3C5 Telecommunications

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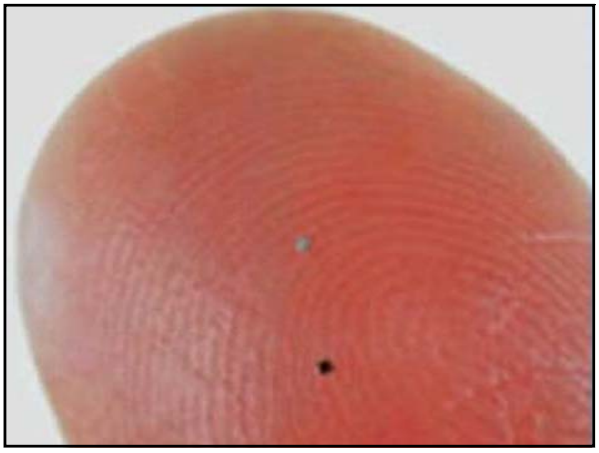
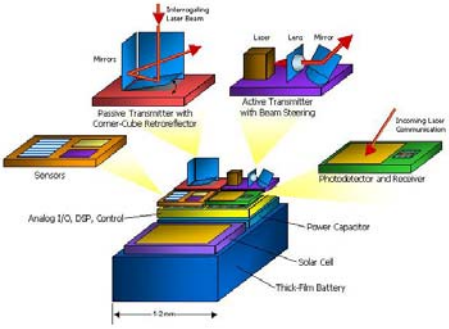
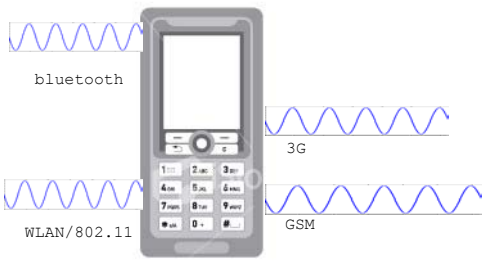
what do radios look like?

mobile phones

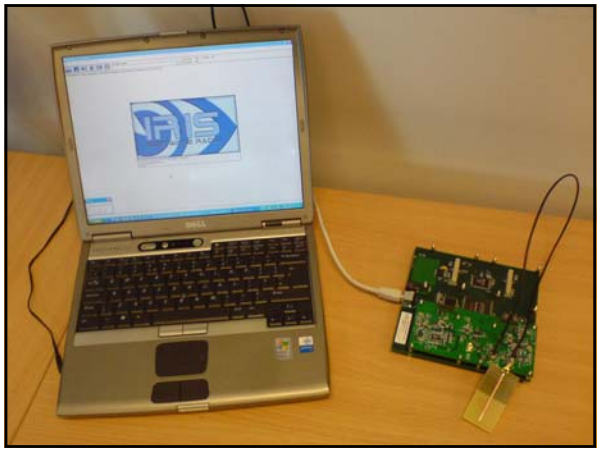
talk is cheap …..

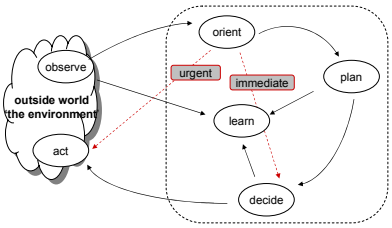


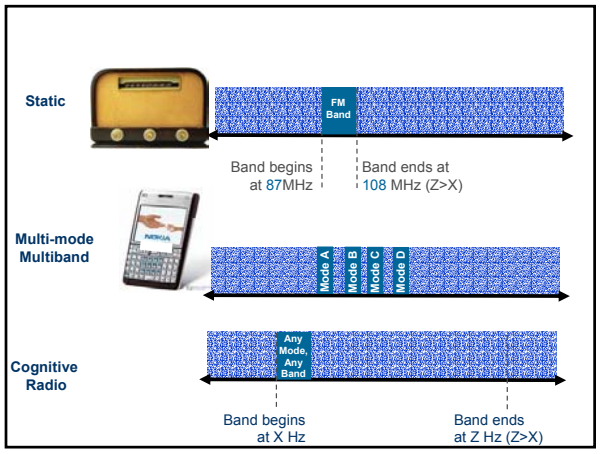




4 radios in one handset!







point of learning

- digital radios look very different
- but you will go on to recognise that there are common components in all radios
- to do this lets look at the general broad job of the radio

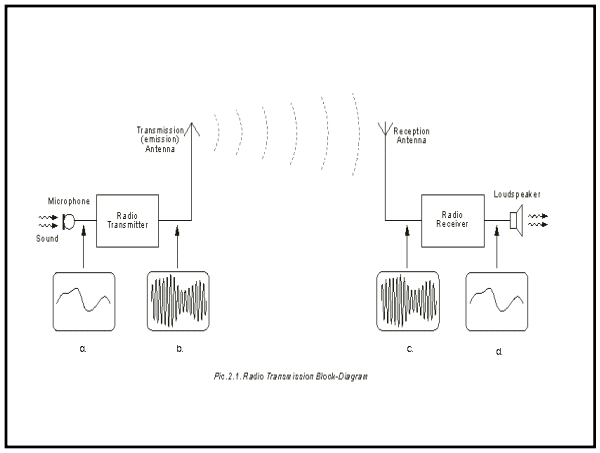
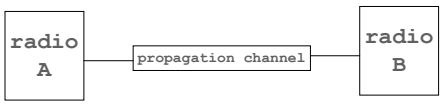


Fig. 2.1. Radio Transmission Block-Diagram

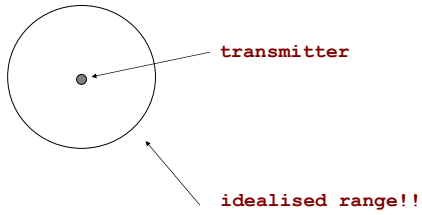
two radios connected



signals propagate from one radio to another using radio waves

different radio systems work at different frequencies

- Essentially radio waves travel between source and destination from one radio to another and all sorts of things happen to the radios along the way.
- There are more complicated equations for describing what happens to them than free space loss – which we are not looking at.
- There are really complex ways of doing propagation modelling – radio engineers use these to plan networks
- While we do not need to know exactly what happens it is useful to get a sense of how radio waves behave.



Free Space Loss = 32.45 + 20log(d) + 20log(f) dB (where d is in km and f is in MHz)

DIGITAL SHELTER KIT Pedro Sepúlveda (1999)

acknowledgements

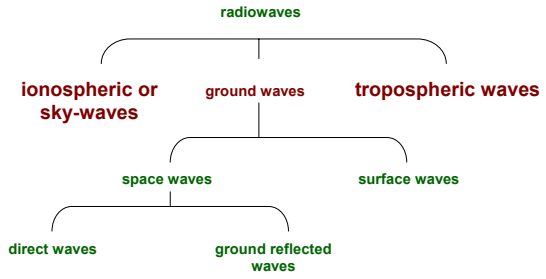
The following slides include text borrowed from the sources below and general comments from me.

1. Phil Weiser and Dale Hatfield, Policing the Spectrum Commons, Fordham Law Review, Volume 74
2. David Parsons, The Mobile Radio Propagation Channel, Pentech Press, London 1992

key learning point

waves of different frequencies travel in different ways

Modes of Radiowave Propagation



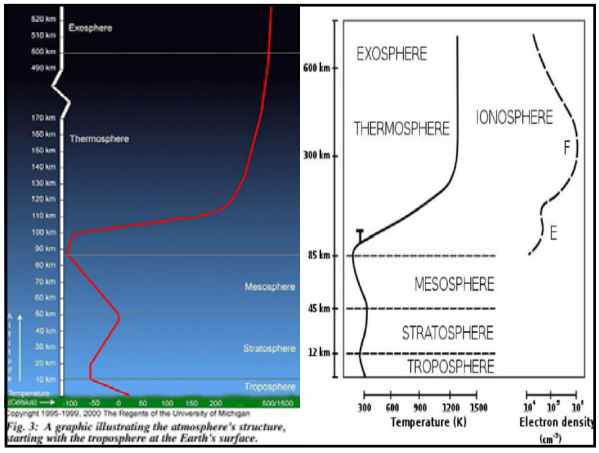
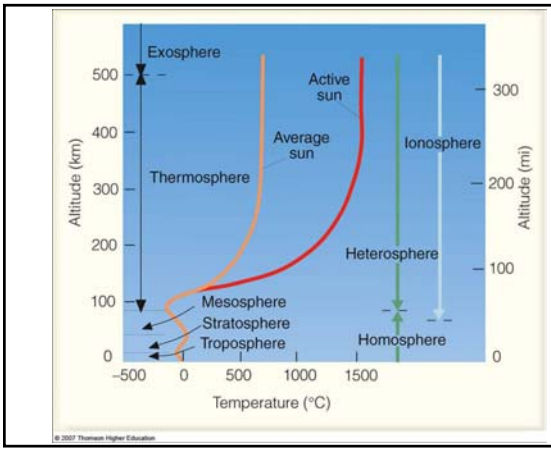
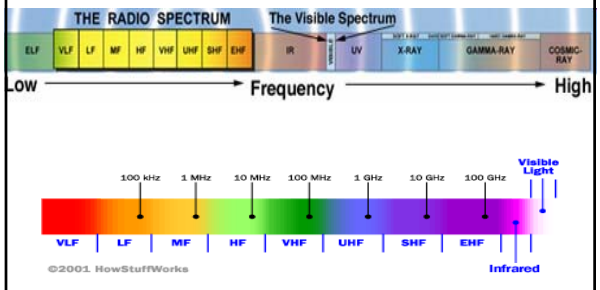


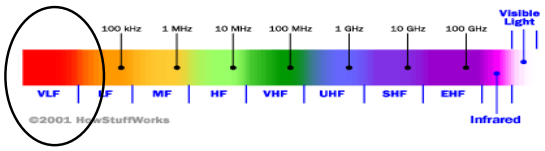
Fig. 3: A graphic illustrating the atmosphere's structure, starting with the troposphere at the Earth's surface.





$c = f\lambda$

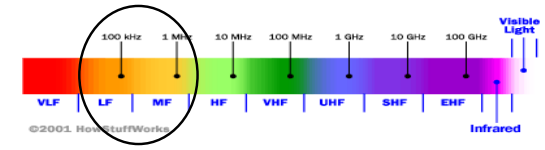
Extremely low frequency	ELF	3–30 Hz	Directly audible when converted to sound, communication with submarines
Super low frequency	SLF	30–300 Hz	Directly audible when converted to sound, AC power grids (50–60 Hz)
Ultra low frequency	ULF	300–3000 Hz	Directly audible when converted to sound, communication with mines
Very low frequency	VLF	3–30 kHz	Directly audible when converted to sound (below ca. 20 kHz; or *ultrasound* otherwise)
Low frequency	LF	30–300 kHz	**AM broadcasting**, navigational beacons
Medium frequency	MF	300–3000 kHz	Navigational beacons, **AM broadcasting**, maritime and aviation communication
High frequency	HF	3–30 MHz	Shortwave, **amateur radio**, citizens' band radio
Very high frequency	VHF	30–300 MHz	**FM broadcasting**, amateur radio, **broadcast television**, aviation,
Ultra high frequency	UHF	300–3000 MHz	**Broadcast television**, amateur radio, **mobile telephones**, cordless telephones, **wireless networking**, remote keyless entry for automobiles, microwave ovens
Super high frequency	SHF	3–30 GHz	Wireless networking, satellite links, microwave links, satellite television, door openers
Extremely high frequency	EHF	30–300 GHz	**Microwave data links**, radio astronomy, remote sensing, advanced weapons systems, advanced security scanning



$c = f\lambda$

VLF

- The wavelength is very long.
- Antennas are large. they are of necessity close to the earth and often actually buried in the ground.
- The radiowaves are reflected from the ionosphere and a form of earth/ionosphere waveguide exists that guides the waves as they propagate.
- The height of the ionosphere experiences diurnal changes.
- VLF is used for navigation systems, communication with submerged submarines (as higher frequencies are rapidly attenuated in water)



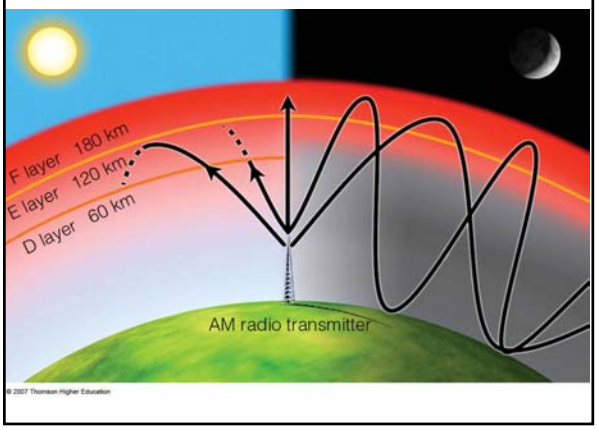
$c = f\lambda$

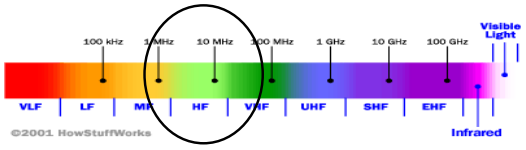
LF and MF

- Ground wave propagation is the more dominant and the radiation characteristics are strongly influenced by the presence of the earth.
- **Ground waves**, as the name suggests, operate close to the earth's surface (and thus travel limited distances unless repeated).
- At night sky waves can come into play. **Sky waves** travel into the earth's atmosphere and bounce back (often over a very long distance). Multiple waves can arrive at a receiver (sky waves and ground waves) and constructive or destructive interference can occur.

AM broadcasting in the MF band

- The strength of signals from traditional AM broadcasting stations (and the interference between and among them) is likely to vary significantly from daytime to nighttime, from location to location (e.g., with latitude) and from season to season.
- In the daytime, coverage is provided by the ground wave and the service is comparatively reliable but relatively limited in range.
- In the night time, however, the radio signals in this range are carried beyond the horizon by reflections from the ionosphere, permitting coverage over much greater distances but with a penalty in terms of stability because of the highly variable conditions of the ionosphere.

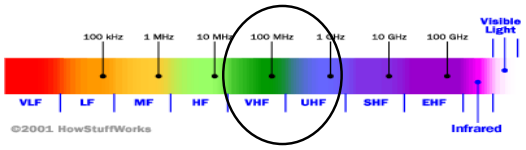




$c = f\lambda$

HF- 3 MHz to 30 MHz

- The next highest range of the spectrum, the 3 MHz to 30 MHz range, is traditionally referred to as the **shortwave region**. In this region, the ground wave component becomes less important and the signals are carried over vast distances by **reflections from the ionosphere** or even **serial reflections between the earth and the ionosphere**.
- At one time, before the advent of communications satellites and high capacity undersea fiber optic cables, this portion of the spectrum was particularly prized for long haul, intercontinental communications in military, governmental, and commercial applications.
- Propagation conditions in this region of the spectrum, however, vary widely with the condition of the ionosphere (including the maximum frequency that will be successfully reflected) and those conditions depend upon location, season of the year, the time of day, and level of solar activity. Because of this high variability, the relatively limited bandwidth available, and the size of the antennas required, this portion of the spectrum **is no longer as highly desirable as it once was.**



$c = f\lambda$

VHF & UHF

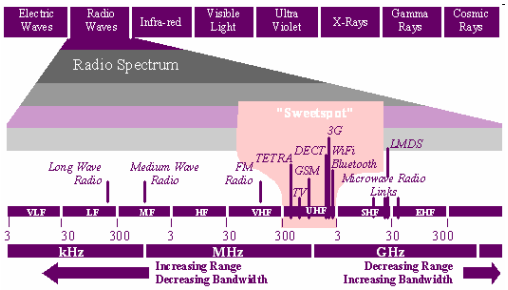
- These frequencies are usually too high for ionospheric propagation and communication takes place **via direct and ground reflected waves**.
- Antennas are **relatively small** in physical size. This makes them quite useful – as some are small enough for mobile devices!

VHF 30 MHz and 300 MHz

- The region of the spectrum between 30 MHz and 300 MHz is known as the **Very-High Frequency (VHF)** region and it is the home to a number of popular services including VHF television, FM radio broadcasting, and a number of mobile services.
- The lower portions of the VHF range exhibit some of the negative characteristics of the shortwave region because very long distance ionospheric propagation (and associated interference) occur in certain seasons, efficient antennas are still somewhat unwieldy for mobile/portable applications, and building penetration is often difficult.

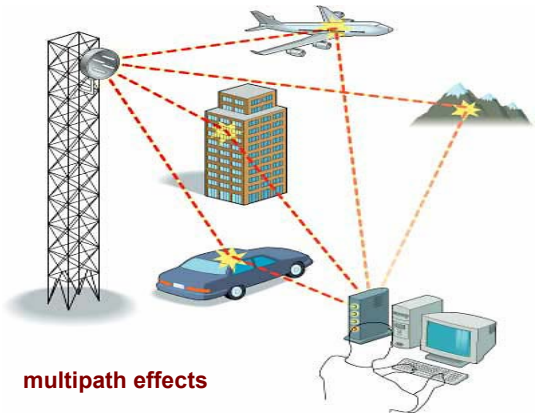
300 MHz and 3,000 MHz (3 GHz)

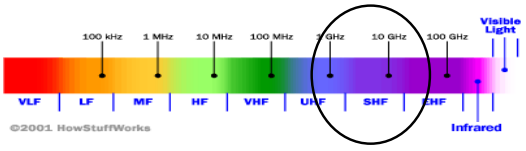
- The Ultra-high Frequency (UHF) portion of the radio spectrum—the portion between 300 MHz and 3,000 MHz (3 GHz)—is widely regarded as the most desirable range for a variety of applications , especially those involving communications with mobile/portable devices.
- In this region, efficient and directive antennas are reasonable in size, the frequencies are high enough to avoid undesirable ionospheric reflections, the necessary power is easy to generate, natural and man-made sources of unintended interference (e.g., from florescent lights or digital computers) are negligible or significantly lower than in other bands, and radio wave propagation into and around buildings is not unreasonably difficult.
- Because of its desirable characteristics, this region of the spectrum is often referred to as "**beachfront property**." The region is home to UHF television broadcasting, to both the cellular and the Personal Communications Service (PCS), and a host of other important services.



UHF- 300 MHz and 3,000 MHz (3 GHz) cont.

- Despite its desirable, more stable characteristics, radio signals in this portion of the spectrum are still subject to a host of vagaries that cause the strength of signals to vary widely.
- The signals are subject to (a) **being bent (refracted) by the earth's atmosphere, (b) diffracted (bent) by edges of obstructions such as buildings, and (c) reflected off of natural and man-made obstacles such as mountains and buildings and moving obstacles.**
- Frequencies can be absorbed to varying degrees by foliage and other clutter.

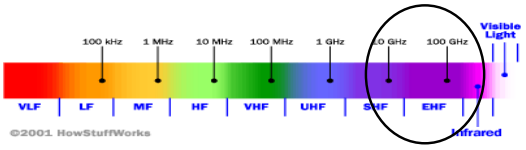




$c = f\lambda$

SHF 3 – 30 GHz

- These are commonly termed **microwaves** (this term is used sometimes also to describe that part of the UHF band over 1.5 GHz).
- Propagation paths must be of **line of sight** (LOS) – otherwise losses are extremely high.

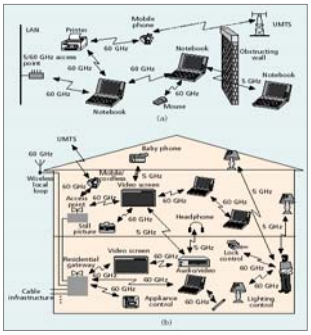


$c = f\lambda$

EHF 20 and 300 GHz

- This is often refereed to as mm wave propagation
- Enormous bandwidths available.
- Frequencies in this range are affected significantly by rain, snow, and fog.
- Increasing interest in these higher frequencies. [Historically the highest frequency of operation was limited by technology capabilities – ever increasing ability to use higher frequencies]

60 GHz is becoming more interesting



so what did we learn?

- when waves propagate all sorts of things happen
- the atmosphere comes into play at some frequencies
- at others they can be reflected from obstacles, refracted around obstacles
- they can be absorbed
- they can combine constructively and destructively – fading occurs

and more: at the receiver

- more than one wanted signal can end up at the receiver – delayed versions of the same signal
- and of course unwanted signals also are received – signals from other transmitters
- and noise is added to the signal

at the receiver

- you get a signal reduced in power
- you get other interfering signals
- you get noise

- in other words there is **mess**

- radios are designed to prepare the signal for the messy journey as best they can and to undo the mess at the receiving side as best they can – THAT IS WHAT IT IS ALL ABOUT

in the radio

There are three important elements

- the **source coder** COMPRESSES the data that is to be transmitted – otherwise you would not get the data rates you need
- the **channel coder**, makes the transmitted data more robust so that it can deal with the mess that happens on the way.
- the **modulator** launches the data to be transmitted onto the carrier wave (frequency of the radio system)
- so you go from a series of 1s and 0s (digital) to an analogue waveform that travels through the air to the destination.

Focus on the course

- This course is about source coding, channel coding and modulation.

- At the receive decoding and demodulation happens and obviously we study this too.

- We need to study **information theory** to really understand source and channel coding.

- Hence we start with that.