



Mobile Telephones Scientific Background

This fact sheet concerns the science behind mobile phones and contains detailed technical information

Introduction

Mobile phone networks consist of base station antennas which communicate with customers' mobile phones via radiofrequency (RF) transmission. In turn the base station antenna is connected to the wired telephone system directly or via a further RF communication link. The mobile phone system is often referred to as cellular telephone technology because the regions being covered are broken up into cells each of which has their own localised service provided by a base station antenna. The networks currently operating in Australia use digital technologies defined by the following technical standards to deliver their mobile phone services:

- Global System for Mobile Communication (GSM),
- Wideband Code Division Multiple Access (WCDMA)
- Universal Mobile Telecommunications System (UMTS) and
- Long Term Evolution (LTE).

There are two sources of radiofrequency (RF) exposure from the mobile phone system: base station antennas and the mobile phone or handset. Exposure from the antennas is continuous (but very low), irradiates the whole body and exposes an entire community. Exposure from the handset to the head is more intense, is only for intermittent periods and is typically greater for the handset user than other people. The RF exposure from these two sources will be dealt with separately.

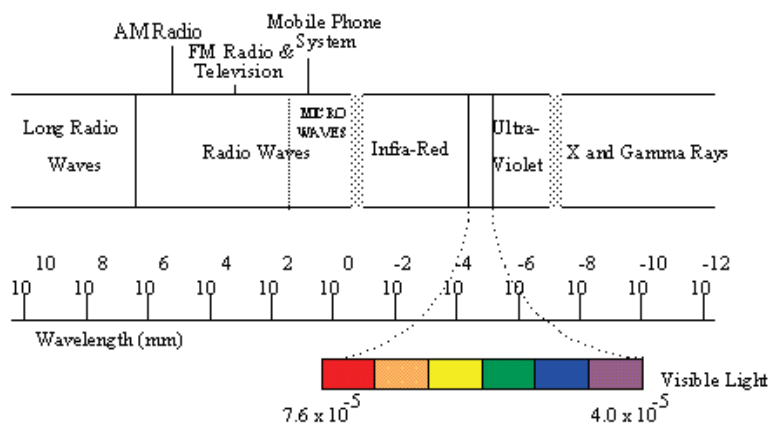
Electromagnetic Radiation

The word radiation is often thought of as referring to the emanations from radioactive material and x-rays. However the term electromagnetic radiation (EMR) refers to energy emitted from a variety of sources such as radio or television transmissions, the humble light globe as well as x-ray machines.

Electromagnetic radiation has electric and magnetic field components and passes through space at the speed of light – about 300,000,000 metres per second (186,000 miles per second). It is the interaction of these fields with matter that determines the effects of EMR. The study of this interaction is an important branch of physics and the knowledge gained enables us to control radiation for the benefit of mankind. The properties of EMR vary with wavelength or frequency (wavelength is inversely related to frequency) and thus we have radio communications, television, radar, microwave ovens, magnetic resonance imaging, toasters, cameras, lasers and x-ray machines, etc.

The Electromagnetic Spectrum

The scale at the bottom of the diagram below measures the wavelength of the electromagnetic radiation (EMR) from long wavelength (low energy) on the left, to short wavelength (high energy) at the right. The human eye is able to discriminate wavelength in the visible part of the spectrum and this region has been expanded in the diagram.



The Electromagnetic Spectrum

The variation in wavelength is sensed as a change in colour.

Immediately to the left of the visible spectrum is infrared radiation which can be detected as heat although not very efficiently when compared with the ability to detect visible light. Further to the left are radio waves (including microwaves) and long radio waves which complete the low energy end of the spectrum. These radiations are unable to be perceived at normal levels.

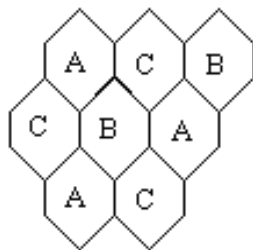
The mobile phone system operating at about 900 & 1800 megahertz (MHz) for GSM, 800 & 900 MHz for WCDMA, 1800 MHz for LTE and 2100 MHz for UMTS is located in a region of the spectrum that is referred to as both microwave radiation and radiofrequency radiation (RFR). For the purposes of this discussion both terms will be used interchangeably.

The Mobile Phone System

Base Station Antennas

The mobile phone system has limitations, similar to the radio and television systems, in that the number of frequencies available restricts the number of handsets or users within each cell. To enable a large number of users, regions are divided up into cells each with its own set of frequencies (GSM system). Adjacent cells have different frequencies to prevent interference and power levels are kept to a minimum to ensure no interference with non adjacent cells which use the same frequency. The size of the cell varies depending on the number of users. In rural areas which typically cover large regions due to the sparse population, more power has to be generated to cover the larger area. This can lead to higher radiation exposure.

The use of a large number of antennas to service a densely populated area does not necessarily equate with greater RF exposure. The number of frequencies available within a cell varies from one to twelve with each frequency able to accommodate up to eight different users. Maximum power will be transmitted only when a frequency has all eight users operating at the same time. In this diagram the non-adjacent cells labelled A can use the same frequencies. Cells A and B share boundaries and so must use different frequencies.



In the WCDMA and UMTS systems all cells of a network use the same range of frequencies simultaneously. Interference is prevented by transmitting a code along with the call information. Each connection between a handset and a base station is given a different code to enable it to be distinguished from all other calls using the same frequencies. Transmitted power levels are kept to the minimum necessary to maintain good communications.

Antennas must be elevated and located clear of physical obstruction to ensure wide coverage and reduce the incidence of dead spots. The radiation from these antennas is beamed horizontally at the horizon with a slightly downward tilt which causes the maximum exposure to occur at distances of about 100-200 meters. The picture shows two sets of three high gain sector antennas - two receive and one transmit - each set of three antennas would service a single cell. The power output from an antenna will vary depending on the number of people using the facility at a given time. A typical antenna will operate at about 25-60



Watts. Dead spots, due to shadows caused by obstructions such as tall buildings are covered by micro cells that have an antenna power output of about 1 Watt. A base station will usually cover three cells in an arrangement similar to those labelled 'B' in the diagram below. RF exposures from WCDMA or UMTS base stations will usually be less than those experienced from GSM installations.

The dish antennas (pictured above - bottom right) are used to provide line of sight communications with other antenna installations and operate in the 5 to 40 Gz range at about 200 milliwatts (mW) to 8 Watts (W). These microwave links are highly directional and apart from the side lobes would not normally affect ground level exposures.

Siting of Base Station Antennas

The siting Guidelines for base station antennas is described in the Australian Standard (AS/NZS 5070.2:2008) titled *Siting and Operation of Radio Communications Facilities: Guidelines for Siting of Radiocommunication Facilities: VHF, UHF and SHF*. This Standard assists those responsible for the planning, construction, installation, operation, maintenance and decommissioning of radiocommunications and broadcasting services. It provides additional information and guidance for organisations and the public, from the viewpoint of the impact on the general

public and operational staff, of the siting of radiocommunications and broadcasting facilities operating at frequencies above 30 MHz. The siting of mobile phone base stations is now subject to State and Territory planning laws as a result of the *1997 Telecommunications Act* (the Act) which came into operation on 1 July 1998. These are usually administered by local councils.

Telecommunication installations which are 'low impact facilities' are exempt from most local council's powers (Subclause 6(1)(b) of Schedule 3 of the Act). These facilities must comply with the *Telecommunications Code of Practice 1997* (amended in 2002) which is administered by the Australian Communications and Media Authority (ACMA).

In addition to State and Federal regulations there is a registered industry code established by the Australian Communications Industry Forum (ACIF), now called Communications Alliance Ltd, titled *Deployment of Mobile Phone Network Infrastructure C564* (the 'ACIF Code').

The Code supplements the requirements already imposed on carriers under the existing legislative scheme by requiring them to consult with the local community and to adopt a precautionary approach in planning, installing and operating telecommunications infrastructure.

Limitations on the RF power emitted by base station antennas are described in the ARPANSA Radiation Protection Standard *Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz*. ACMA uses this Standard as the basis for regulating exposure under section 162 of the Act.

The Mobile Phone

GSM phones operate in such a way that they transmit RF in short bursts (or time-slots) rather than continuously. This arrangement permits up to eight handsets to communicate through a single base station antenna by transmitting only during their allocated time slot. In effect each handset waits for its turn to speak to the base station.

Peak power output of a GSM handset is limited to a maximum of 2 W or 2000 mW which, since it is transmitted in only one of eight time slots, averages to 250 mW of continuous power. However, in order to limit interference between neighboring cells (and conserve battery life) mobile phones are designed to use the minimum power necessary to maintain communication. If the phone is moved from one cell to

another the base station with the strongest signal will generally handle the connection.

A WCDMA or UMTS phone transmits with an average power of 200mW, the power varying depending on the quality of communication with the base station (peak power of 2 W). Multiple users are accommodated by transmitting the signal over a wide spectrum (spread spectrum) and applying digital codes to the data. The mobile phone uses the code to distinguish its intended message from other users. All users share the same range of radio spectrum at the same time. This technique permits more users in a given cell than for an equivalent GSM site and in general results in lower exposures from base stations than from GSM sites.

The Interaction of Radiofrequency Radiation with Matter

Introduction

Although radiation, such as x-rays and RF radiation are both part of the electromagnetic spectrum their interaction with matter is not related. Radiation such as x-rays and gamma rays are able to ionise matter and this in turn causes chemical reactions. Ionising radiation is known to be carcinogenic (cancer causing). Electromagnetic radiation at longer wavelengths than x-rays does not have sufficient energy to cause ionisation and this region of the spectrum is collectively known as non-ionising radiation. RF radiation forms a part of this region of the spectrum at wavelengths longer than infra-red radiation and has not been proven to be a carcinogen.

When RF radiation is absorbed by matter it causes molecules to vibrate which in turn causes heating. This **thermal effect** is the basis for determining the health hazard from RF exposure.

Absorption of Radiofrequency Radiation from a Mobile Phone

At distances within a wavelength from a RF transmitter is a region known as the near field. Since the RF radiation from a mobile phone has a wavelength of 10-30 cm (depending on the type of technology) the users head will be within this near field region. The head disturbs the field and alters the manner in which RFR interacts with tissue. This interaction complicates the absorption of RF energy within the head and makes calculations difficult. Absorptions within the head are therefore determined experimentally or by simulation on a computer. The specific absorption rate (SAR) is defined as the rate at which a mobile phone user absorbs energy from the handset. The ARPANSA Standard specifies exposure limits to RFR for mobile

phone handsets in terms of the SAR. In the ARPANSA Standard the SAR limit for mobile phone handsets is 2 watts per kilogram (W/kg) of tissue (averaged over 10 grams). A SAR of 4W/kg is associated with a 1 degree temperature rise in humans. In practice a mobile phone will only cause a temperature rise of a fraction of a degree which is unlikely to be noticed compared with the normal daily variations in body temperature.

Exposure to RFR Emitted by a Base Station Antenna

As described above the RFR power emitted from a base station varies from one site to another. To date ARPANSA has conducted three surveys of RFR from base station antennas. ARPANSA found that emissions from these antennas were usually many orders of magnitude below the applicable limit (frequency dependent 4-10 W/m²) set by the ARPANSA Standard.

Thermal Effect

Thermal effects from RFR exposure are defined as biological effects which result from absorbed electromagnetic energy which elicits a biological response from the heat it produces. Radiofrequency radiation interacts with matter by causing molecules to oscillate with the electric field. This interaction is most effective for molecules that are polar (have their own internal electric field) such as water. The water molecule loses this rotational energy via friction with other molecules and causes an increase in temperature. This effect is the basis for microwave cooking. RFR absorbed by the body occurs primarily as a result of the interaction with water.

Comparison with Heating by Conduction

In conventional cooking a gas flame or electric radiator will transfer heat into a metal pot and then into food via conduction. In this process molecules rotate and vibrate rapidly with increased temperature and pass the energy onto neighboring molecules through collisions. This is a relatively slow process relying on the thermal conductivity of the food to transfer heat into the centre. In the case of heating with RFR the energy is absorbed deeper in the object allowing rapid heating to occur. The depth of penetration of RFR in matter varies depending on the nature of the absorbing material. For example, at 1 MHz the depth of penetration (the depth at which the EMR is reduced by about a third) varies from 0.25 meters in seawater to 7.1 meters in fresh water. Thermal conduction still plays a role in this type of heating but it is less important.

Comparison with Heating by Infra Red Radiation

The effect of heating by infra-red radiation is commonly experienced when exposed to direct sunlight. In fact all heat received from the sun comes to us via infra-red. Infra-red radiation interacts with matter by causing molecules to vibrate when the radiation is absorbed. This vibrational energy is then transferred to adjacent molecules by conduction as described above. Since infra-red radiation is readily absorbed by the skin it does not cause internal heating (other than by conduction) as does RF radiation.

The radiated power at approximately one meter from a typical electric bar heater (albeit infra red rather than RF radiation) is about 100,000 microwatts/cm².

Athermal Effects

There is a considerable body of scientific literature which describes effects of RFR in biological systems that cannot be directly attributed to heating. Low levels of RFR have been demonstrated to cause alteration in animal behaviour, or changes in the functioning of cell membranes. These low level effects, often referred to as athermal or non-thermal, are controversial and have not been shown to cause adverse health effects.

Definition of Technical Terms

Electromagnetic Power Flux Density

The rate of flow of electromagnetic energy per unit area is used to measure the amount of radiation at a given point from a transmitting antenna. This quantity is expressed in units of watts per square meter (W/m²) or milliwatts per square cm (mW/cm²). The maximum exposure level for members of the public exposed to RFR from different mobile phone technologies is 0.4-1.0 mW/cm². This figure can be compared with the amount of heat radiated by the human body at room temperature of about 2 mW/cm². (Note this energy is radiated primarily in the infra red region not as RFR).

Specific Absorption Rate

The absorption of RFR energy is measured by the quantity specific absorption rate (SAR) in units of Watts per Kilogram (W/kg). It is defined as the rate at which RF energy is absorbed per unit mass of a biological body. A SAR of 0.4 W/kg would take 10 days to melt a kilogram of ice.