Electromagnetic fields and public health: radars and human health

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Radar systems detect the presence, direction or range of aircraft, ships or other, usually moving objects. This is achieved by sending pulses of high frequency electromagnetic fields (EMF). Invented some 60 years ago, radar systems have been widely used for navigation, aviation, national defence and weather forecasting. Their primary objective is individual and collective safety and protection.

People who live or routinely work around radars have expressed concerns about long-term adverse effects of these systems on health, including cancer, reproductive malfunction, cataracts and changes in behaviour or development of children. A recent example has been the alleged increase in testicular cancer in police using speed control hand-held radar "guns".

It is important to distinguish between perceived and real dangers that radars pose, as well as to understand the rational behind existing international standards and protective measures used today.

EMF emissions

Radars usually operate at radio frequencies (RF) between 300 MHz and 15 GHz. They generate EMFs that are called RF fields. RF fields within this part of the electromagnetic spectrum are known to interact differently with human body.

RF fields below 10 GHz (to 1 MHz) penetrate exposed tissues and produce heating due to energy absorption. The depth of penetration depends on the frequency of the field and is greater for lower frequencies. Absorption of RF fields in tissues is measured as a Specific Absorption Rate (SAR) within a given tissue mass. The unit of SAR is watts per kilogram (W/kg). SAR is the quantity used to measure the "dose" of RF fields between about 1 MHz and 10 GHz.

- An SAR of at least 4 W/kg is needed to produce known adverse health effects in people exposed to RF fields in this frequency range.

RF fields above 10 GHz are absorbed at the skin surface, with very little of the energy penetrating into the underlying tissues. The basic dosimetric quantity for RF fields above 10 GHz is the intensityof the field measured as power density in watts per square metre (W/m2) or for weak fields in milliwatts per square metre (mW/m2) or microwatts per square metre (µW/m2).

- Exposure to RF fields above 10 GHz at power densities over 1000 W/m2 are known to produce adverse health effects, such as eye cataracts and skin burns.

Human exposure

The power that radar systems emit varies from a few milliwatts (police traffic control radar) to many kilowatts (large space tracking radars). However, a number of factors significantly reduce human exposure to RF generated by radar systems, often by a factor of at least 100:

- Radar systems send electromagnetic waves in pulses and not continuously. This makes the average power emitted much lower than the peak pulse power.
- Radars are directional and the RF energy they generate is contained in beams that are very narrow and resemble the beam of a spotlight. RF levels away from the main beam fall off rapidly. In most cases, these levels are thousands of times lower than in the main beam.
- Many radars have antennas which are continuously rotating or varying their elevation by a nodding motion, thus constantly changing the direction of the beam.
- Areas, where dangerous human exposure may occur are normally inaccessible to unauthorized personnel.

Radar sources

Some of the common types of radars encountered in daily life include:

Air traffic control radars are used to track the location of aircraft and to control their landing at airports. They are generally located at elevated positions where the beam is inaccessible to persons on the ground. Typical air traffic control radars can have peak powers of 100 kW or more, but average powers of a few hundred watts. Under normal operating conditions, these systems pose no hazard to the general public.

Weather radars are often co-located with air traffic control radars in remote areas at airports. They operate at higher frequencies but generally have lower average and peak powers. As with air traffic control radars, under normal conditions, they pose no hazards to the general public.

Military radars are numerous and vary from very large installations, which have large peak (1 MW or greater) and average powers (kW), to small military fire control radars, typically found on aircraft. Large size radars often evoke concern in communities living around them. However, because its power is radiated over a large surface area, the power densities associated with these systems vary between 10 and 100 W/m2 within the site boundary. Outside the site boundary RF field levels are usually unmeasurable without using sophisticated equipment. However, small military fire control radars on aircraft can be hazardous to ground personnel. These units have relatively high average powers (kW) and small area antennas, making it possible to have power densities up to 10 kW/m2. Members of the general public would not be exposed to these emissions because during ground testing of radars access to these areas by all personnel is prohibited. The military also use most other types of radars described below.

Marine radars can be found on small pleasure boats to large ocean going vessels. Peak powers of these systems can reach up to 30 kW, with average powers ranging from 1 to 25 W. Under normal operating conditions, with the antenna rotating, the average power density of the higher power systems within a metre of the antenna is usually less than 10 W/m2. In accessible areas on most watercraft, these levels would fall to a few percent of present public RF exposure standards.

Speed control radars are hand-held by police in many countries. The average output power is very low, a few milliwatts, and so the units are not considered hazardous to health, even when used in very close proximity to the body.

Possible health effects

Most studies conducted to date examined health effects other than cancer. They probed into physiological and thermoregulatory responses, behavioural changes and effects such as the induction of lens opacities (cataracts) and adverse reproductive outcome following acute exposure to relatively high levels of RF fields. There are also a number of studies that report non-thermal effects, where no appreciable rise in temperature can be measured.

Cancer-related studies: Many epidemiological studies have addressed possible links between exposure to RF and excess risk of cancer. However, because of differences in the design and execution of these studies, their results are difficult to interpret. A number of national and international peer review groups have concluded that there is no clear evidence of links between RF exposure and excess risk of cancer. WHO has also concluded that there is no convincing scientific evidence that exposure to RF shortens the life span of humans, or that RF is an inducer or promoter of cancer. However, further studies are necessary.

Thermal effects: RF fields have been studied in animals, including primates. The earliest signs of an adverse health consequence, found in animals as the level of RF fields increased, include reduced endurance, aversion of the field and decreased ability to perform mental tasks. These studies also suggest adverse effects may occur in humans subjected to whole body or localized exposure to RF fields sufficient to increase tissue temperatures by greater than 1°C. Possible effects include the induction of eye cataracts, and various physiological and thermoregulatory responses as body temperature increases. These effects are well established and form the scientific basis for restricting occupational and public exposure to RF fields.

Non-thermal effects: Exposure to RF levels too low to involve heating, (i.e., very low SARs), has been reported by several groups to alter calcium ion mobility, which is responsible for transmitting information in tissue cells. However, these effects are not sufficiently established to provide a basis for restricting human exposure.

Pulsed RF fields: Exposure to very intense pulsed RF fields, similar to those used by radar systems, has been reported to suppress the startle response and evoke body movements in conscious mice. In addition, people with normal hearing have perceived pulse RF fields with frequencies between about 200 MHz and 6.5 GHz. This is called the microwave hearing effect. The sound has been variously described as a buzzing, clicking, hissing or popping sound, depending on the RF pulsing characteristics. Prolonged or repeated exposure may be stressful and should be avoided where possible.

RF shocks and burns: At frequencies less than 100 MHz, RF burns or shock may result from charges induced on metallic objects situated near radars. Persons standing in RF fields can also have high local absorption of the fields in areas of their bodies with small cross sectional areas, such as the ankles. In general, because of the higher frequencies that most modern radar systems operate, combined with their small beam widths, the potential for such effects is very small.

Electromagnetic interference: Radars can cause electromagnetic interference in other electronic equipment. The threshold for these effects are often well below guidance levels for human exposure to RF fields. Additionally, radars can also cause interference in certain medical devices, such as cardiac pacemakers and hearing aids. If individuals using such devices work in close proximity to radar systems they should contact manufacturers to determine the susceptibility of their products to RF interference.

Ignition of flammable liquids and explosives: RF fields can ignite flammable liquids and explosives through the induction of currents. This is a rare occurrence, and normally of most concern where there is a large concentration of radars, such as on board a naval ship where measures are taken to prevent such effects.

International standards

Exposure limits for RF fields are developed by international bodies such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP is a non-governmental organization formally recognised by WHO. The Commission uses health risk assessments developed in conjunction with WHO to draft their guidelines on exposure limits. The ICNIRP guidelines protect against all established RF health effects and are developed following reviews of all the peer-reviewed scientific literature, including reports on cancer and non-thermal effects. Environmental RF levels from radars, in areas normally accessible to the general public, are at least 1,000 times below the limits for continuous public exposure allowed by the ICNIRP guidelines, and 25,000 times below the level at which RF exposure has been established to cause the earliest known health effects.

Protective measures

The aim of protective measures is to eliminate or reduce human exposure to RF fields below acceptable limits. An extensive program of measurement surveys, hazard communication, coupled with effective protective measures, is required around all radar installations. In most countries, comprehensive documentation is prepared, including an environmental impact statement, before a radar system can be constructed.

Following construction of the radar facility, site surveys should be performed to quantify RF field levels in the area. While extremely high RF field levels can be measured directly in front of a radar, in most cases levels in public areas are not easily measurable. In order to prevent both workers and the general public from entering areas where the RF levels are above the limits, both engineering and administrative controls are used.

- Engineering controls include interlocks, electronic means to exclude the radar pointing in certain areas, and shielding.
- Administrative controls include audible and visible alarms, warning signs, and restriction of access through barriers, locked doors, or limiting access time to radar.

When engineering and administrative controls do not suffice, workers should use personal protective equipment to ensure compliance with exposure standards. Conductive suits, gloves, safety shoes and other types of personal protective equipment for RF fields are now commercially available.

- They should be used with great care, since the attenuation properties of the material used to make this protective equipment can vary dramatically with frequency. Only when the attenuation properties of the equipment is known at the frequency in question can they be used reliably.
- Special care should be exercised with RF safety glasses since any metal may enhance local fields by acting as a receiving antenna.
- There are no exposure situations where members of the general public need to use protective equipment for RF fields from radars.
- In recent years, clothing and other materials have appeared on the consumer market claiming to have RF shielding properties, and directing their claims to "sensitive" members of the general population, such as pregnant women. The use of these types of products is unnecessary and should be discouraged. They offer no effective RF shielding, and there is no need for these devices.

Human exposure to EMF emitted by radar systems is limited by international standards and protective measures, which were adopted on the basis the currently available scientific evidence. In summary:

- RF fields cause molecules in tissue to vibrate and generate heat. Heating effects could be expected if time is spent directly in front of some radar antennas, but are not possible at the environmental levels of RF fields emanating from radar systems.
- To produce any adverse health effect, RF exposure above a threshold level must occur. The known threshold level is the exposure needed to increase tissue temperature by at least 1oC. The very low RF environmental field levels from radar systems cannot cause any significant temperature rise.
- To date, researchers have not found evidence that multiple exposures to RF fields below threshold levels cause any adverse health effects. No accumulation of damage occurs to tissues from repeated low level RF exposure.
- At present, there is no substantive evidence that adverse health effects, including cancer, can occur in people exposed to RF levels at or below the limits set by international standards. However, more research is needed to fill certain gaps in knowledge.