

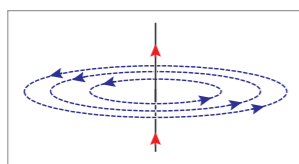


The beginning of radio

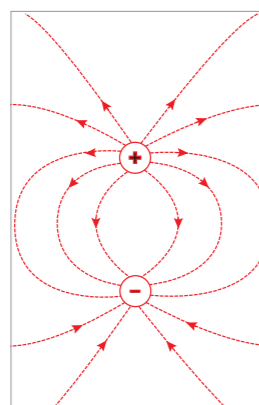
The first radio transmission was made in 1895. It did not carry audio signals (voice or music) but consisted of just short bursts of a fixed **radio frequency** using Morse code. **Morse code** had been in use from the 1840s to send messages via telegraph wires. The code consists of short and long pulses, commonly known as dots and dashes, and may be represented by electrical signals or flashes of light. For example, the code for 'S' is ••• and the code for 'O' is — — —. The code for SOS is therefore ••• — — — •••.

Magnetic and electric fields

An electric current in a conductor (e.g. a copper wire) produces a **magnetic field** around the wire. If the current is reversed then the magnetic field is also reversed. This effect, which was discovered by Ørsted in 1831, is easy to demonstrate.



The strength of the magnetic field decreases as the **cube** of the distance from the wire increases (if the distances are large compared with the length of the wire). For example, the magnetic field strength at a distance of one kilometre is a millionth of its strength at a distance of ten metres.

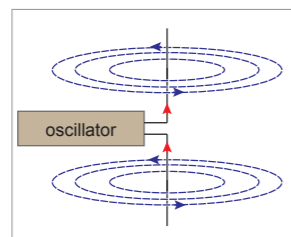


In a similar way, opposite electric charges have an associated **electric field**, the direction of which is designated as 'positive to negative', as shown in the diagram. If the charges are reversed then the direction of the electric field is reversed.

But how quickly are these effects propagated. Do the changes occur instantly or do they take some time to travel? Can the effects travel faster than light?

How is a radio signal transmitted?

Consider an **antenna** (aerial) made of two vertical conductors attached to variable voltage source as shown in the diagram. When it is switched on, almost instantly the top part becomes positively charged and the bottom part becomes negatively charged. In that brief instant while the charges are moving a magnetic field is set up. Once the charges are established no further charge moves (i.e. there is no longer any electric current) and so the magnetic field strength drops to zero.



Magnetic field of a dipole antenna

At the same time an electric field is set up between the positive and negative charges. This field is perpendicular to the magnetic field. If the aerial is vertical then the magnetic field is horizontal and the electric field is vertical; in this case the propagated wave is said to be **vertically polarised**.

If the voltage source is reversed then the magnetic and electric fields reverse. If this happens two million times per second then the aerial radiates alternating electric and magnetic fields, i.e. 'radio waves', at a frequency of one **megahertz** (1 MHz). These **electromagnetic waves** travel at the speed of light. (We now know that light itself is an electromagnetic wave.) Note that one full wave or oscillation involves two changes of direction.

From Morse code to analogue radio

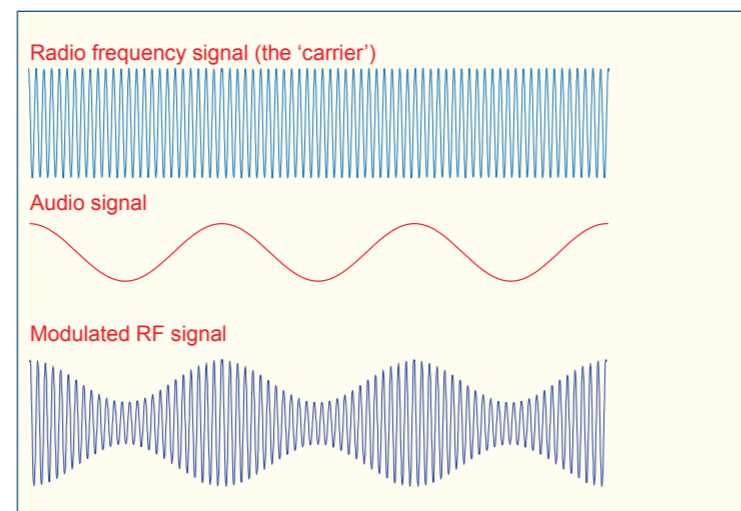
Maconi's original radio transmitters and receivers were intended to replace **wired telegraphy** with wireless telegraphy. His radio signals were detected by a relatively simple circuit which would activate an electromagnet or turn on a small light when a burst of radio frequency signal was picked up by a large receiving antenna. In 1897 he established a number of transmitters on the south coast of England for communication with ships.

In 1907 the first commercial transatlantic wireless telegraph service was set up by Marconi between stations in Clifden in Ireland, and Glace Bay in Newfoundland. The power of the Clifden transmitter was 150,000 watts.

Wireless voice communication was first demonstrated publicly in 1900 by Roberto Landell de Moura (in Brazil). In 1920 regular radio transmission for the public started; **broadcasting** had begun. Initially the audiences were small because relatively few people had radio receivers. **Crystal radios** could be bought or made but they required **headphones** and were little more than a curiosity. The BBC radio service began in 1922. Ireland's national radio station, known as 2RN, began broadcasting from McKee Barracks in Dublin, on 1st January 1926.

How can audio be transmitted?

Sound normally enters our ears as rapid air pressure variations. Audible frequencies range from about 16 Hz to 16,000 Hz. Sound is not electromagnetic; it is a propagated disturbance of a medium. In air it travels about 330 metres per second. In contrast, radio signals are electromagnetic; they do not require a medium and they travel at about 300 million metres per second. The frequency of radio signals ranges from about 100 kHz to beyond 1000 MHz.



So, how can sound be transmitted by radio? The simplest way to do it is to vary the strength (or amplitude) of the radio signal to match the variation in amplitude of the audio signal. This process is called '**amplitude modulation**' or AM. Note that the frequency of the transmitted radio signal is fixed; only its amplitude changes. A radio transmitter therefore does not actually transmit sound but only an inaudible electromagnetic wave. A radio receiver detects the radio frequency and from the variation in its amplitude it can reconstruct the audio signal.

Further developments

AM radio signals are prone to interference from electric motors, fluorescent lamps, electric cables and from other radio stations. During the 1950s a number of **frequency modulation** (FM) systems were evaluated and in 1961 one became the standard. FM radio requires more complex electronics in both the transmitter and receiver. However, the sound quality is generally better than AM and it can be used for stereo broadcasts.

One significant disadvantage of FM results from its higher frequency and consequent shorter wavelength than AM. (Remember that the wavelength = 300,000,000 ÷ frequency). Shorter waves **diffract** less around large objects such as mountains and so FM reception may be poor in valleys unless extra transmitters are installed. (This problem is more pronounced in the case of mobile phones, which use even shorter wavelengths.)

	AM radio	FM radio	TV	Mobile
frequency	200 – 1600 kHz	88 – 108 MHz	300 – 3000 MHz	900 MHz or 1800 MHz
wavelength	1500 – 19 m	3.4 – 2.8 m	1 – 0.1 m	34 cm or 17 cm

Table 1: Typical frequencies and wavelengths of radio signals

In the early 1930s a few different systems were devised to transmit moving images by means of radio waves; **television** was born. In 1936 the BBC began regular television broadcasts. RTÉ began broadcasting black and white TV in 1961 and by 1971 it was broadcasting colour TV (PAL).

The first communications satellite, Telstar 1, was launched in 1962. It could relay just one television channel or a number of phone calls. It did not provide a direct broadcast service to the public.

The digital revolution

Direct digital satellite broadcasting began in the late 1980s. The satellites involved were placed in geostationary orbits and so the receiving dishes can be placed in fixed positions.

In the 1990s **digital terrestrial** TV (DTT) broadcasts began. Initially the service was experimental and operated alongside the analogue TV transmissions but it gradually replaced the older system. In the European Union analogue TV broadcasts were phased out in 2012.

The main advantage of digital transmission is that several TV channels can be broadcast on one frequency at the same time and so more efficient use is made of the available **bandwidth**.



ComReg is the statutory body responsible for the regulation of the electronic communications sector (telecommunications, radiocommunications and broadcasting transmission) and the postal sector. Its remit covers all kinds of transmission networks including:

- Traditional telephone wire
- Television and radio frequencies
- Radiocommunications including fixed wireless
- Mobile operators providing voice and data services
- Satellite services

ComReg enables competition in the communications sector by facilitating market entry for networks and services and by regulating access to networks so as to ensure that consumers, both business and residential, have choice in the services which they wish to use. In a rapidly evolving sector, both in technological and commercial terms, ComReg provides the framework for the introduction of new services such as next generation mobile to support smartphones and similar applications.

Encouraging innovation is also a key role for ComReg. This covers both regulatory innovations, such as implementation of market reviews under the new European regulatory framework, and technical innovations. On the radio spectrum side the role involves development of strategies for management and use of the radio spectrum, new initiatives in the wireless licensing area, and the promotion of Ireland as a test bed for innovative uses of spectrum (See Test & Trial Ireland at www.testandtrial.ie). ComReg publishes the following websites, offering a wide range of information and advice to users.

Advice for communications consumers
www.askcomreg.ie

Interactive guide on phone and broadband pricing
www.callcosts.ie

Information on Premium Rate services
www.phonesmart.ie

Statistical information on the Irish electronic communications market
www.comstat.ie

Find out more about the work of ComReg at www.comreg.ie

Find this and other lessons on www.sta.ie



Syllabus references

The main syllabus references for the lesson are:

Leaving Certificate Physics (pp. 30-33)

- Wave phenomena: reflection, refraction, diffraction, interference, polarisation. Everyday examples, e.g. radio waves, waves at sea, seismic waves.
- Longitudinal and transverse waves: frequency, amplitude, wavelength, velocity. Relationship $c = f\lambda$.
- The electromagnetic spectrum: Relative positions of radiations in terms of wavelength and frequency.
- Polarisation of transverse waves: Demonstration of polarisation (of light) using polaroids or other suitable method.

Science and Technology in Action is also widely used by Transition Year classes.

Learning Outcomes

On completion of this lesson, students should be able to:

- explain the general principles of radio frequency transmission
- calculate the wavelength of an electromagnetic wave given the frequency, and *vice versa*
- explain what is meant by amplitude modulation
- outline the advantages and disadvantages of using higher radio frequencies.

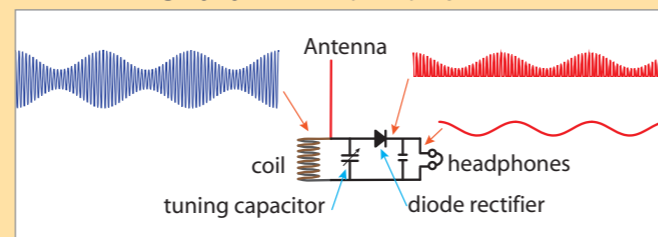
General Learning Points

These are additional relevant points which are used to extend knowledge and facilitate discussion.

- An electric current in a conductor has an associated magnetic field. When the current stops the magnetic field disappears, but the effect takes time to propagate.
- Opposite electric charges have an associated electric field.
- If an alternating potential is applied to an aerial it radiates electromagnetic waves.
- The first radio transmitters were used to send messages (telegrams) using Morse code.
- Radio signals are electromagnetic and so cannot be heard. In order to transmit speech or music the radio signal is modulated either in amplitude or frequency.
- Satellites are now used to relay television, radio, phone and fax messages.

Student Activities

- In the early days of radio broadcasting (1920s) so called "crystal sets" were commonly used to pick up the transmissions. Apart from headphones these devices typically had just three components: a coil of insulated wire, a capacitor and a crystal which acted as a diode. Find out more about crystal radios on websites such as: https://en.wikipedia.org/wiki/Crystal_radio
The coil + capacitor (in parallel) acted as a 'tuned circuit' which would respond best to one frequency. The diode rectified the alternating radio frequency oscillation which could then be 'smoothed' slightly by a second (small) capacitor.



Make a poster that illustrates the operation of a crystal radio. Note that the basic principles of tuned circuits apply to modern radio and television receivers, mobile phones and wifi communication.

- On the following website there is a table of radio transmitters in the Munster area. The power of some transmitters is over 100,000 watts while others are around 20 watts. What do you notice about the location of the high power transmitters?
http://homepage.eircom.net/~fm_radio/munsterFM.html

True/False Questions

- | | |
|---|-----|
| a) The first radio transmission was made in 1875. | T F |
| b) Radio wavelengths are typically less than 1 mm. | T F |
| c) The direction of polarisation of electromagnetic waves is that of the electric field. | T F |
| d) A radio antenna radiates electric and magnetic fields. | T F |
| e) Radio signals do not travel as fast as light. | T F |
| f) The frequency of AM broadcasts is generally much lower than the frequencies used for FM. | T F |
| g) AM broadcasts are being phased out because they are not as effective in mountainous areas. | T F |
| h) The wavelength of a 1 MHz electromagnetic wave is 300 metres. | T F |
| i) Digital broadcasting makes more efficient use of the available bandwidth. | T F |

Check your answers to these questions on www.sta.ie.

Examination Questions

Leaving Certificate Physics (OL) 2002 Q. 7

The following table gives examples of electromagnetic waves and their typical wavelengths.

wave	radio	micro-wave	infrared	light	ultraviolet
wavelength	100 m	0.1 m	1 μ m	600 nm	10 nm

- Name one property that all of these waves have in common.
- What is the frequency of the radio waves?
- Describe how infrared radiation can be detected.
- Give two uses of microwaves.

The speed of light is 3×10^8 m s⁻¹. ($c = f\lambda$)

Leaving Certificate Physics (HL) 2006 Q. 12 b

The diagram shows the relative positions of electromagnetic radiations in terms of their wavelength.

gamma rays	A	UV	light	IR	micro-waves	B
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- Name the radiations marked A and B.
- Give one property which is common to all electromagnetic radiations.
- Which one of the radiations has the shortest wavelength?
- Describe how IR radiation is detected.
- Give one use for microwaves.

Leaving Certificate Physics (HL) 2005 Q. 6

A satellite transmits radio signals to earth. At a particular time the satellite is 1.2×10^{12} m from Earth. How long does it take the signal to travel to earth? It is noticed that the frequency of the received radio signal changes as the satellite orbits Saturn. Explain why.

(universal gravitational constant = 6.7×10^{-11} N m² kg⁻²; mass of Saturn = 5.7×10^{26} kg; speed of light = 3.0×10^8 m s⁻¹)

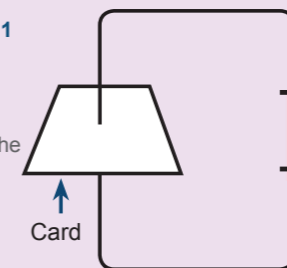
Leaving Certificate Physics (HL) 2004 Q. 5 (f)

What is meant by polarisation of waves?

Junior Certificate Science (HL) 2005 Q. 1

(j) The diagram shows a current carrying wire passing through a card.

Show a magnetic field line on the card in the diagram with direction clearly indicated.



Did You Know?

- The original use of the term "broadcasting" was in agriculture. Many crop plants are sown in rows or drills to facilitate harvesting. However, grass seeds are generally scattered more widely and randomly — a practice known as broadcasting.
- Telephone calls are usually 'one to one' and are bidirectional. In contrast, radio and TV broadcasting is a 'one to many' process and is unidirectional.
- The Athlone radio transmitter was opened in 1932, broadcasting on 567 kHz (i.e. in the m'medium wave' band). Its name was changed from Radio Athlone to Radio Éireann in 1937. It was replaced by the Tullamore transmitter in 1975. That too was switched-off in 2008. The only remaining AM broadcast by RTÉ (at least until 2017) is on 252 kHz (longwave) transmitting from Clarkstown, Co Meath.

Biographical Notes

Reginald Fessenden 1866 - 1932

Reginald Fessenden was born in Quebec, Canada, in 1866. At the age of fourteen he was employed as a mathematics teacher for the younger pupils while he was studying in the University.



At the age of twenty he applied for a job with Thomas Edison and, though he was turned down at first he was eventually successful. He gained valuable practical experience there. When he was 24 he was appointed professor of Electrical Engineering at Purdue University.

In 1898-99 he successfully developed a wireless telephone system. When he learned of Marconi's work he realised that he could make a much more efficient system. In 1900 he began work for the US Weather Bureau to set up radio stations to transmit weather data. He received hundreds of patents for his inventions, including the continuous wave transmitter. In January 1906 he succeeded in making the first two-way transatlantic transmission of Morse code.

Revise The Terms

Can you recall the meaning of the following terms?

Revising terminology is a powerful aid to recall and retention.

aerial, amplitude modulation, antenna, bandwidth, broadcasting, crystal radio, cube, diffract, digital terrestrial, direct digital satellite, electric field, electromagnetic waves, frequency modulation, headphones, magnetic field, megahertz, Morse code, radio frequency, television, vertically polarised, wired telegraphy

Check the Glossary of terms for this lesson on www.sta.ie