Commission for Communications Regulation

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12th edition

Short Range Radio Device Communications

Radio transmission

Radios and TVs pick up and process ***radio waves***, i.e., ***electromagnetic waves*** typically ranging in frequency from 30 ***Hz*** to 30 ***GHz***. Such ***broadcasts*** require high ***power*** transmitters. Most of the RTE radio transmitters operate at 200,000 ***watts*** (i.e. 200 ***kW***) while the power of some local radio transmitters may be as low as 10 watts.

In Ireland (as in most countries) a person must obtain a licence for radio transmission. The type of licence depends on the application (mobile phone, amateur radio, air traffic services etc.). The licence specifies the maximum power and the frequency ranges or '***bands***'.

However, no licence is required for certain transmissions that we take for granted today. For instance, a mobile phone must be able to transmit radio signals as well as receive them. Mobile phones operate in specific radio frequency bands and their power is less than 0.4 W.

A smart phone may also have ***WiFi*** capability, that is, it uses a specified communications ***protocol*** and transmits radio signals at low power (generally less than 0.1 W). WiFi therefore has a ***short range*** — typically less than 100 metres.

What are SRDs?

Today SRDs or '***short range (radio) devices'*** are in common use. Below are some examples, together with their allocated frequencies:

- wireless local area networks (***WLAN***s) including Wi-Fi — 5 bands in range: 2.4 − 5.9 GHz
- ***Bluetooth*** devices — 2.4 − 2.4835 GHz
- car door openers, automatic gates — 433 MHz
- baby alarms — 2.4 GHz
- wireless microphones — 5 bands in range: 470 MHz − 1800 MHz
- ***RFID*** tags (Radio Frequency Identification) — 13.56 MHz
- Near-field communication (***NFC***) — 13.56 MHz

These devices use low power ***RF*** (radio frequency) in specified RF bands. They are not likely to cause harmful interference to other networks or to essential public services and so no licence is required for their use.

What are electromagnetic waves?

We take light for granted. At the flick of a switch we can turn on an electric lamp. The shape of shadows lead us to think that something is coming from the lamp and it seems to travel in straight lines. We can reflect light with a mirror and ***refract*** it with a lens.

In 1678 Christiaan Huygens explained the properties of light in terms of waves of some sort. In 1690 Isaac Newton tried to explain the properties of light in terms of little particles or 'corpuscles' as he called them. However, around 1804 Thomas Young demonstrated ***diffraction*** and ***interference*** of light — properties that are characteristic of waves. The wave theory of light was then universally accepted. But nobody knew what was actually waving.

In 1831 Michael Faraday discovered ***electromagnetic induction***, i.e the generation of electricity using a magnet and a conductor. Faraday thought that light might have electrical or magnetic properties and after years of trial and error he was eventually successful. He published his findings the following year (1845). This was a remarkable discovery. Indeed, many people today would not expect light to be affected by a magnet.

An electric current in a straight conductor produces a circular ***magnetic field*** which gets weaker with distance. An ***alternating current*** produces an alternating magnetic field. But does this field appear the instant the current starts or does it take time to travel?

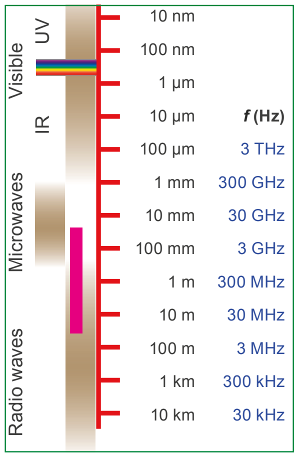
In the 1850s James Clerk Maxwell began to consider such questions. He produced a very comprehensive theory of ***electromagnetic waves*** and calculated that they should travel at a speed of approximately 300,000,000 metres per second. This led him to propose that light was in fact an electromagnetic wave.

Maxwell's theory (1867) described the propagation of electromagnetic waves — including radio waves. Twenty years later Heinrich Hertz first demonstrated the propagation of radio waves.

Types of electromagnetic waves

A conductor carrying a current alternating one million times per second (i.e. at one megahertz or 1 MHz) radiates electromagnetic waves whose wave length is 300 metres. At a frequency of 300 MHz the wavelength would be just 3 metres. The higher the frequency, the shorter the wavelength. (Their product is 300,000,000, i.e. the speed of light in m s^{-1}.)

The table shows the part of the ***electromagnetic spectrum*** used by SRDs.



Radio

How can electromagnetic waves carry information? For example, an ***FM*** radio station (e.g. RTE Radio 1 on 88.5 MHz) transmits a RF signal centred, in this case, on 88.5 MHz. Its frequency is varied or '***modulated***' continuously to match the variation in the audio signal that it 'carries'. An FM radio (receiver) detects the '***carrier***' (i.e. the RF signal) and generates an audio signal from the variation in its frequency. The communication is in one direction only.

SRDs

A **wireless car door 'key'** contains an RF transmitter; when activated it transmits a signal that carries a unique ***digital code***. A receiver in the car pick up and decodes the signal and if the code is correct it responds by locking or unlocking the doors. This communication is in one direction.

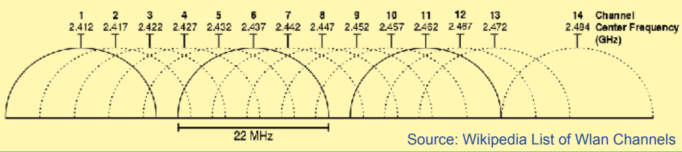
RFIDs, on the other hand, use ***bidirectional*** communication. RFID tags do not have batteries and are powered by the RF signal that is sent from the tag reader. The tag responds by sending the required information which is picked up and decoded by the reader. In contrast to ***barcodes***, RFIDs do not require line of sight. For example, a hand held RFID reader can scan up to fifty items of clothing on a shelf in one second and record all their details. Some RFID tags contain memory chips and can be updated by the tag reader. The following are some applications of RFIDs:

- Identification of goods entering of leaving a premises
- Personal identity tags with access control
- Monitoring of runners at specified points in a race
- Laundering of work clothing (and recording number washes)

Short Range Radio Device Communications

The majority of Irish homes get Internet access via ***wireless routers***.[1] Communication between a wireless router and any smart connected device is ***bidirectional***. Both devices contain a transmitter and a receiver and so can 'talk' to one another. The communication is complex and the data rate is very high (e.g. 600 ***Mbps***). Each device can detect errors in the received ***packets*** of data and 'request' that be sent again. At the same time the router may be communicating with several other local devices and with remote computers via the worldwide web.

Wireless routers use 2.4 GHz and 5 GHz ***bands*** (2400 MHz & 5000 MHz). As the word 'band' implies, each of these is not single frequency but a range of frequencies that is divided into several '***channels***'. A dual-band router can use both of these bands. The diagram shows how the 2.4 GHz band is divided into 14 channels, many of which overlap; each band is 22 MHz wide. A router can send large amounts of data very quickly by using several channels at the same time.



Source: Wikipedia List of Wlan Channels

Bluetooth is a lower power, bidirectional wireless communication system that also uses the 2400 MHz band but divides it into 79 channels, each of which is just 1 MHz wide or 40 channels that are 2 MHz wide. Bluetooth divides the data to be transmitted into packets that are sent on different channels. The receiving device reassembles the data in the correct order. The maximum transmission speed is 50 Mbps and the range is typically about 10 metres. Bluetooth applications include:

- smart watches, headphones, earbuds, home audio systems
- hands-free mobile phone answering (in car)
- printing from mobile devices (phone, tablet etc.)
- transfer of images from digital cameras.

The future and the 'Internet of Things'

The rapidly expanding use of SRDs enables many domestic and commercial devices to communicate with one another. This '***Internet of things***' (IoT) with embedded communications technology brings with it the possibility of so-called smart homes, intelligent transportation and smart cities. Appropriate standards and operating protocols are being developed to help support the various IoT uses mentioned above. It is estimated that by 2020 there will be around 50 billion connected devices

[1] *According to ComReg in its key quarterly report for Q2 2016 there were 1,330,946 fixed broadband subscriptions (an increase of 0.7% from Q1 2016 and an increase of 3.9% compared to Q2 2015). Most such subscriptions rely on the use of wireless routers.*

Regulation

In Ireland, the technical criteria for the operation of SRDs on a licence-exempted basis is set out in ComReg document 02/71R9 (www.comreg.ie/media/dlm_uploads/2015/12/ComReg15131.pdf) and all SRDs placed on the Irish market are required to comply with this.

In Europe, the radio spectrum requirements for SRDs are being considered by an expert group of radio frequency managers. The group will assist and advise on the future radio spectrum needs of IoT.

Commission for Communications Regulation

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 the spectrum (See Test & Trial Ireland at www.testandtrial.ie).

ComReg's expertise in the wireless sector is widely recognised. In the recent past ComReg has chaired the high level advisory group to the European Commission, the Radio Spectrum Policy Group, as well as the Body of European Regulators for Electronic Communications. In addition, for the second year in a row, ComReg was awarded the Business in Excellence for Research and Development for its Test and Trial Ireland service. That award honours the valuable contribution and difference that ComReg makes to wireless innovation in Ireland.

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

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Syllabus References

The main syllabus references for the lesson are:

Leaving Certificate Physics (pp. 30-33)

- Wave phenomena: reflection, refraction, diffraction, interference, polarisation.
- Diffraction effects: at an obstacle and at a slit with reference to significance of the wavelength.
- 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.

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:

- outline the key discoveries that led to the development of wireless communication
- outline how radio waves are propagated
- calculate wavelengths and frequencies
- explain what is meant by 'SRD'
- describe some common SRD applications
- distinguish between broadcast radio and SRD
- give examples of unidirectional and bidirectional SRDs.

General Learning Points

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

- Radio waves form the long wavelength part of the electromagnetic spectrum. The shortest wavelength radio waves are called microwaves (1 mm to 1 m).
- Light is also electromagnetic but has much shorter wavelength than radio waves ($<1 \times 10^{-6}$ m).
- Electromagnetic waves travel at the speed of light. (3×10^{8} m s^{-1})
- Short range devices (SRDs) are digital communication devices that operate at low power (< 1 W). No licence is required for their normal use.
- Common SRDs applications include Bluetooth, RFID tags (Radio Frequency Identification), Near-field communication (NFC) and wireless local area networks (WLANs).
- It is estimated that by 2020 there will be around 50 billion connected devices — that is many times more than the global population.

Student Activities

1. Using a microwave oven and an egg it is possible to estimate the wavelength of microwaves as follows.
   - Remove the turntable device.
   - Crack the egg and separate and retain the egg white. This should be gently mixed (not whisked) to make it as uniform as possible.
   - Spread the egg white evenly on the glass microwave oven plate and place it in the microwave oven. Cook it at full power for about 30 seconds. Stop the cooking as soon as you see cooked patches appearing.
   - Measure the distance between the centres of adjacent pairs of cooked spots. This would be expected to be about 6 cm.
   - The cooked spots indicate the positions of the antinodes of the microwaves; this is half the wavelength.
   - Use the relationship $c = f\lambda$ to calculate the frequency. (This is typically 2,450 MHz.)
2. Investigate possible medical applications of SRDs such as:
   - wireless monitoring of patient vital signs in hospital
   - home monitoring of people with chronic diseases
   - programmable implants (e.g. pacemaker).
3. Investigate current applications of RFIDs, including:
   - event ticketing
   - tracking goods
   - security (anti theft).
4. What future uses can you envisage for RFIDs?

True/False Questions

a)	TV signals are in fact radio waves.	**T F**
b)	The frequency of radio waves ranges from 30 Hz to 30 MHz	T F
c)	A licence is required to broadcast radio signals.	T F
d)	SRDs signals are confined to specified radio bands.	T F
e)	The power of SRDs is about 10 watts.	T F
f)	WiFi is a particular SRD application.	T F
g)	Credit card transactions can be carried out using Near-field communication (NFC).	T F
h)	Isaac Newton discovered radio waves in 1690.	T F
i)	Light waves are electromagnetic.	T F
j)	RFIDs can transmit radio signals.	T F
k)	An alternating current produces an alternating magnetic field.	T F
l)	Bluetooth devices transmit on one radio frequency band.	T F

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

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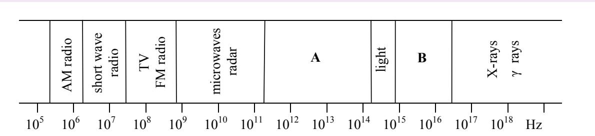
Examination Questions

Leaving Certificate Physics (HL) 2015, Q. 6

a) The diagram shows a simplified version of the electromagnetic spectrum. Name the sections labelled A and B in the diagram.



b) Describe how to detect each of these radiations.

c) An electromagnetic radiation has a wavelength of 4 m. Name the section of the electromagnetic spectrum in which this radiation is located.

d) Distinguish between interference and diffraction. Can a diffraction grating which diffracts light also diffract X-rays? Justify your answer.

e) Light travels as a transverse wave. Name another type of wave motion and give two differences between these two types of wave motion.

Leaving Certificate Physics (OL) 2009, Q. 5 d

Calculate the wavelength of a radio wave whose frequency is 252 kHz.
($c = f\lambda$, $c = 3.0 \times 10^8$ m s^{-1})

Leaving Certificate Physics (OL) 2003, Q. 12 b

The diagram shows a simple form of the electromagnetic spectrum, with wavelength increasing from left to right.

short wavelength	⟶	long wavelength
gamma rays	light	radio waves

Copy this diagram and indicate on it the positions of the following: microwaves; infrared; ultraviolet; X-rays.

Leaving Certificate Physics (HL) 2015, Q. 6

A Global Positioning Systems (GPS) receiver can calculate its position on Earth to within a few metres. It picks up radio-wave signals from several of the 32 GPS satellites orbiting the Earth. GPS satellites orbit the Earth in Medium Earth Orbit (MEO) with a period of 12 hours.

Calculate

(i) the height of a GPS satellite above the Earth's surface

(ii) the speed of a GPS satellite

(iii) the minimum time it takes a GPS signal to travel from the satellite to a receiver on the surface of the Earth.

Explain why GPS satellites are not classed as geostationary satellites.

Radio-waves, such as those used by GPS satellites, have the lowest frequency of all electromagnetic radiation types. What type of electromagnetic radiation has the next lowest frequency?
(mass of Earth = 5.97×10^{24} kg; radius of Earth = 6371 km)

Did You Know?

Frequency Hopping

- As the name implies, frequency hopping is a radio technology in which the transmitter does not use a single frequency but 'hops' between many different frequencies in a particular range. This makes it difficult for someone using a radio receiver to 'listen in' unless they know the sequence of frequencies in advance.
- There are a few different implementations of frequency hopping in common use today. In the case of FHSS (Frequency Hopping Spread Spectrum) the frequency switches between 79 frequencies (or 'channels') in a seemingly random manner hundreds of times every second. Early versions of Bluetooth used this technique.
- Since 2003 Bluetooth devices use AFH (Adaptive Frequency Hopping). For example, in a room in which a wireless local area network (WLAN) is in use a Bluetooth device adapts by avoiding frequencies that clash with those used by the WLAN router.

Biographical Notes

Charles Walton (1921 – 2011)

Charles Walton grew up in Maryland and New York State. He graduated in 1943 with a degree in Electrical engineering, and later received a master's degree. Initially he worked with the US Army Signal Corps and later with at IBM's research and development laboratories until 1970. He then set up his own company (Proximity Devices) to manufacture devices based on his patents.

Although he registered more than 50 patents his fame rests on one in particular 1973 patent -- a 'portable radio frequency emitting identifier'. Many of his inventions took a long time to catch on and in some cases the patent had already expired. As a result he did not profit from some of his inventions.

Charles Walton is best known as the first patent holder for the RFID (radio frequency identification) device. Although others contributed to the invention Walton was awarded ten patents in all for various RFID-related devices. His 1973 design for a "Portable radio frequency emitting identifier" was awarded a patent in 1983; it was the first device to be specifically called an RFID.

Revise The Terms

Can you recall the meaning of the following terms?
Revising terminology is a powerful aid to recall and retention.

alternating current, bands, barcodes, Bluetooth, broadcasts, carrier, channels, diffraction, digital code, electromagnetic induction, electromagnetic spectrum, electromagnetic waves, FM, GHz, Hz, interference, Internet of Things, kW, magnetic field, Mbps, modulated, NFC, packets, power, protocol, radio waves, refract, RFID, short range, SRD, watt, WiFi, wireless routers, WLAN.

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