms.
9. Direct current always flows in one direction usually from the positive terminal to the negative. It does not have to be constant.
Alternating current alternates in direction. It usually varies sinusoidally but it could be a square wave for example.
10. Insulators include plastics, rubber, glass and ceramics. If an insulator is wet, it can conduct.
11. The current in a series circuit is the same everywhere; before a resistor and after a resistor, for example.
12. In a parallel circuit the current divides at a junction, but the sum of the currents into the junction is equal to the sum of the currents out of the junction.
13. For items in parallel, the potential difference is equal.
14. In a series circuit the voltages add up to give the battery voltage.
15. The electrical energy is transformed to heat energy in a resistor.
16. Proportional means that if we double the current through a resistor we double the potential difference across it. The resistance of the resistor does not change.
17. The polarity of a circuit refers to the positive and negative terminals. It is important because getting it wrong can damage a component.
18. A battery is a group of two or more cells. For example three 1.5v cells in series gives a 4.5 v battery.
19. The electrical energy comes from chemical energy.
20. When a primary battery becomes discharged, it needs to be disposed of properly. When a secondary battery becomes discharged, it needs to be recharged as the chemical process is reversible.

Transmitters and Receivers

1. See the Mind Map for a block diagram of a simple transmitter.
2. In a transmitter the function of
a) the microphone and audio amplifier is to amplify the signal to a level required to drive the modulator and to limit the audio frequencies to the range 300 Hz to 3 kHz.
b) the modulator is to mix the audio or data signal with the radio carrier frequency.
c) the frequency generator or oscillator is to set the frequency on which the transmitter operates.
d) the RF power amplifier is to amplify the power of the modulated RF signal to the final output level.
3. See the Mind Map for a block diagram of a receiver.
4. In a receiver the function of
a) the tuning and RF amplifier is to select the signal of the required frequency and to amplify it.
b) the demodulator or detector recovers the audio signal from the modulated radio frequency.
c) the audio amplifier amplifies the signal to a level to drive the loudspeaker.
d) the loudspeaker converts the electrical signal to a sound wave.
5. See the Mind Map diagrams showing how a signal is transmitted using the technique of Amplitude Modulation. The frequency of the carrier wave is not changed but its amplitude changes in response to the amplitude of the audio signal. The amount of amplitude change or depth of modulation depends on the amplitude of the audio signal.
6. See the Mind Map diagrams showing how a signal is transmitted using the technique of Frequency Modulation. The amplitude of the carrier wave is not changed but its frequency changes in response to the frequency of the audio signal. The amount of frequency change or deviation depends on the amplitude of the audio signal.
7. It is possible to over modulate for AM and FM if the level of the audio signal is too high. This could be due to too much microphone gain or shouting!
8. If there is excessive amplitude modulation this can cause a distorted output and interference to adjacent channels. For FM excessive frequency deviation can also cause interference to adjacent channels.
9. It's possible to transmit on a wrong frequency if the oscillator is not set correctly.
10. If your transmitter is connected to the wrong mis-matched antenna this could result in damage to your transmitter.
11. Data, such as binary 1's and 0's, are transmitted by different audio tones.
12. Amplitude modulation produces two sidebands and the carrier with a bandwidth of 6 kHz. Therefore radio amateurs transmit using only one single sideband with a bandwidth of 3 kHz.
13.The radio signal for the letter 'a' would consist of a short burst of carrier wave followed by a longer burst of carrier wave.
14. The function of the software in a software defined radio SDR transmitter is to modulate the radio signal.

15. The function of the software in a software defined radio SDR receiver is to digitise the input signal and select the desired frequency. It can also demodulate the signal.
16. The function of a radio transmitter is to send information from one place to another using electromagnetic radiation.
17. Modulation is the process of adding information to the radio frequency carrier.
18. Data are transmitted by modulating the carrier using audio tones, generated by the an audio interface, such as a computer sound card.
19. Amplitude modulated signals have the carrier and the two sidebands. An SSB signal has just one sideband.
20. If your oscillator was incorrectly set, it could result in operation outside the band and cause interference to other users.
21. It is important to have the correct microphone gain so as not to cause distortion. Also you could be operating outside the permitted bandwidth.
22. A mathematical operation sifts all the signals into separate frequencies. A filter, defined in software, then selects the required signal.

Feeders

1. The advantage of coaxial cable for RF signals is that the braid screens the signal, keeping it within the cable.
2. The advantage of twin feeder cable is that it is balanced, as equal and opposite signals pass through the two wires. Coaxial feeder is unbalanced with the signal on the centre conductor.
3. The braid of coaxial cable must be connected to the body of the plug to minimise RF signals getting in or out of the cable.
4. A horizontal polarised wave produced is produced by a horizontal antenna.
5. If a VHF antenna was erected vertically and the incoming signal is horizontal the reception would be weak.
6. See the Mind Map for labelled diagrams of these antennas: a) a half wave dipole b) quarter wave dipole c) Yagi d) 5/8 ground plane e) end fed.
7. The total length of a half wave dipole for 20m is approximately 10m.
8. A Yagi antenna is able to be directional because the elements focus the energy into a forward direction.
9. The purpose of an ATU (antenna tuning unit) or AMU (antenna matching unit is to match the antenna to the transmitter, preventing it from being damaged and ensuring that the energy is transferred to the antenna efficiently.
10. The purpose of an SWR (standing wave ratio) meter is to show that the antenna is presenting the correct match to the transmitter and is reflecting minimum power back to the transmitter. A higher reading than 2:1 indicates that there could be a fault in the antenna or feeder.
11. The purpose of a dummy load is to allow the transmitter to be operated without radiating a signal.
12. A half wave dipole antenna is a balanced antenna but the coaxial cable is not. We rectify this by using a balun.
13. See the Mind Map for the polar diagram for a half wave dipole. The radiation is greatest at right angles to the wire and least at the ends.
14. The Effective Radiated Power = 2 x 5 W = 10 W.
15. Feeders exhibit loss because some of the RF energy is converted to heat. The longer the cable, the greater the loss.
16. You should use a short length of cable because you can lose signal strength on both transmit and receive.
17. Feeder loss increases with frequency. That is why you should use low loss feeders at VHF and UHF.
18. The omnidirectional antennas are the half-wave dipole mounted vertically, the quarter wavelength ground plane and the 5/8 wavelength antennas.
19. The gain of an antenna is normally expressed relative to a half-wave dipole.
20. When antenna gain is expressed relative to a theoretical antenna that radiates equally in all directions, it is called Effective Isotropic Radiated Power or EIRP. 10W EIRP is equivalent to 6.1 W ERP.
21. The feed point is where the feeder connects to the antenna.
22. The impedance of the feed point and the impedance of the feeder and the transmitter should all match.
23. The feed point impedance of an antenna is affected by its dimensions and the wavelength of the applied signal.

24. If there is no match, some energy will be reflected back down the feeder, depending on the degree of mismatch.
25. A standing wave is produced when energy is reflected back from the antenna to the transmitter if there is mis-match.
26. A high SWR reading, measured at the transmitter does not indicate a fault in the transmitter, but in the antenna or feeder.
27. It is important to correctly connect the braid of a coaxial cable to minimise RF signals getting into or out of the cable.

Propagation

1.The energy of radio waves is spread over a larger area as they spread out so the signal strength decreases.
2. Radio waves, especially UHF and VHF, normally travel in straight lines.
3. The ionosphere comprises of ions, which are charged particles. Ultra-violet rays from the Sun break the atoms into electrons and ions.
4. The lower height of the ionosphere is 70km and the upper height is 400km.
5. The range achieved at both VHF and UHF depends on 3 factors: the frequency (a 145 MHz wave will travel further than a 433 MHz wave), the height of the antenna and the power.
6. An HF wave is 'reflected' by the ionosphere. The place where it returns to Earth, its range, depends on 3 factors: the frequency (a 30 MHz will travel further than a 3 MHz wave, the time of day (further during the day) and the season (the maximum useable frequency is greater in the winter).
7. Signals travel mainly by line of sight propagation by c) 144 MHz.
8. In the shadow of a hill the frequency or frequencies which will give the best reception is HF because the longer wavelength allows for more diffraction.
9. The frequencies best to communicate with satellites or the ISS are UHF and VHF.
10. The Maximum Useable Frequency indicates to an operator the best band to operate.
11. a) solar radiation has the greatest effect on the reflecting properties of the ionosphere.
12. Very long distances are generally worked on the HF bands. The most reliable band is c) 14 MHz.
13. VHF signals could be generally considered as c) Local.
14.The band for which a station in America is most likely to be connected during the afternoon is d) 20 m.
15. The sort of weather conditions that can attenuate UHF signals are snow, ice and heavy rain.
16. Sporadic-E occurs when the E layer is active and reflects radio waves at VHF allowing for a skip distance of 2000 km. This usually happens in the summer.
17. Atmospheric ducting happens when warm air is trapped in the troposphere and signals at VHF can also get trapped and travel long distances.
18. VHF and UHF signals propagate within the troposphere, situated below the ionosphere.
19. A band is said to be 'open' when skywave propagation is possible.
20. The 4 factors that affect the range achieved by VHF and UHF are the antenna height, antenna gain, a clear path and transmitter power.
21. A higher antenna is preferable to higher power because it will improve the performance on transmit and receive.
22. An outdoor antenna will perform better than an indoor antenna.

EMC

1. Electromagnetic compatibility (EMC) is the avoidance of interference between electronic equipment.
2. RF Immunity for electrical equipment means that it functions correctly in the presence of strong RF signals.
3. The 4 places in the home where your radio transmissions could affect equipment are a) through pick-up in house wiring, b) in the TV antenna down-leads c) telephone wiring and d) in their internal circuits.

4. The 3 ways to minimise electromagnetic interference (EMI) problems in your radio station design are a) site your antenna as far away from the house as possible b) as high as possible and c) use balanced antennas at HF.
5. One way how you can minimise EMI when you operate is to use less power.
6. External chokes and filters should be fitted in mains or antenna leads as close to the affected device as possible.
7. It is important to fit an RF earth connection in an HF amateur station to minimise RF currents entering the mains earth system which could cause interference to electronic equipment.
8. When installing a radio in your car the safety implications are a) that the radio is compatible with the vehicle's electrical and management system and b) that it is tested when the car is static with all its electronic systems operating before any on-road tests are carried out.
9. If you have a dispute with your neighbour about interference both of you should keep a log of transmissions and any interference. You should both be co-operative and diplomatic.
10. As a radio amateur you can get help from the RSGB with information leaflets and the RSGB EMC committee can offer advice.
11. The modes less likely to cause interference are CW Morse, FM and HF data modes such as PSK31. The worst are SSB and AM.
12. You should do a test of transmitting into a dummy load to see if any unwanted RF is being conducted out of the transmitter along its power supply leads or any connected interface leads and into the mains.
13. A dummy load is a screened resistor of the correct value, 50 ohms or 75 ohms, and of suitable power rating.
14. A dummy load allows you to operate the transmitter without radiating a signal.

Operating Procedures and Practices

1. You should listen before calling CQ and then ask if the frequency is in use because you may not be able to hear a distant station which is transmitting to someone near you.
2. A CQ call on HF is longer than one on VHF/UHF because it gives the listener time to tune accurately to your frequency.
3. On VHF/UHF you should move off the calling channel once a contact is made to allow the calling channel to be used by others.
4. You should respond to inappropriate language by simply ignoring them and changing frequency.
5. The purpose of repeaters is to extend the range of your transmissions.
6. A CTCSS continuous tone-coded squelch system is important for repeaters so that it does not re-transmit unintended noise and unwanted signals.
7. A frequency offset is a difference in frequency between the transmit and receive frequencies.
8. Keeping a log is advisable even though it is not a licence requirement because you might want to exchange QSL cards. You should record the time, date, mode and the call sign of the station worked.
9. Q in the phonetic alphabet is Quebec.
10. Sierra is the proper phonetic term for the letter S. You might hear the variation Sugar.
11. UTC means Universal Co-ordinated Time and is preferable to British Summer Time because it avoids confusion and is used worldwide.
12. It is important to know the allocated amateur radio frequency bands because there are frequency bands allocated to other users such as broadcasting, radio astronomy and satellites.
13. The narrow modes are CW and data modes.
14. You use the lower side band on frequencies less than 10 MHz.
15. The RST code is a way of describing a signal in terms of its readability on a scale of 1 to 5, strength on a scale 1 to 9 and tone for CW on a scale from 1 to 9.
16. When using a friend's digital radio you must be aware that their call sign might be embedded in the radio.
17. The Centre of Activity on 2m SSB is 144.300 MHz where you would call 'SSB calling' similar to the calling channel on FM.
18. A signal report of 4 and 8 means 'Readable with practically no difficulty' and a strong signal.
19. Aeronautical radio-navigation stations use the band 108·0 to 117·975 MHz.
20. Each repeater has a specific CTCSS tone so that you don't access two repeaters at the same time.
21. Repeaters may have a 'reset' tone and a time-out facility to remind users that other people may want to use the repeater so they should not have long conversations!
22. Definitely not! simplex operation is definitely not allowed on repeater frequencies.

23. If you use a different microphone to the one that was supplied to the transmitter, you should check it operates the PTT line correctly and that the audio signal levels are correct.
24. The best report you could give for a perfect tone is 9.
25. The main issue with Digital voice (DV) and Digital Date (DD) modes is that different systems may not be compatible. Also you need appropriate radio equipment for each of the different systems.
26. When using digital voice, you should check that the channel is not is use by other modes. However these checks are not 100% reliable!
27. If you want to operate a satellite, you should be aware of the allocated frequencies within the bands.
28. Definitely No!

Safety

1. High voltages are dangerous because they can cause electrocution.
2. High currents dangerous because there is a risk of overheating and fire.
3. An RCBO (Residual Current Circuit Breaker with Overcurrent protection) is better than a fuse because it only takes about 30 mA to earth to be detected while a fuse will only blow at several amps.
4. A 13 A fuse is fitted to equipment requiring a 3 A fuse. This could cause the cable to overheat if there is a problem without the fuse blowing.
5. The first action in the event of an accident with electricity is to turn off the power at the main switch which should be clearly marked.
6. 2 reasons why wires should not be trailed across the floor are a) they are a trip hazard and b) the insulation could become frayed.
7. 5 precautions when erecting an antenna on a roof are a) wear a hard hat b) work with another person, c) set the ladder at the 4:1 height to base ratio, d) secure the ladder to prevent it slipping, e) don't overreach, f) use a tool belt to prevent falling tools!
8. Wires should not be run under carpets, out the way, because the insulation could become frayed.
9. The hazards that could be met by a) your ears are excessive volume on headphones b) your eyes could be damaged by small metal particles (swarf) when using tools or by looking down a microwave frequency waveguide or from splashing from solder of flux while soldering and c) your skin could be burnt if you touch an antenna element while transmitting or by exposure to electromagnetic radiation.
10. When charging a battery you need to do so in accordance with the manufacturer's instructions especially lithium batteries which can cause fire and explosion if not treated properly and be aware that you must use the correct type of charger.
11. The District Network Operator should be consulted before making changes to your earthing arrangements such as an RF earth.
12. The colours of the wires for a 3-pin plug are blue - neutral, green and yellow - earth, brown - live.
13. If a fuse blows, you should find out what caused it to blow, a short circuit for example.
14. When working or servicing inside equipment, you should first disconnect any power sources and follow the manufacturer's instructions.
15. 3 precautions when soldering would be 1. Wear eye protection to prevent solder or flux from splashing into the eyes. 2. Use a soldering-iron stand to avoid skin contact from the hot bit of the iron. 3. Make sure there is adequate ventilation and avoid inhalation of solder fumes, which can be a problem to asthmatics.
16. The main health effect of exposure to electromagnetic radiation is heating of body tissue, with the eyes particularly susceptible to damage.
17. You can get guidance on the safe levels of RF radiation from Public Health England and the ICNIRP, the International Commission on Non-Ionising Radiation Protection.

18. A waveguide is used to transmit microwaves. It can be dangerous to look down it or to stand in front of it, especially high gain antennas.
19. Antenna elements carrying RF should not be touched whilst transmitting. They should be mounted where people will not come into accidental contact with them.
20. High antennas may need special protection with lightning. Advice can be given by the local authority building department.
21. When setting up a station outside with a tall mast, you need to make sure that the antenna is secured and well away from overhead power cables, which could give you a lethal electric shock.
22. When you are operating outdoors or in temporary premises, new hazards can be temporary mains connections, trailing cables and damp ground. Therefore you should take additional safety precautions with risk assessments, cable routing, protection, correct fusing, use RCBO's and not to make adjustments or repairs to live equipment.
23. The responsibility for safety is everyone's. You need to warn the appropriate person if you are unsure of anything. This also applies in your own home, when entertaining visitors.

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