RF Hazard Awareness Course (Arqiva)

DURATION
Half Day

COURSE REQUIREMENTS
No requirements—this is a lecture based course

RATIO OF TRAINERS TO TRAINEES
Up to 1 to 12



Height Safety Training
Equipment Supply
Kit Inspection

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Radio Frequency Radiation Hazards

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- Who determines 'safe' levels?
- How 'safe' levels are determined.
- Practical safety measures to manage RF exposure.
- Typical exclusion zones around common antennas.

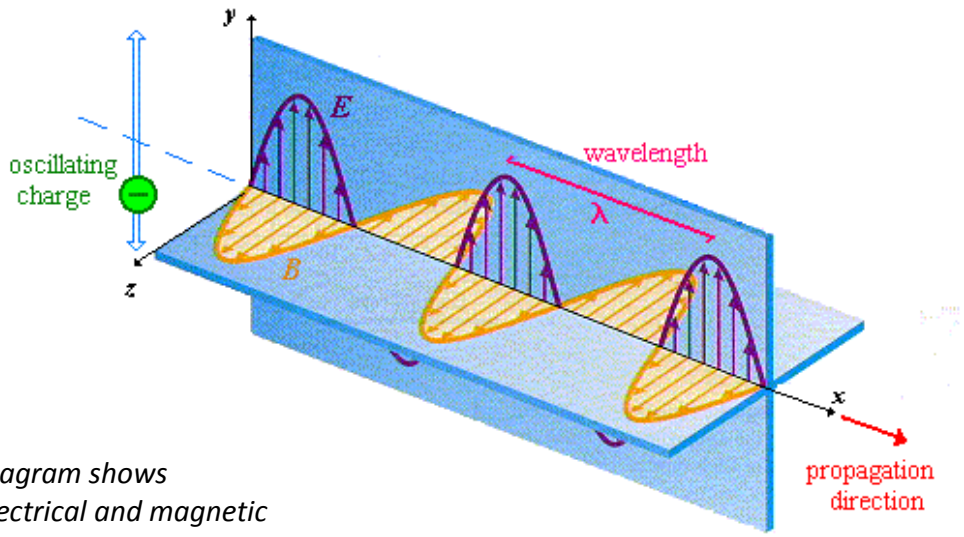


Diagram shows Electrical and magnetic components of a radio wave in the Far Field

How To Define Radio Frequency Radiation.

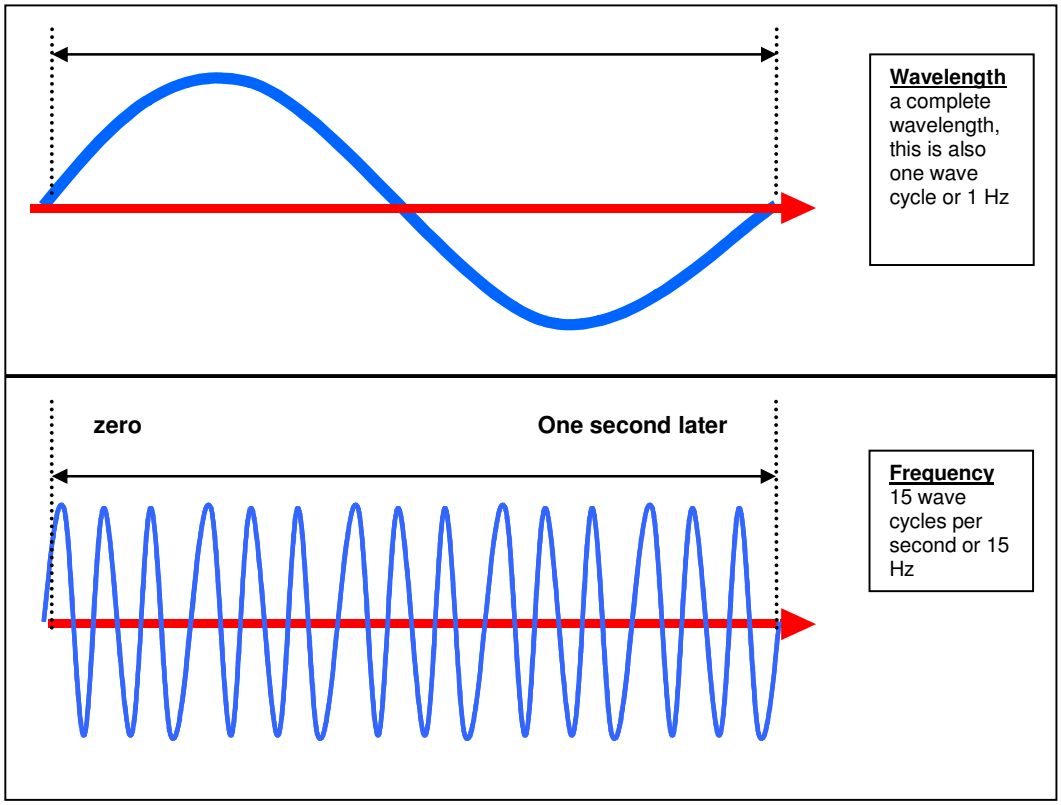
When we talk about Radio Frequency Radiation we are referring to a section or band of the Electromagnetic Spectrum. This spectrum contains a wide range of radiation sources all of which contain both an electrical and a magnetic component. See front cover

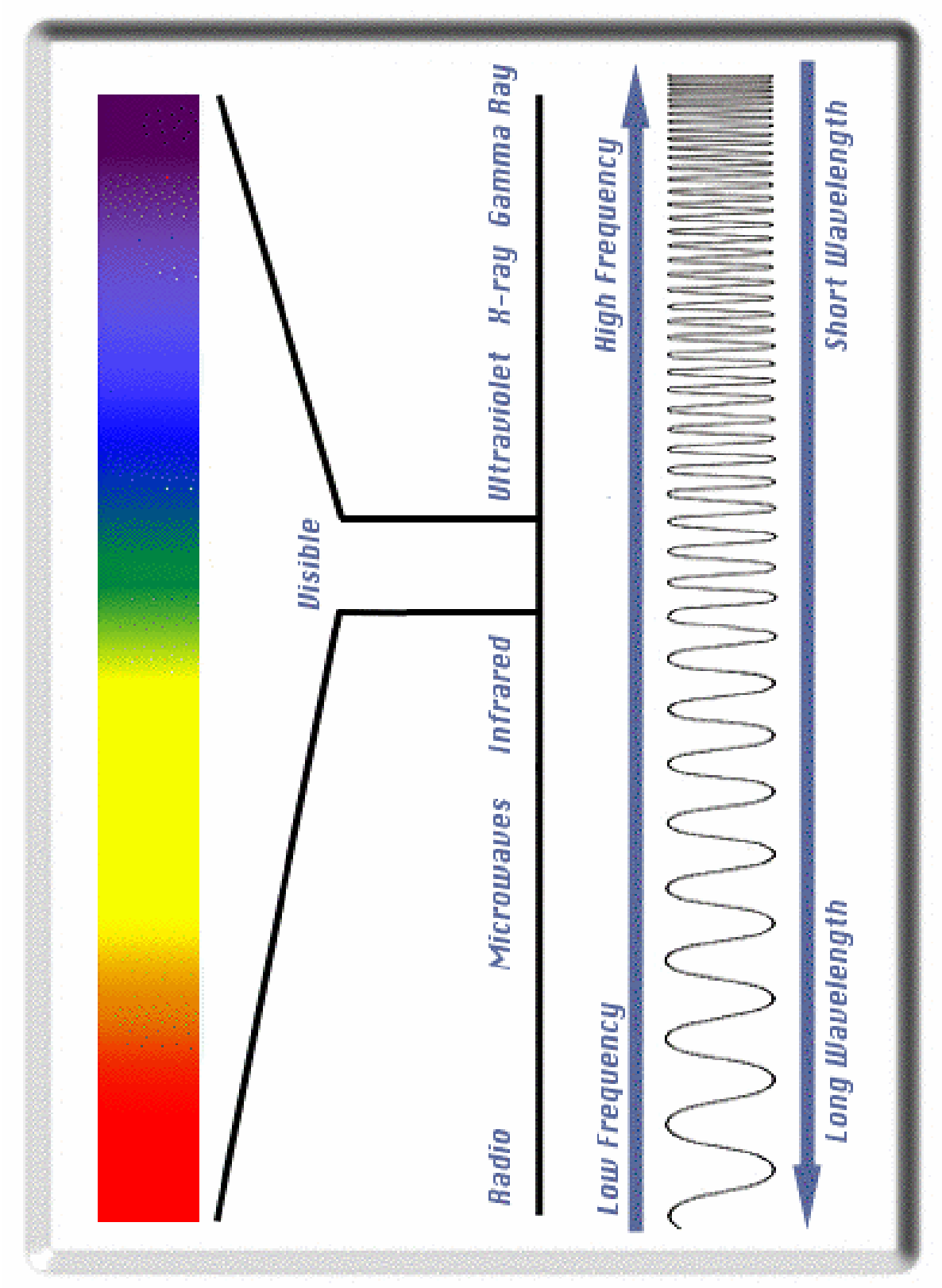
All such sources of radiation travel through free space in the form of very regular waves at the speed of light; 300,000,000 m/s.

The main characteristics that define an electromagnetic field (**EMF**) or wave are its **wavelength** and corresponding **frequency**.

- **Wavelength**, describes the distance between one wave and the next, i.e. the length of one complete wave cycle. This is referred to in units of metres (**m**) and is given the symbol (**ƛ**) Lambda.

- **Frequency** describes the number of complete cycles or oscillations, which pass in one second. This is referred to in units of Hertz (**Hz**), which is simply cycles / second and is given the symbol (**f**).




Visible
Ultraviolet
X-ray
Gamma Ray
Radio
Microwaves
Infrared
High Frequency
Low Frequency
Short Wavelength
Long Wavelength

The Electromagnetic Spectrum

Frequency	1Hz (1Cycle)	1kHZ (1000)	1MHz (1000000)	1GHz (1000000000)	10^{12}Hz	10^{15}Hz	10^{18}Hz	10^{21}Hz	10^{24}Hz	10^{27}Hz				
Wavelength	$3x10^{8}$m 300Km	300m	30Cm	0.3mm	3x10^{-7}m		3x10^{-10}m	3x10^{-13}m	3x10^{-16}m	3x10^{-19}m				
Common Name		Radio Waves		Microwaves	Infrared	Ultra-Violet	X-Rays		Gamma		Cosmic			
Radiation	Non- Ionising						Ionising							
Energy	Low → High													
Electron Volts	*4.1X10^{-15} eV*			*4.1X10^{-6} eV*		*4.1X10^{0} eV*				*4.1X10^{12} eV*				
Sources	Domestic Power	Radio / TV Masts		Radar	Arc	Sun Beds	Hospital		Nuclear Power	Outer Space				
Harm	Shock RF Burns	Pain at Narrow points		Heating generally leads to nausea, headaches, vomiting,			Sterility		Cancer	Death				

Ionising or Non-Ionising Radiation

Wavelength and frequency determine another important characteristic of Electromagnetic fields. Electromagnetic waves of higher frequency carry more energy than those of lower frequency. This is described in terms of electron volts. See table previous page. An electromagnetic wave on the far right of the table carries millions of times more energy than that on the left. This starts to give an idea of the potential for damage.

At frequencies above the Ultraviolet Range the waves have enough energy to break the bonds between molecules of water it encounters. As we are made of 60 PERCENT water this is a relevant molecule to consider!

This is known as **Ionisation.** An electron is displaced in a molecule, not much of a worry on its own. However if this happens in billons of cells in the body causing a large-scale permanent material and chemical change it is another story. Those working near X-ray and Gamma Sources need special protection. In organisms, the DNA chain is often subject to damage to the information string – this can have major consequences with regards to cell reproduction causing cancers etc.

At the RF Radiation band the much-reduced power levels do not have the ability to break bonds between molecules. Instead they cause heating through increased molecular vibration, and shock/burns through induced current build up. These are the basic effects of **Non-Ionising rf** Radiation.

The point at which radiation changes from Ionising / Non-Ionising is hard to pinpoint. Different molecules all have different frequencies at which they ionise, and these frequencies are affected further by the state that these molecules are in. For practical purposes, it is sufficient to say that the boundary of ionisation for water molecules lies somewhere within the high end Ultraviolet range of the spectrum.

Is RF Radiation a Health Hazard?

When considering whether or not RF radiation is a health hazard it is important to be clear about the difference between Biological Effects and Adverse health effects.
Biological effects are measurable responses to stimuli or the environment. These are not necessarily harmful to health and are short term such as an increased pulse rate and sweating.

However biological effects, which lead to irreversible detectable impairment **may** constitute an **adverse health effect** such as tissue damage e.g. a burn.

Established Effects When Humans Are Exposed to RF Radiation

In broad terms there are two key potential effects when the human body is exposed to an EMF. Induced currents / voltages and heating. The precise effects are dependent upon two key factors considered below: frequency and intensity.

1. Frequency

There are discreet differences within four key bands (sections) of the RF spectrum as follows:

300Hz – 10 MHz

The central nervous system relays signals around the body via electrical impulses. For example, when either we move a limb or feel a sensation such as pain the information is sent to and from the brain in this way.

At high output intensity, the dominant direct effect of exposure is nerve and muscle stimulation (muscle /nerve tingling).This is caused by induced circulating electric currents in the body tissues (which is also used in medical tests to check the integrity of nerve pathways).

The heart is kept beating by electrical signals from the brain. Obviously interference within these mechanisms can have severe consequences. We do not currently have enough evidence to know what the long-term effects are at this area of the frequency spectrum.

The other major issue is that the effects happen instantaneously rather than building up over a period of time and therefore it is not possible to use time averaging as can be done in other frequency ranges.

The indirect effect of EMF in this band and indeed upto 110MHz, is that metallic structures in the field may accumulate electrical potential (voltage) which, if not sufficiently grounded, can produce a spark discharge if a person comes into close enough proximity. If contact is made with the structure a contact current may result which can cause electrical shock and / or RF burn and the stimulation of muscles or periphery nerves. For RF burns the visible effects are commonly white or pink pimpling / blistering of the skin contact area. Examples include towers, cranes, MEWPS and large antennas.

At this range due to the wavelength being bigger than the length of the human body there is reduced absorption into the body mass. This is because the body cannot act as an effective receiving antenna

10 MHz - 300MHz

At this range the body can act as an effective receiving antenna due to matching between human height and wavelength. (30-300MHz). **Dielectic Composition** (conductivity+insulation properties) of body tissues causes certain organs to be affected more than others, it largely depends on the water content.

This becomes more accute if only small areas are exposed to the source e.g. the head or limbs. Localised warming effects are felt at constrictions in the body, noteably at joint areas where there is more resistance to current flow. The amount of energy absorbed and subsequent heating is closely related to the size of the body or exposed surface and it's resonant absorption frequency. For a person the whole body resonance is typically between 40 and 80MHz. For example a person 1.75m in height this is approximately 65MHz.

300MHz - 10GHZ

At this range the body does act as an effective receiving antenna due to matching between human height and wavelength. As a result absorption is high and effects can be serious and complex.

In this range the EMF can result in significant localised non-uniform heating. This is primarily due to the human body having differing dielectic composition. Key areas of the body which absorb EMF well in this band are those with a high water content such as the eyes and brain - particularly as they are contained within a cavity which contains any heating caused. Localised heating can lead to permanent cell damage. Medical diathermy devices and microwave ovens operate in this band because of it's ability to penetrate tissue and heat effectively at depth. Remember what a piece of chicken looks like after its been defrosted for too long!

10GHz - 300GHz

At this range the body does not act as an effective receiving antenna as a result energy absorption is lower and heating effects are confined to that area directly exposed to r.f radiation.
In this band energy absorption occurs primarily at the skin surface with very little of the energy penetrating into the underlying tissues. Due to the position of nerve receptors this is often readily apparent as a feeling of fierously heated skin. Effectively used by US Forces as a non lethal weapon

2. Intensity

The intensity of the EMF is dependent upon a number of factors listed below:

Field strength. This is itself dependent on a number of factors such as the transmitting power, the proximity of the antenna to the person or object, the number of radiating sources, reflective and shielding properties of the environment i.e. roof spaces and the propagation characteristics of the antenna i.e. how directional or not it is.

Exposure Time. At frequency ranges above 10MHz, the longer you are exposed to the RF the more you will absorb and therefore the greater will be the heating effect. As a result it is often a practical option, as we are primarily concerned with managing the thermal effects, to use time averaging to ensure compliance with the guideline levels. The time interval normally given is a period of 6 minutes. At frequencies below 10MHz the effects are instantaneous and therefore are not suitable for time averaging.

Signs & Symptoms of RF Overexposure

The vast majority of RF exposures result in no symptoms at all, largely due to the safety margins that exist and the engineering control measures in place. When over exposure does occur the effects may still be so small as not to cause the recipient any acute signs or symptoms. Much anecdote exists but in reality cases of over exposure resulting in acute effects are exceptional rather than a common occurrence.

The most common non-psychological symptom of overexposure is an internal warming sensation in the area of the body exposed. This may turn to pain if over-exposure continues. Over-exposure is often limited by the individual moving away from the area of RF propagation. Other more general symptoms of RF induced over-warming may be manifested by symptoms of heat exhaustion (if temperature reaches 38C) such at headaches, dizziness, thirst or in more acute cases heat stroke (if temperature reaches 41C) and can be treated in a similar manner.

If you suspect an symptoms from an RF dose, get checked out at Hospital and state the suspected cause. Beware however that other causes of dehydration; (symptoms of which are headaches etc.) should also be considered. i.e. hot weather and hangovers

Many symptoms have been attributed to RF exposure such as anxiety, suicide, depression, nausea and fatigue. To date the scientific evidence does not support a link between these symptoms and RF exposure. Many may be caused by other environmental factors.

Who Determines 'Safe' Levels

The organisations, which are involved in determining 'safe' levels of occupational and public exposure to RF sources, are as follows:

- **The Health & Safety Executive (H.S.E.)**
  This body has an overall remit with relation to policing all health and safety matters within the UK, and has a number of specialists in respect of RF hazards. Investigation in respect of measurements in the field to verify guideline compliance in respect of legal duties of care etc. tends to be passed to the Health Protection Agency.

- **Health Protection Agency (H.P.A.)** formerly the National Radiological Protection Board (N.R.P.B.) changed 04/05
  This is the UK wide body, which has expertise in all areas of the electromagnetic spectrum, and is able to undertake full-scale investigations on behalf of other organisations such as the HSE and local authorities. The HPA works closely with other international bodies to agree upon the standards in relation to RF exposure.

- **International Commission For Non-Ionising Radiation Protection (I.C.N.I.R.P.)**
  This is the international body which co-ordinates research and data into non-ionising radiation. It serves as a forum for sharing information and produces the most widely accepted safety standards worldwide.

How 'Safe' Levels are Determined

ICNIRP publishes guidance standards in respect of limits for exposure to EMF. These aim to provide protection against established adverse health effects. Within the UK the HPA although publishing guidance, effectively refer to the ICNIRP standards for safe exposure limits. The exposure limits, which are referred to as **Basic Restrictions**, are based upon scientific data alone, drawn from over 25,000 articles, and are based on worse case scenarios where maximum **coupling effects** are present. Coupling refers to the interaction between magnetic and electric fields and the exposed body (size, shape, orientation and tissue type).

As humans cannot be used for experiments, guidelines have relied heavily upon animals or phantoms in respect of physical experimentation. Epidemiological studies of human cohorts have also been extensively used and computational and physical modelling of humans based upon CAT and MRI scans of a number of human subjects, has been used to assess the non-uniformity of tissue in the human body and their specific absorption rates. Such research allows clearer correlations to be made between the factors involved.

Subtle behavioural changes in animals at low levels often precede more drastic changes in health at higher levels. Abnormal behaviour is a very sensitive indicator of a biological response to a stimulus and has been selected as the lowest observable adverse health effect and thus the threshold level. For example in a number of tests on monkeys species a whole-body energy absorption of **4 W / kg** and a temperature rise of 1˚C was found to be the **threshold level.**

The **Basic Restrictions** (to become known as Exposure limit Values) for **occupational** exposure are set at **1/10th** of the threshold level and those for **public** exposure at **1/50th** of the threshold level. Based on short-term / long-term exposure.

These are defined in terms of power density (W / m²) or **Specific Absorption Rate** (SAR). For example a whole-body SAR of 0.4 W / kg and 0.08 W / kg have been chose as the occupational and public **basic restrictions** respectively.

The **Reference Levels** (soon to be Action Values) are provided for practical assessment purposes to determine whether the basic restrictions are likely to be exceeded. The values are derived quantities, which are measurable in the field such as electric field strength (V / m) and magnetic field strength (A / m).

Compliance with the Reference Levels ensures compliance with the basic restrictions, but exceeding them does not necessarily mean that the basic restrictions have been exceeded. Further investigation should be undertaken.

The guidelines are set for the average population and cannot directly address the requirements of a minority of potentially more sensitive people. Equally they do not address the hazards of explosive / electro-explosive environments or implanted electro-medical equipment interference.

Practical Controls and Contingency Arrangements.

The management of RF exposure can be usefully divided into three key areas, site design, general safety principles and site specific Information.

Site Design

Due to compliance requirements, most are sites are designed in such a way as to reduce the likelihood of people entering zones where RF exposure is likely to exceed the basic restrictions. This is typically achieved through engineering and administrative controls such as access restriction via security measures, careful positioning and spacing of antennas (such as at the edge of rooftop and platform sites, on elevated stubs and extended arms) and through the use of signs and warnings to alert workers of specific or general hazards.

General Safety Principles

When on site there are a number of broadly applicable practical safety measures which can be employed to reduce and manage exposure. These are as follows:

- Assume all antennas are active and energised unless you have direct knowledge to the contrary.
- Obey all posted signs and warnings.
- Habitually maintain a distance of at least one metre from all antennas.
- Do not stop within the transmitting zone of any antenna. This assumes you understand how the antenna is propagating.

Site Specific Information

Irrespective of the nature and complexity of the site all workers should aim to have sufficient information to make informed decisions about the nature of any RF hazard and how this is to be managed. Ultimately this will come down to information and this may be from any of the following sources.

- The **site supervisor / manager**, where possible he / she may be able to agree a method of work detailing access, egress and areas of work including exclusion zones.
- A **site file / plans**, this may include detail such as a recent RF survey which may indicate which antennas are on / off / transmitting / receiving / frequency / power / direction / height / orientation / hazard category/ exclusion zone etc. This may be in the format of a cross sectional RF profile held on a computer format.
- **Warning signs** at key access points on sites which typically detail the antenna types and exclusion zones around them and the contact number for a network management centre.

After assessing the nature of the hazard it may be necessary to manage RF exposure by reducing the power on one or a number of antennas or by shutting them down. When this option is used, it is imperative that a check is made to assess when the antenna is inactive and where possible it is prudent to then physically isolate such antennas by removal of the input feed at the radio set or employing interlock mechanisms at the transmitter.

As a last resort it may be necessary to employ personal protective equipment such as RF suits and electrically insulated gloves to manage the hazard sufficiently. In reality this option is confined to use within the TV / commercial radio broadcast sector and only then rarely.

As an additional source of information **Personal RF Detector/ Monitors** can be invaluable and may allow verification of particular hazards and an up-to-date assessment of survey accuracy / changes in the EMF characteristics at a site. Such devices should never be the

only source of information however; as personal monitors are relatively basic devices in assessing EMF exposure due to the need for rugged portability and can have errors of up to 50%.

These devices can be either preset or programmable and are typically set at or below the reference level within each of the frequency bands measured. They usually have a specific frequency band in which they will scan (e.g. 300kHz – 300GHz) and measure one or both of the EMF components, i.e. the Electrical field strength (E) or Magnetic field strength (H).

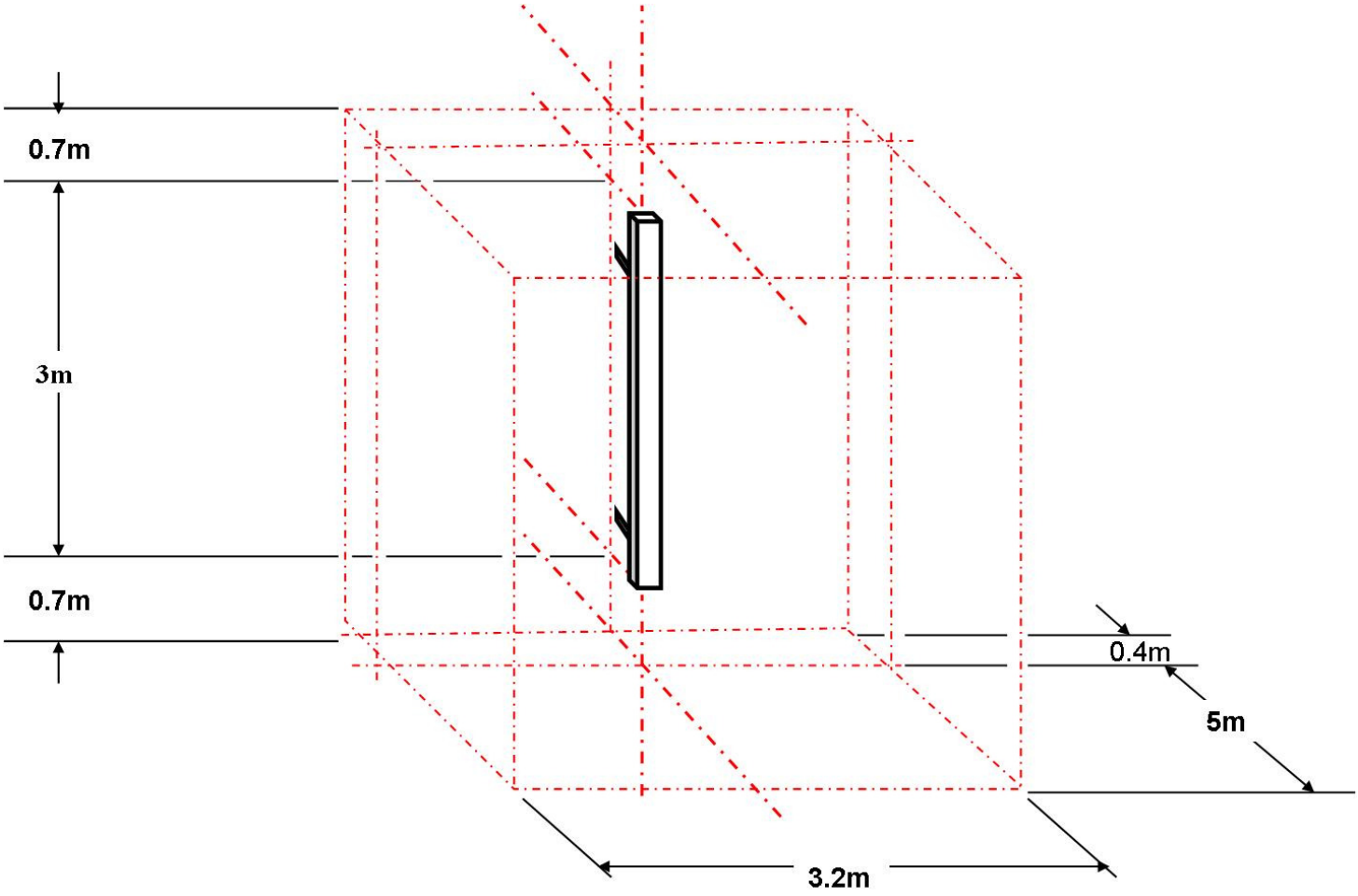
E field devices are used widely for surveying purposes and H field ones for frequencies below 100MHz. Devices, which measure both, have advantages, as do ones that give information on a visual display, in the form of the measured values and / or corresponding power density. Many such devices are not isotropic and as such it matters which way they are held. A sweep of your surroundings is a prudent action to enable the device a clear 'view' of the surrounding RF.

Such devices must be tested before each use and periodically calibrated (typically every 6-24 months). Tests can be performed using a handheld radio or other transmitter; this should ideally be the same device each time to enable consistency.

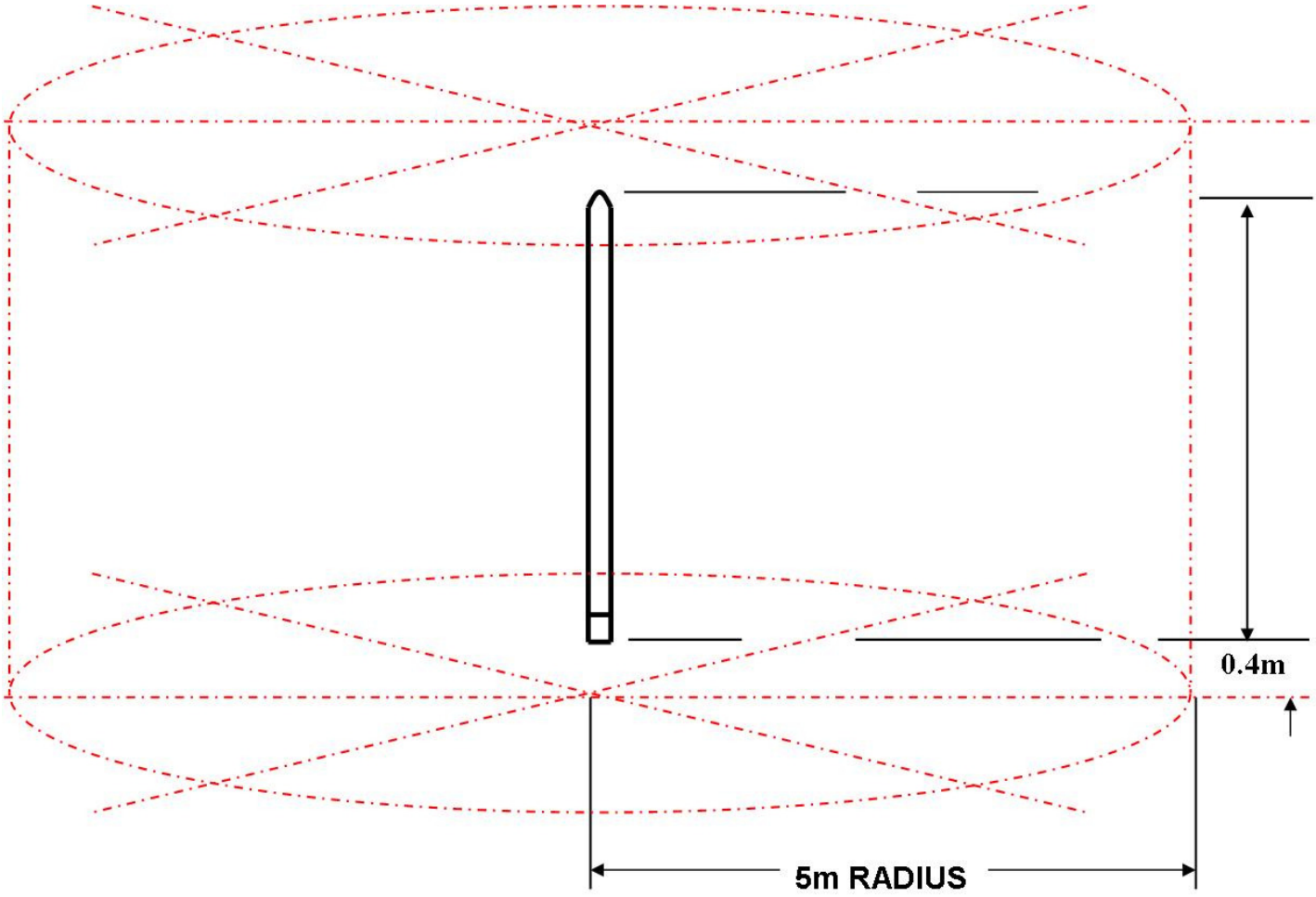
Typical Exclusion Zones Around Common Antennas.

On the following pages are some examples of four common antennas and their typical exclusion zones. These are for demonstration purposes only and should not be taken as defined values for field use.

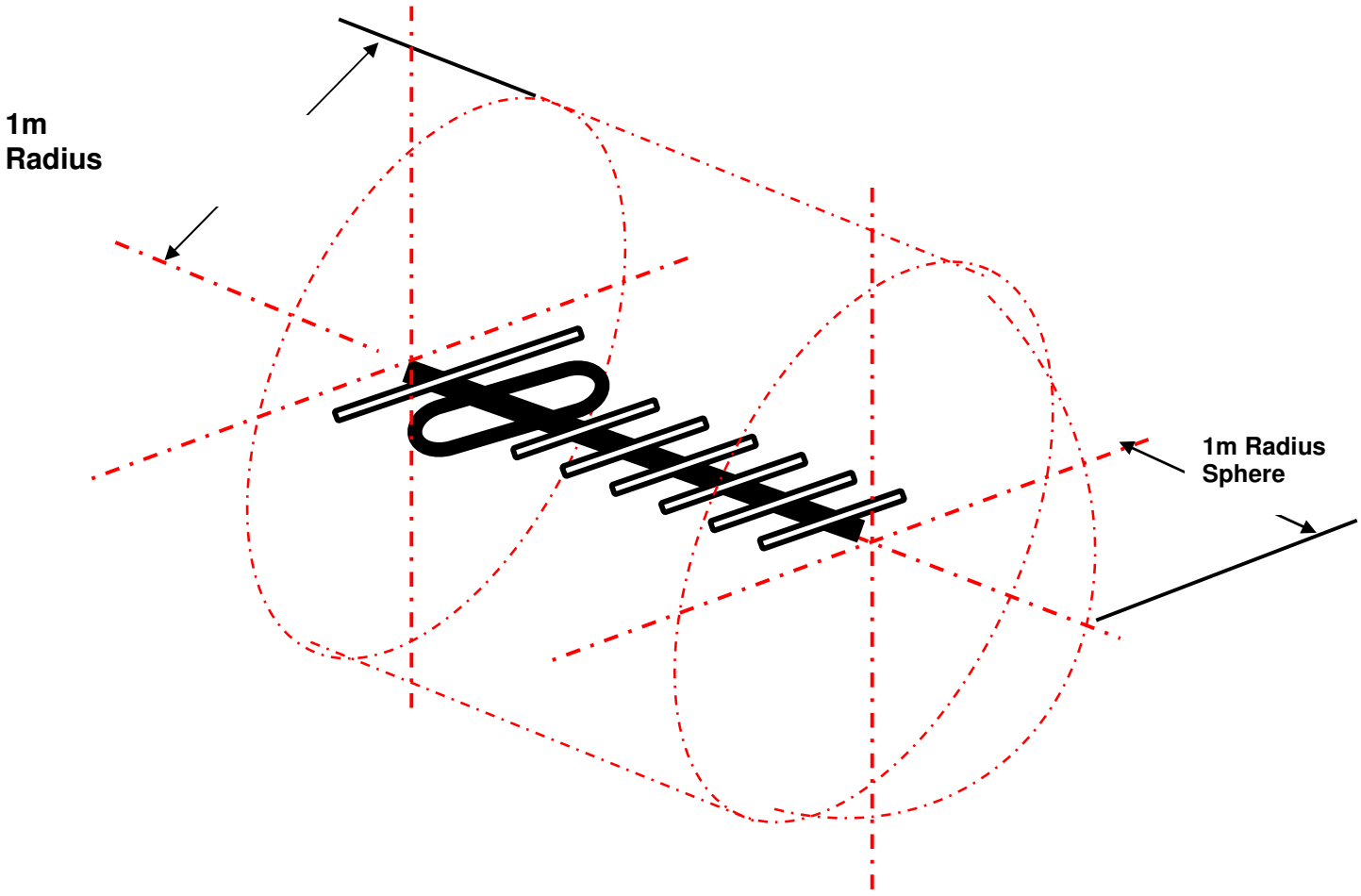
Unidirectional / Sector Antenna *(typical of a Macro cellular site operating at 100w or more providing coverage of up to 8 miles*)



Omni Directional Antenna *(typical of a small broadcast antenna operating at 100w and more to give coverage of up to 10 miles)*



Unidirectional Antenna / Yagi *(typical of a point to point link for telemetry operating at up to 10 watts and providing a link for up to 10 miles)*



Point to Point / Microwave Antenna *(typical of a point to point data link operating at 0.1-10 watts and providing a link over 3-60 miles)*

