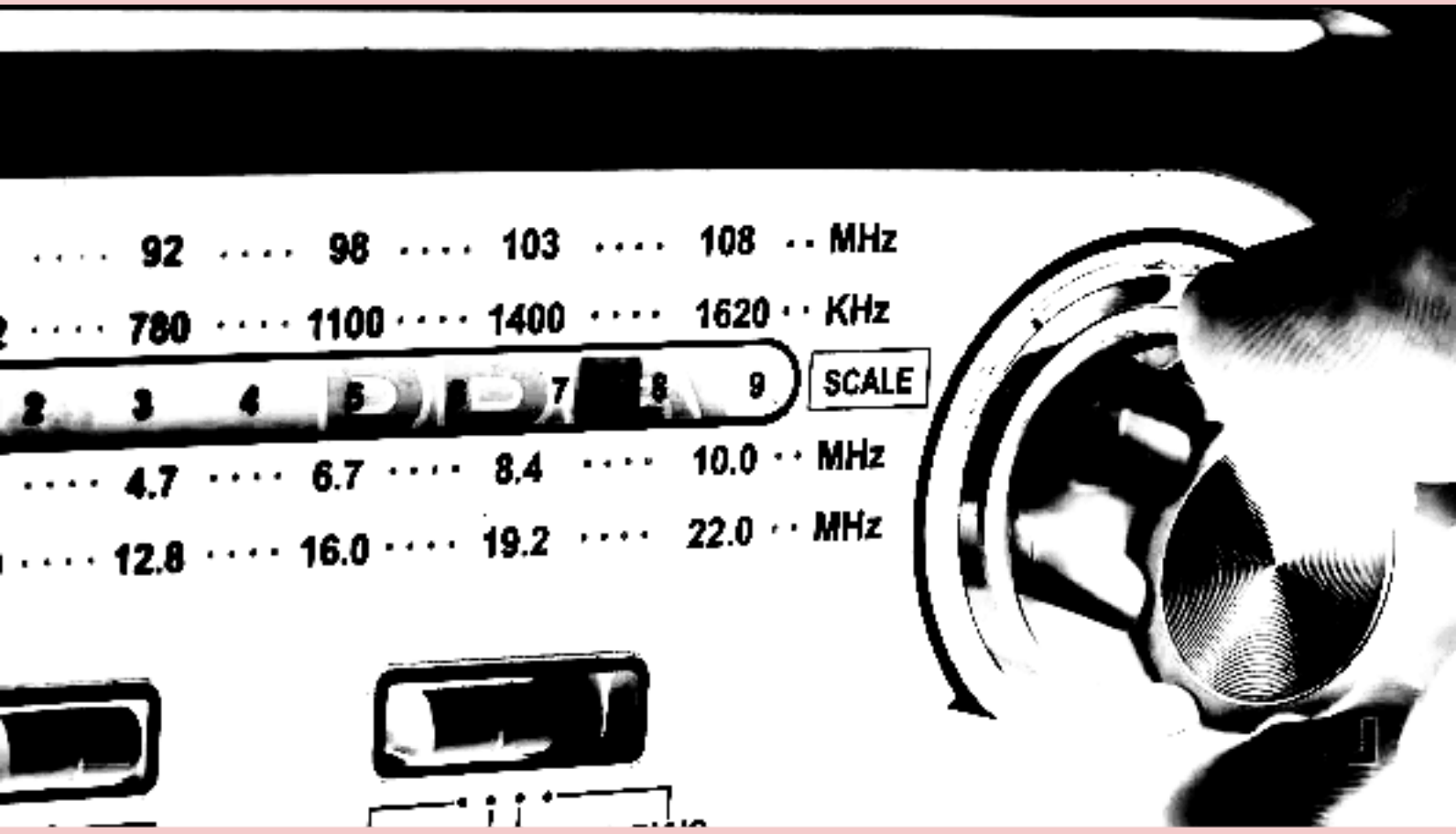
Shortwave listening

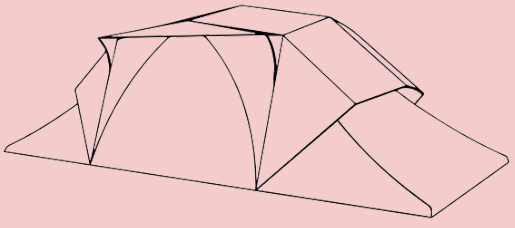
Hannah Kemp-Welch



A toolkit produced for Soundcamp 2020

With special thanks to...

Cray Valley Radio Society
Cambridge and District Amateur Radio Club

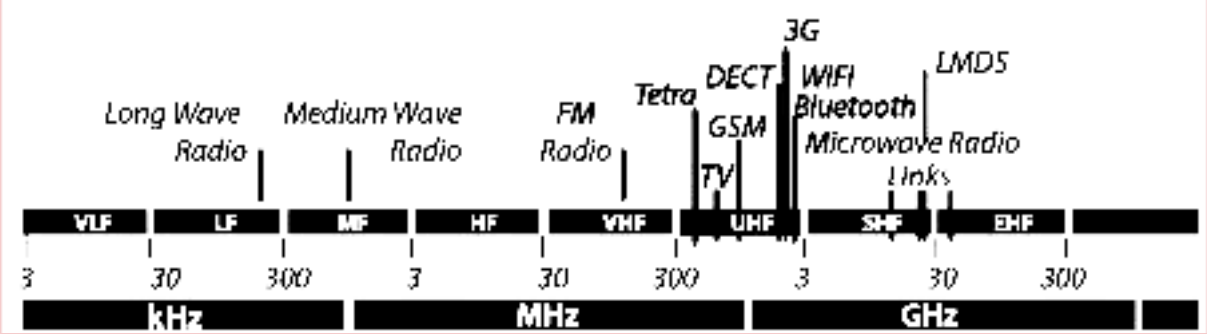


Hannah Kemp-Welch, 2020
http://sound-art-hannah.com/

The radio frequency spectrum

When we think of radio, we usually think of public broadcast and commercial stations such as BBC Radio 1 or LBC Radio. Each of these stations has an address - an allocated space in the frequency spectrum that would allow you to find the station from your stereo. For example, you can find Radio 1 by tuning your radio to between 97-99 FM. Radio 4 can be found between 92-95 FM. Each station has dedicated frequencies to prevent interference with other broadcasts.

But FM radio transmissions only take place on a small part of the radio frequency spectrum - between 88-108 MHz, located in the Very High Frequency (VHF) band. There are many more bands which house different kinds of radio communications.



In between the medium wave radio and FM radio bands, is a range called shortwave radio - approximately between 3-30 MHz on the High Frequency (HF) band. Shortwave radio can travel extremely long distances, so some international stations use this for their broadcasts, including the BBC World Service. It's also used for some military, aviation and marine communications, as well as for international communication by hobbyists called amateur radio enthusiasts. They can transmit messages back and forth over extreme distances.

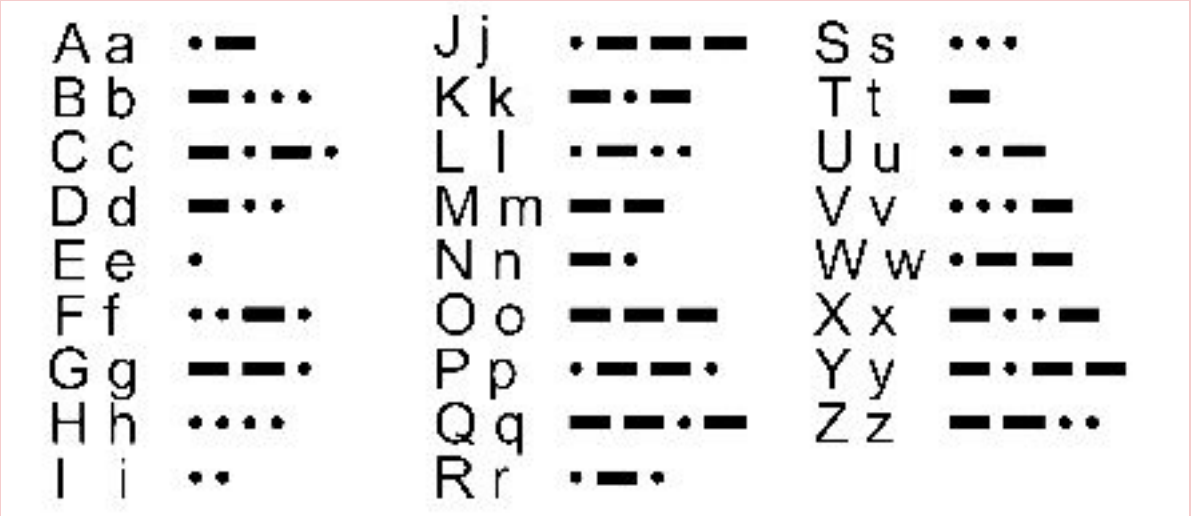
The purpose of this guide is to equip you with tools to be able to find and listen to these and other kinds of communications happening across the radio spectrum. A little bit of physics will help you to find your way around and understand the acronyms. You'll be able to listen to individuals and organisations from all over the world using voice or telegraphy (Morse code!) in real time via WebSDR (software-defined radio online).

Here's a sample of what you might hear:
https://soundcloud.com/soundarthannah/shortwave-records

You can also listen to shortwave transmissions in analogue form, using a shortwave radio or world band receiver – you can get a decent one online for around £25.

Radio history

The first mode of electrical telecommunication was the telegraph - invented by Samuel Morse in the 1830s. Electric pulses travelled vast distances across dedicated wires, and activated a telegraph sounder to make a click. A series of these long and short clicks became Morse code. Transmissions using simple on / off signals such as Morse are called continuous wave (CW).



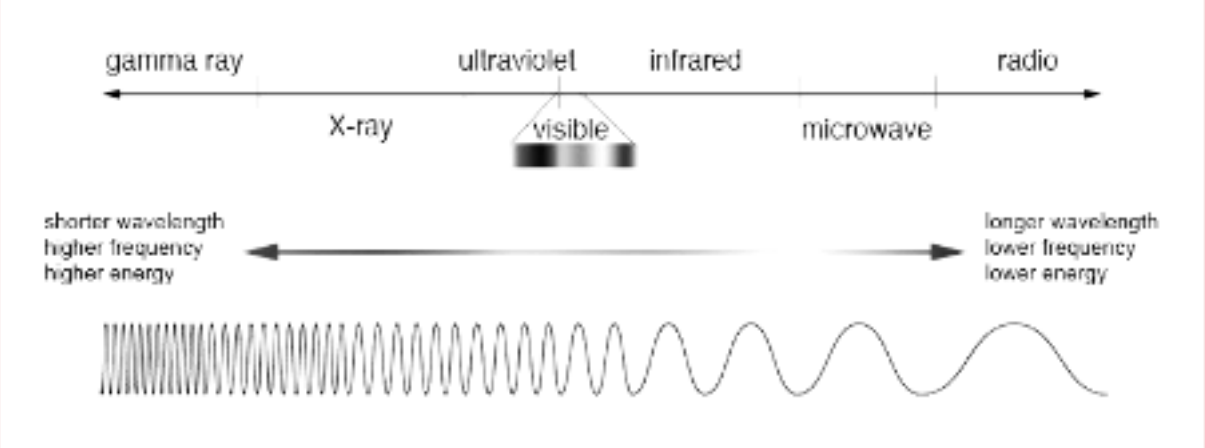
Skilled Morse code operators can decode words by ear without writing down the letter sequence received. Some can decipher up to 40 words per minute in this way. Listen to this short audio sample of Morse, and see if you can decipher the message.

Telegraphy relied on wires, strung up on poles and crossing vast distances, to carry communications. Pictures of major cities in the late 19th century show an absolute mass of wires. During extreme weather conditions, structures holding these networks of wires could fall and cause havoc on the city.

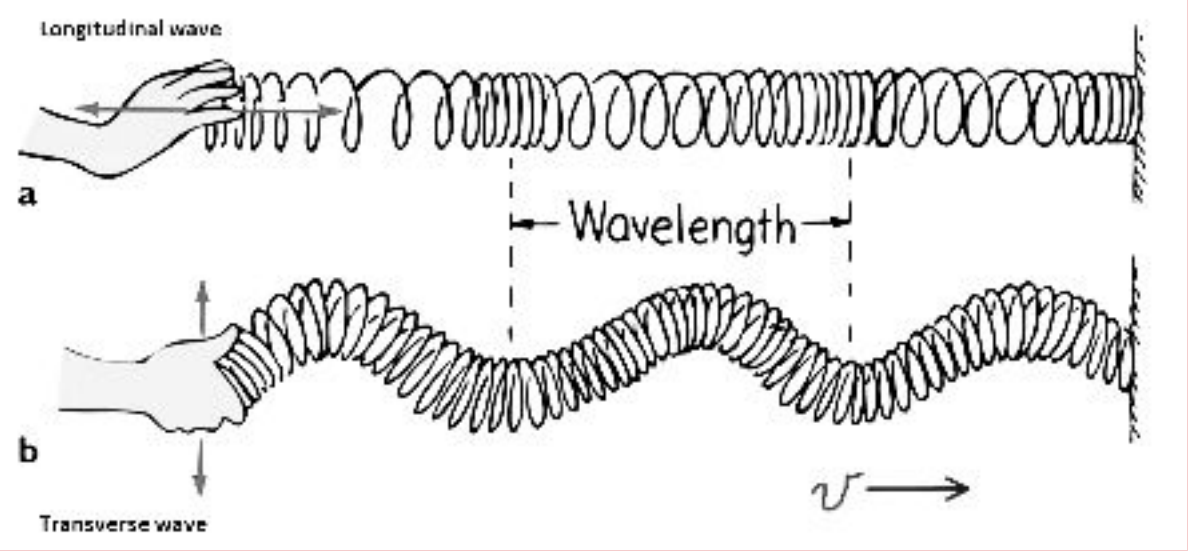
In 1886, physicist Heinrich Hertz identified and studied radio waves. He and his predecessor James Clerk Maxwell studied these waves as potential transmitters for wireless telegraphy. Within 10 years, Guglielmo Marconi developed radio transmitters and receivers. Radio began to be used commercially around 1900.

Some physics

Electromagnetic radiation is all around us, in many forms. Sunshine is a type of electromagnetic radiation. Radio waves, just like light waves, are also a type of electromagnetic radiation.



Radio waves have loads of energy, which they transfer from one store to another. They behave differently to sound waves – sound waves are longitudinal (imagine a coil of wire moving back and forth in a straight line), and radio waves are transverse (imagine shaking a slinky from side to side).



Waves are measured by their frequency - the number of cycles (you can picture this as rotations) the wave completes in a second. This is counted in Hertz (Hz) after our physicist friend Heinrich Hertz. Humans can hear waves that are approximately between 20 Hz and 15 kHz. The higher the frequency, the higher the pitch – 15 kHz (or 15,000 Hz) sounds like a very high note to us! For context, a middle C on a piano is 262 Hz. Dogs can hear approximately 40 Hz to 60 kHz. Bats emit calls from about 12 kHz to 160 kHz.

More about waves

Radio waves travel at between 3,000 and 300,000,000,000 cycles per second - or simply put, their frequency is between 3 kHz and 300 GHz. These frequencies are divided up into groups or 'bands' and assigned different uses based on the properties that the waves are best suited to – some waves can travel longer distances than others.

FM radio operates in megahertz (a million Hertz) or MHz. The numbers in, for example, Radio 1's address - 97.7 FM - refers to 97.7 MHz or 97,700,000 cycles per second. This is in the very high frequency (VHF) band.

FREQUENCY	DESCRIPTION
30 GHz – 300 GHz	Extremely high frequency (EHF)
3 GHz – 30 GHz	Super high frequency (SHF)
300 MHz – 3 GHz	Ultrahigh frequency (UHF)
30 MHz – 300 MHz	Very high frequency (VHF)
3 MHz – 30 MHz	High frequency (HF)
300 kHz – 3 MHz	Medium frequency (MF)
30 kHz – 300 kHz	Low frequency (LF)
3 kHz – 30 kHz	Very low frequency (VLF)
300 Hz – 3 kHz	Voice frequency
up to 300 Hz	Extremely low frequency (ELF)

UHF is used for television broadcasting, mobile phones, satellite communication including GPS, personal radio services including Wi-Fi and Bluetooth, walkie-talkies and other devices.

VHF is used for digital audio broadcasting (DAB) and FM radio broadcasting, television broadcasting, two-way land mobile radio systems, amateur radio and marine communications.

HF communications are best suited for long distance communication between ground operators and base stations.

MF is mostly used for AM radio broadcasting, navigational radio beacons, maritime ship-to-shore communication, and transoceanic air traffic control.

VLF is used for a few radio navigation services, government time radio stations and for secure military communication, including with submarines.

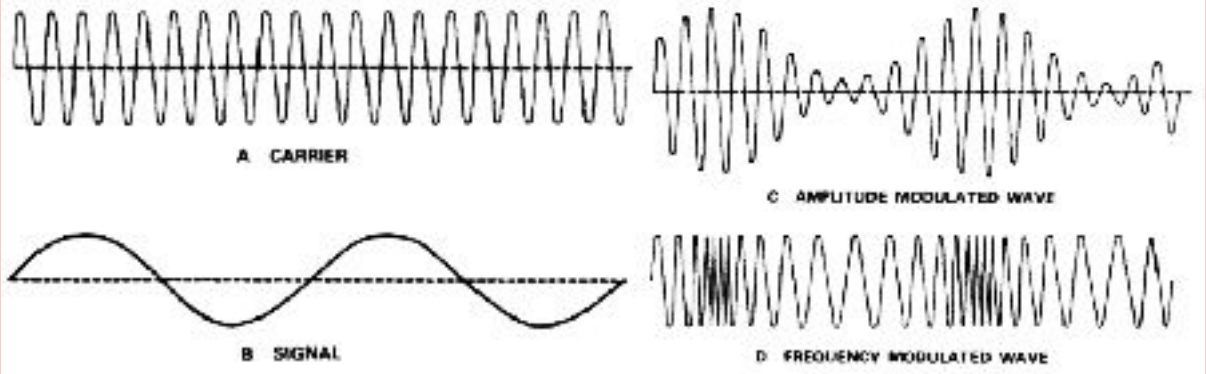
ELF signals have been used to order a submarine to rise to a shallow depth where it could receive some other form of communication

Transmission

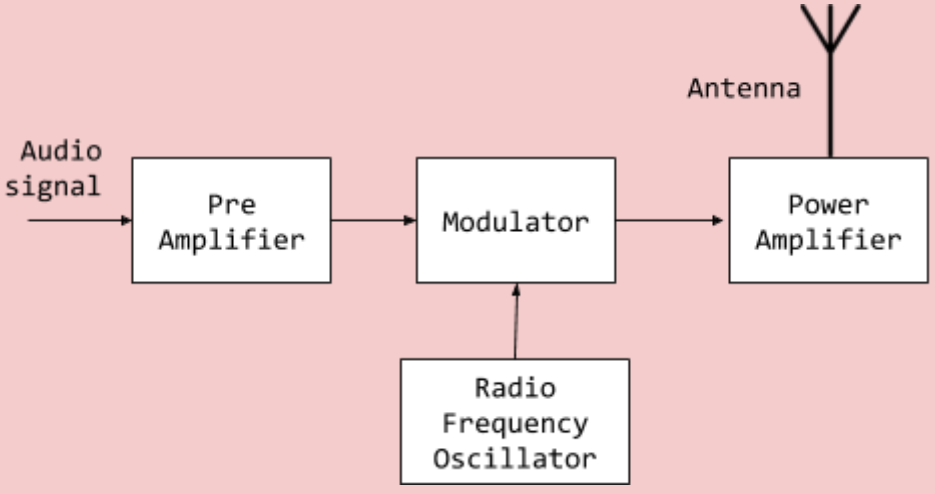
Radio waves by themselves do not contain audio information. They are like empty cars, which can be loaded up to carry audio by a process called modulation.

The FM in FM radio refers to a type of modulation called frequency modulation. In order to attach the audio signal to a carrier wave, the carrier wave is moved or 'oscillated' at the same frequency as the audio signal.

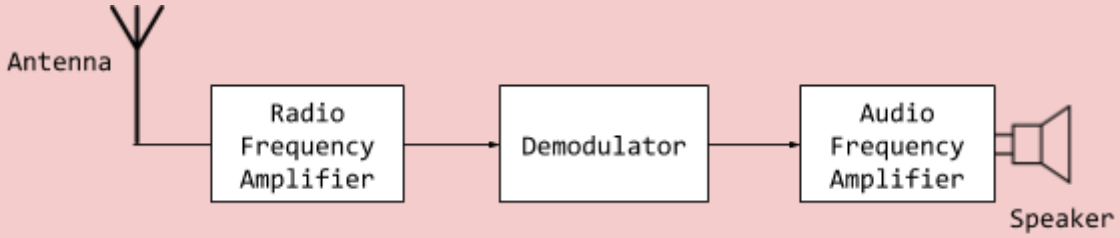
You may have also heard of AM radio - this refers to amplitude modulation. This is where a carrier wave is oscillated in time with the audio signal by amplitude rather than frequency.



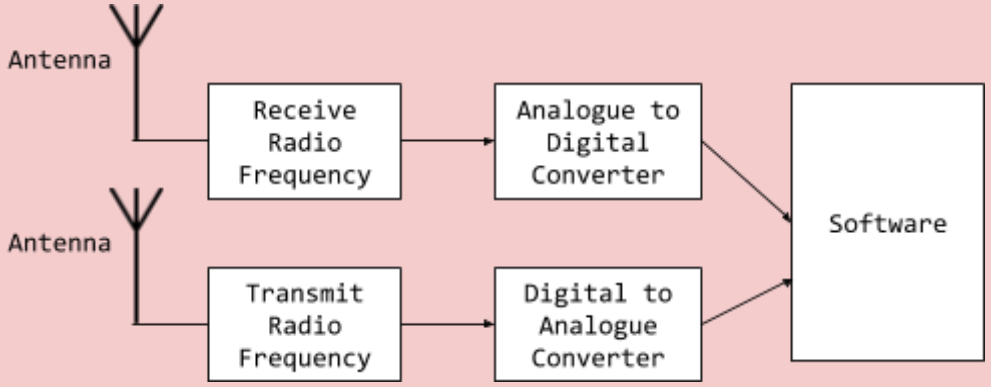
A radio frequency oscillator is a device which modulates the wave. The below block diagram shows the process by which an audio signal moves from a microphone into an audio amplifier to gain some power. It moves into a modulator - where it is met by radio frequencies which are oscillated (moved) in time with the audio signal in order to join them together. These radio frequencies, now loaded up with your audio, travel to a radio frequency (RF) power amplifier to draw more energy. Finally, they are sent through an aerial out to the world.



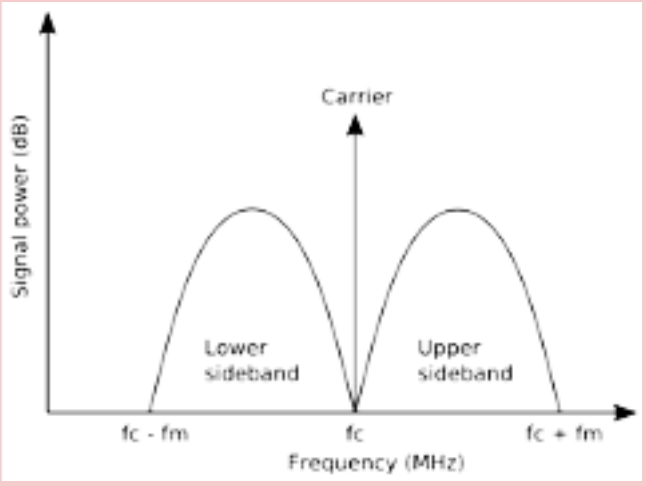
Once your modulated radio wave has travelled to the device wishing to receive it, it goes through a process to extract the audio signal from the carrier wave, so it can be understood by your loudspeaker. Your antenna receives the carrier wave and pulls it through to the frequency amplifier in your radio, where it is demodulated. You're left with the audio signal, which is amplified and sent through the loudspeaker.



In digital devices, the modulation and demodulation is done by software. For this to work, an analogue to digital converter (ADC) or digital to analogue converter (DAC) is used, as in this diagram.



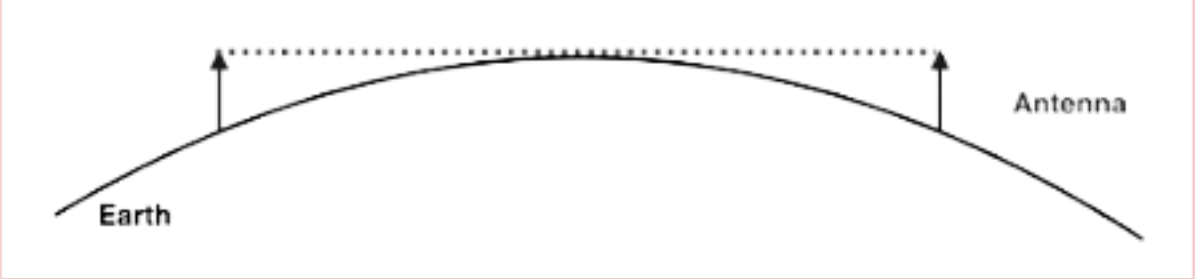
The radio wave is known as the 'carrier' and as a product of its modulation (being loaded with audio), creates two 'sidebands'. Each sideband is a mirror of the other and contains exactly the same audio signal as the carrier. You could actually remove both the carrier (which contains the strongest audio signal) and one of the sidebands and still be able to retrieve your audio, but using much less power. This is called single sideband transmission - or SSB.



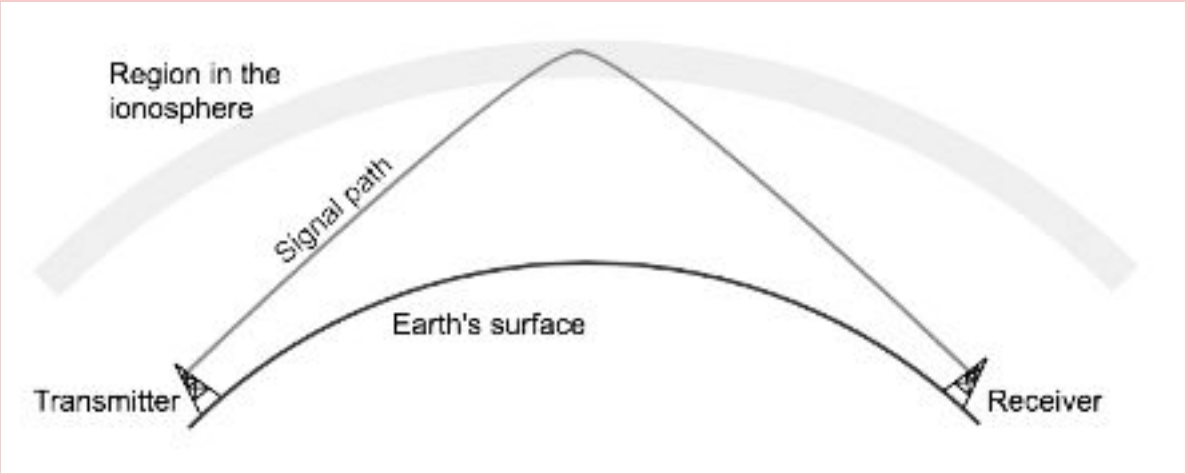
How radio travels

Radio waves can travel great distances. The way they behave when they travel is called propagation. Radio waves spread out from an antenna and can be diffracted over buildings and mountains. The waves can pass through buildings, and be reflected off smooth surfaces.

Line-of-sight propagation describes radio waves travelling in a straight line from antenna to antenna. As the name suggests, this is limited to the visual horizon, though depends on how high your transmitting and receiving antennas are positioned. Line-of-sight is used for medium range radio transmission including mobile phones, wireless networks, FM radio and TV.



Skywave propagation describes radio waves which can travel beyond the horizon by being bent (refracted) thousands of miles off the earth's ionosphere - a layer of ionised air between 70 and 400 km above the earth. Only high frequency (HF) or shortwave radio can use skywave propagation, so can travel very long distances in the right conditions. Skywave propagation is influenced by the time of day or night, the seasons, weather, and the sunspot cycle, and so can be unreliable.



Amateur radio

Amateur radio is a technical hobby, where enthusiasts can use an allocated part of the radio frequency spectrum to send and receive (non-commercial) messages, for wireless experimentation, for self-training, fun and contests. They may also manage emergency communications should other systems fail. In order to pursue the hobby, you must take an exam and obtain a license, to ensure that your experiments don't interfere with other radio communications. You can attend a course over a weekend, and provided you pass your exams to obtain your Foundation License, you'll soon be able to transmit and receive messages over the amateur bands. The course is the difficulty level of a GCSE.

Prior to getting my license, I produced this audio piece with Cambridge and District Amateur Radio Club so you can get a feel for the hobby:
https://soundcloud.com/soundarthannah/amateur-radio

Once you have your license, you can register with Ofcom for your 'call sign' - your unique identifier. My call sign is M7HKW - the M7 signifies I have a Foundation License based in England, and I chose the three letters following this for my call sign as they are my initials. The phonetic alphabet is used for clarity when making contact over the radio.

A	Alfa	J	Juliett	S	Sierra
B	Bravo	K	Kilo	T	Tango
C	Charlie	L	Lima	U	Uniform
D	Delta	M	Mike	V	Victor
E	Echo	N	November	W	Whiskey
F	Foxtrot	O	Oscar	X	X-ray
G	Golf	P	Papa	Y	Yankee
H	Hotel	Q	Quebec	Z	Zulu
I	India	R	Romeo		

In order to allow for all the different kinds of radio communications to take place across the radio spectrum without disrupting each other, the uses of frequencies and bands are agreed internationally by an agency of the United Nations known as the International Telecommunications Union (ITU). The UK Frequency Allocation Table is published on the Ofcom website, and it's a condition of the radio license that you must adhere to this, and not broadcast on frequencies outside of those allocated to amateur radio.

When you have set up your kit, you can scroll through the frequencies from your home station and make contacts (this is called a QSO) with radio amateurs around the world. You can do this by finding a frequency that isn't being used, and 'calling CQ' with your call sign.

A CQ call is a call out from a radio ham looking to make contact with another radio ham. In the UK, 145.5 FM is used as the amateur radio 'calling frequency' on the 2 metre band (144-148 MHz). It's a centre of activity where you're most likely to be heard and to make a 'contact'.

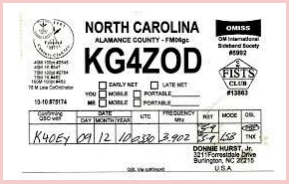
Here's what my CQ call would sound like:

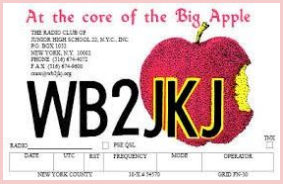
> 'CQ CQ CQ, this is M7HKW Mike Seven Hotel Kilo Whiskey, calling CQ'

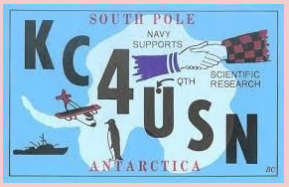
Hopefully, someone will answer and we can have a brief conversation. They might say:

> 'M7HKW this is M7LLL Mike Seven Lima Lima Lima do you copy?'
> 'M7LLL hello, my name is Hannah and I'm based in south London, over.'
> 'Hello Hannah, this is Lisa in Hampton, your report is 5 and 9, 59 over.'

Keeping contacts to this short formula is helpful when communicating internationally where there may be language barriers. The numbers 5 and 9 here denote a signal report - a scale that shows how clearly the transmission can be heard, with 5 as the top of the scale for readability, and 9 indicating the maximum signal strength. Signal reports are often recorded by radio hams on a log sheet. This is often as far as the conversation will go. Some radio hams enjoy testing their equipment to reach far across the world, and logging contacts made with distant places. Some post each other 'QSL cards' to mark the contact made.







If, in the example above, we wanted to have a longer conversation, we'd need to move away from the calling frequency. Meeting on the calling frequency is like meeting in a pub by the bar – you'd usually move from there into a quieter room so as not to clog up the bar space preventing other customers from ordering. Either of us would suggest a frequency to meet on, and then me and Lisa would congregate there a few seconds later. From the perspective of an artist interested in collaboration, the potential of amateur radio for international creative collaboration seems endless.

Some amateur radio enthusiasts communicate via telegraphy (textual messages) such as Morse code. There are also various data modes for different kinds of set ups. Shortwave radio is just buzzing with all kinds of activity.

WebSDR

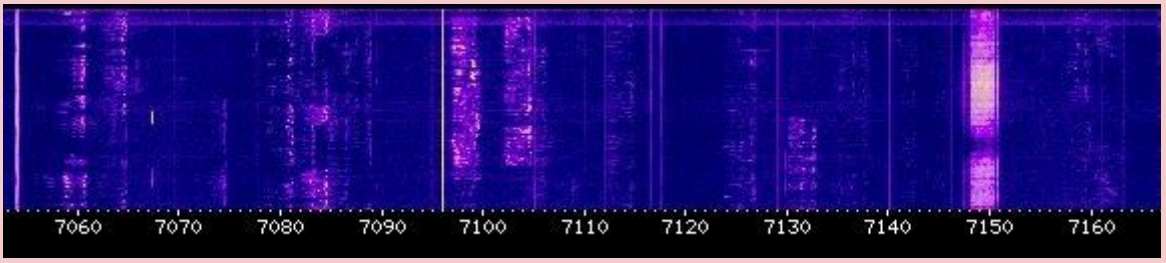
Though you may not be able to transmit messages without an amateur radio license, you can start to listen to shortwave radio online at any time! There are a number of WebSDR platforms you can find online for this purpose. These are software-defined radio receivers connected to the internet, allowing many users to listen and tune them simultaneously.

A full list of WebSDR platforms and the bands you can listen to on them, is located here: http://www.websdr.org/

Hack Green allows you to listen to the amateur bands online. It's located at the Nantwich Secret Nuclear Bunker, formerly R.A.F. Hack Green, now a working museum. http://hackgreensdr.org:8901

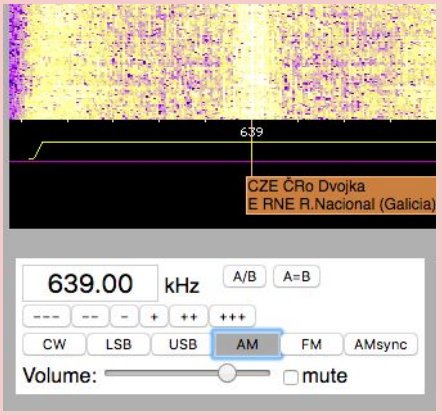
The University of Twente in Enschede, the Netherlands, hosts a short-wave receiver set up for general bands too: http://websdr.ewi.utwente.nl:8901/

When you enter one of these platforms, the first thing you'll notice is the 'waterfall display' pictured below. This shows the radio frequency along the bottom axis, and has vertical moving pink to yellow lines to indicate signals transmitting in real time.

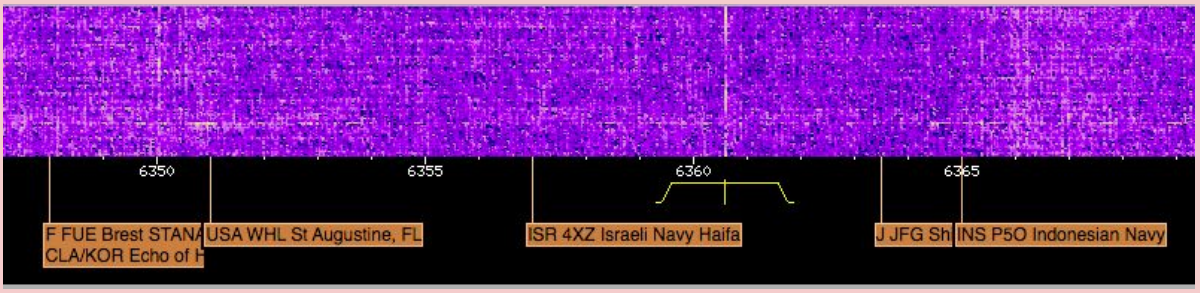


Underneath the waterfall display, you'll see some controls. The first thing to do is to use the controls to zoom in or max in. Then, you'll find it easier to select the frequencies you'd like to listen to.

You can start by typing a known frequency or 'address' into the controls. Using the University of Twente platform, try typing in 639 kHz, and selecting AM. Can you hear a radio broadcast from the Czech Republic? Nearby at 648 KHz you may be able to hear Radio Caroline. Though now licensed, this was a pirate radio station for 50 years based on a ship in the North sea.

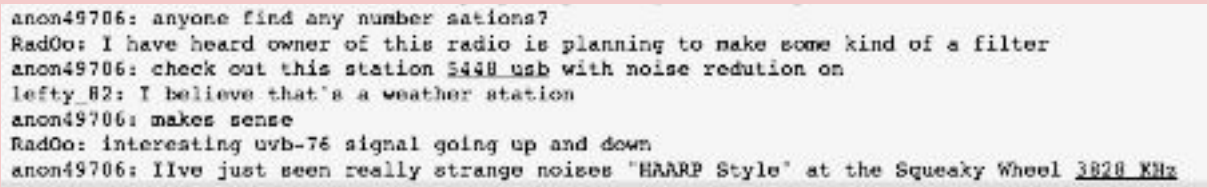


Use the waterfall zoom to navigate around the radio spectrum display. You'll see a yellow cursor moving around the bottom of your waterfall display that shows you where you are. Zoom in alot and you'll start to see orange labels with names of individual stations appearing. Try and position your yellow cursor to focus on one band or station.



You have options to listen in modes adapted for CW (continuous wave / Morse code). You'll notice that your yellow cursor has a central line – the signal, and an upper and lower sideband. These switch if you change the options in this controller between single sideband transmissions (LSB for lower sideband and USB for upper sideband), AM (amplitude modulated) or FM (frequency modulated) transmissions. You may find it helpful to use the noise reduction filters on your dashboard.

Listening to WebSDR may take some patience and experimenting, and depend on the time of day you are listening and other factors in skywave propagation. Explore the spectrum and see what you can hear. There's a chatbox where other visitors post links to frequencies on which they've found interesting activity.



You can also try using the Chilton receiver to listen to Shortwave radio. It's built to look like an analogue receiver, so don't forget to start with the Power button!
http://www.chilton.com/R8/receiver.html

Here's some tips from experienced radio amateur G4AWP at the Cambridge and District Amateur Radio Club:

VLF (very low frequency) - at a few kHz you may hear noises called 'whistlers' - created by lightning strikes or coded data signals to submarines.

LF (low frequency) - long wave broadcast stations such as BBC Radio 4 198 kHz, or the Irish broadcaster RTE at 252 kHz.

MF (medium frequency) - medium wave broadcast stations such as Radio Caroline at 648 kHz. During daytime hours you will hear it better from the University of Trente platform than from the Farnham platform. BBC Radio 5 live is at 693 kHz, and there are many other stations nearby.

HF (shortwave) - houses lots of amateur radio bands!

If you are listening in the **morning,** try using LSB between 3600-3780 kHz, where you are likely to find UK amateurs making CQ calls and contacts. During **daylight hours**, also using LSB, on 7180-7200 you may hear UK and Western European stations, and **later in the day** you will hear Eastern European, and perhaps Polish stations. **In the evenings**, using the Farnham SDR platform, you may hear USB signals from amateurs around 144300 kHz. **Amateur radio contests** take place here on the first Tuesday of each month between 8pm-10:30pm. You can also explore the UHF amateur band – another contest takes place on the second Tuesday of each month on USB around 432300 kHz. Also using the Farnham SDR set to 143049 kHz (Graves 143050 kHz near Dijon in mid-France just below the 2m amateur band) you may occasionally hear **'pings' off meteors** in the mornings. As meteors enter the atmosphere they ionise part of the atmosphere, which then reflects the radio signal.

Using USB, set your frequency to 7074 kHz and you will hear lots of tones switching on and off every 15 seconds. This is a **data mode called FT8**, where radio amateurs make CQ calls via text encoded by a computer, but limited to just 13 characters per message.
Morse code can be found at the lower end of the amateur bands. You will also find lots of CW (telegraphy such as Morse) between 7000-7070 kHz and 14000-14050 kHz.
For SSB stations further afield listen between 14150-14350 kHz (20m amateur band), and 18100-18168 kHz. You may hear some '**warbling tones**' around 14230 kHz - this will be SlowScan TV, a bit like a fax.

Glossary

Frequency - the amount of cycles a wave completes in a second, measured in Hertz. This also relates to the 'address' of a station, for example BBC Radio 4 can be found at 198 kHz.

Oscillate - to move or vibrate repetitively.

Modulate - the process of adding an audio signal to a carrier wave.

Carrier - a radio wave that is modulated so as to carry an audio signal.

Sideband - each of two frequency bands either side of the carrier wave, which contain the modulated signal.

USB - upper sideband.

LSB - lower sideband.

FM - encoding of audio signal in a carrier wave by varying the frequency of the wave.

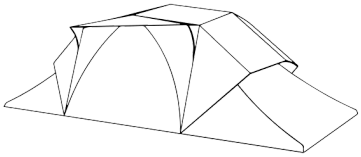
AM - encoding of audio signal in a carrier wave by varying the amplitude of the wave.

CW - continuous wave, mode of communications such as Morse code.

SDR - software-defined radio.

Hannah Kemp-Welch
http://sound-art-hannah.com/

Soundcamp
http://soundtent.org/



Southwark Council
southwark.gov.uk

Resonance EXTRA

Co-funded by the Creative Europe Programme of the European Union

LOTTERY FUNDED

Supported using public funding by
ARTS COUNCIL ENGLAND