REMOTE CONTROL

BY BOB YOUNG

Are R/C transmitters a health hazard?

In the light of current concerns over cellular phones and a possible link with brain tumours, is there a health hazard for R/C modellers? Let's have a good look at the topic and see if there are reasons for concern.

I have been holding R/C transmitters close to my body for the past 45 years and I must admit this issue concerns me. On the other hand, R/C transmitters are fairly low in power and so they probably don't pose much of a hazard – or do they?

The radiation we are concerned with is NIR or non-ionising electromagnetic radiation – radiation in the electromagnetic spectrum that does not have sufficient energy to produce ionisation in matter. This radiation has an energy per photon of less than 12.4eV, wavelengths longer than 100nm and frequencies less than 3000THz. Included in the NIR part of the spectrum are magnetic fields, static electric fields, extremely low frequencies (ELF), radio frequencies (RF) up to and including microwaves, visible infrared (IR), lasers and ultraviolet (UV) – see Fig.1.

From Fig.1, it can be seen that the energy per photon is related to frequency. The higher the frequency, the greater the energy in the photons. This is good news for modellers in regard to the relatively low radio frequencies we use but bad news for those who operate models in direct sunlight.

Let's have the bad news first. The key factor in assessing the effects of radiation is the exposure level and this is usually related to time and the power density. The rate at which RF electromagnetic energy is imparted to a biological body is defined as the SAR (specific absorption rate) and is expressed in watts per kilogram (W/kg).

For optical radiation (UV, visible and IR), two systems of quantities and units are used: the photometric and radiometric systems. The photometric system covers only the visible portion of the EM spectrum whilst the radiometric system is used for all optical radiations.

When RF energy is absorbed in a medium, the most obvious effect is heating, so the radiation intensity can be determined calorifically. In SI terminology, the radiant intensity, irradiance or more commonly "power density" is expressed in watts per square metre. It is also valid to express radiant energy flow in the associated electric (E) and magnetic (H) field strengths. The units are volts per metre (V/m) and amperes per metre (A/m).

One further point which is important to grasp is the difference between the "far field" and "near field" measurements and their effects. In the far field (more than one wavelength from the source), either V/m or A/m can be used to describe the intensity of energy flow as there is a constant phase relationship between them ($E/H = 120\pi$). The source can be regarded as a point where the inverse square law holds.

However, in the near field, at points normally less than one wavelength from the source, there is not a constant phase relationship between E and H and so both the electric and magnetic field strengths must be given to properly express the intensity of the field. In the near field, the inverse square law does not hold. Keep in mind here that the near field for ELF can be measured in hundreds or thousands of kilometres so you are almost always in the near field. The near field for R/C transmitters is in the range 7-10 metres.

In the case of sunlight, we are very definitely in the far field and the inverse square law applies. Yet from a distance of 148 million kilometres, there is still enough power in the radiation to quite literally burn the skin off your body.

The biological effects of exposure to all optical radiations are mainly to the skin and eyes and can be divided into three major categories: thermal (including thermo-mechanical), photochemical and direct electric field effects, the last being a special case. Most damage is thermal and photochemical (athermal).

The ability of optical radiation to damage the skin and eyes depends on their transmission and the absorption in the critical organ. Figs 2 & 3 give various absorption levels of optical radiations in the skin and eyes. For modellers, this has serious ramifications and for professional flyers such

Table 1: Injuries To Humans Exposed To Optical Radiation

Radiation	Skin Damage	Eye Damage
UV	Erythema, aging, skin cancer, photosensitive reactions	Photokeratitis, conjunctivitis, cataract, corneal oedema
Visible	Photosensitive reactions, burns	Retinal injury
Near infrared	Burns, heat stress	Cataract, retinal injury, corneal injury
Far infrared	Burns, heat stress	Corneal injury

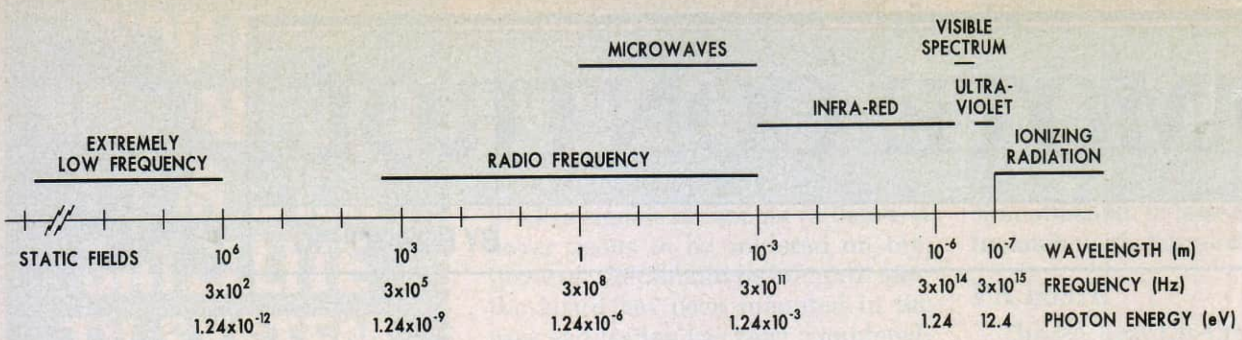

Fig.1: as can be seen from this diagram, the photon energy of radiation is directly proportional to the wavelength.

as myself, very serious consequences. At times, particularly when flying for the military, test flying new radios, practising for contests or on contract work, I would spend 5-6 hours daily, staring up at the sky. I did this for over 20 years.

The result is that my face is now a mass of blotches and I need to have skin cancers removed regularly. In my early days, sunscreens were almost unheard of and by the time they were in common use, the damage had been done. The skin specialist I attend recommends applying blockout daily and yet I still find myself reluctant to apply gooey creams for everyday wear.

UV damage

Table 1 shows the principle injuries to the skin and eyes from the various optical radiations. The wavelength significantly affects the final outcome when considering eye damage. The effects of UV are generally photochemical on the lens and cornea. Because of the imaging characteristic of the cornea, UV-A is the greatest hazard.

UV-B and UV-C are absorbed in the cornea and conjunctiva and at sufficiently high doses will cause keratoconjunctivitis. UV causes damage to the epithelial cells which would normally be repaired in a day or so. If the dose is high enough however, scaring, giving a milky appearance, may result. Sometimes, it can induce an invasion of blood cells in the cornea or cause long term damage.

Chronic exposure to sunlight, especially the UV-B component, accelerates the skin aging process and increases the risk of skin cancer. Exact quantitative and dose-response relationships have not been established although fair-skinned individuals, especially of Celtic origin, are much more prone to develop skin cancer. Work populations exposed to artificial sources of UV-B have not been studied in detail to ascertain the risk of cancer from this source. However, be careful of the UV light boxes used in PC board manufacture. Squamous cell carcinoma is the most common cancer associated with UV-B.

There is also a wide range of drugs which increase sensitivity to UV. These include sulphurs, diuretics, some antibiotics, estrogens and many others. Cosmetic ingredients (in perfumes, deodorants and soaps) may react with UV to produce photo-allergenic or phototoxic effects which can include redness, itching, hives, blistering or uneven pigmentation, so do not use them before going out in the sun.

Compared to the foregoing, what is to follow on RF radiation pales into insignificance. Do yourself a favour and buy the best sunglasses you can afford, use blockout daily or at least when out modelling and generally follow the "slip, slop, slap" routine.

Finally, there are good aspects of sunlight. Rickets, a disease long thought to be banished from modern society, has suddenly become a menace once more. This is caused by people avoiding sunlight so much that they are now not producing enough vitamin D to protect them from the disease.

RF exposure

When a biological organism is exposed to RF or microwave radiation, electric and magnetic fields are induced within it. A perfect dielectric absorbs no energy from the electromagnetic field and the field is propagated through the medium unattenuated. However, the human body is a lossy dielectric and there is, as a result, a motion of free ions (conduction loss) and molecular rotation (dielectric loss). The nett result is an energy transfer from the field to the human body. This absorbed energy will be the source of work and a temperature rise will occur. This work may be electrical, mechanical or chemical.

It is difficult to measure the exact absorption in a complex shape such as a human body or animal and the distribution of the energy within the body will vary by several orders of magnitude depending on the size of the body, irradiation frequency and orientation.

To complicate matters further, the RF spectrum can be divided into four ranges as far as absorption is concerned. These are the sub-resonance range, the resonance range, the hot spot range and surface heating range.

By far the greatest influence is frequency. The critical frequencies for humans in the resonance range peak at 70MHz and will vary between 30MHz and 300MHz depending on size and on whether a ground plane is present. Between 400MHz and 3GHz, significant localised energy absorption occurs, giving rise to hot spots. Depending on frequency, these may vary in size from 1cm in cross section to several centimetres. At frequencies over 2GHz, the effects are mainly confined to surface heating.

Testing on animals is difficult because of the differences in size and the heat transfer characteristics of fur bearing animals. Frequency scaling is one approach used, where the frequency is increased or reduced to match the size of the animal.

Exposure of tissues to RF results in a temperature rise when the rate of energy absorption exceeds the rate of dissipation. Heat dissipation mechanisms include active and passive thermo-regulatory mechanisms. Passive mechanisms include heat radiation, conduction, convection and evaporative cooling. Active mechanisms include blood circulation and cutaneous vasodilation to shift the internal heat to the skin so that passive mechanisms can dissipate the heat into the environment. A good stiff breeze adds a chill factor which aids cooling.

The possibility of local hot spots exists where the rate of absorption is high compared to the vascular heat transfer

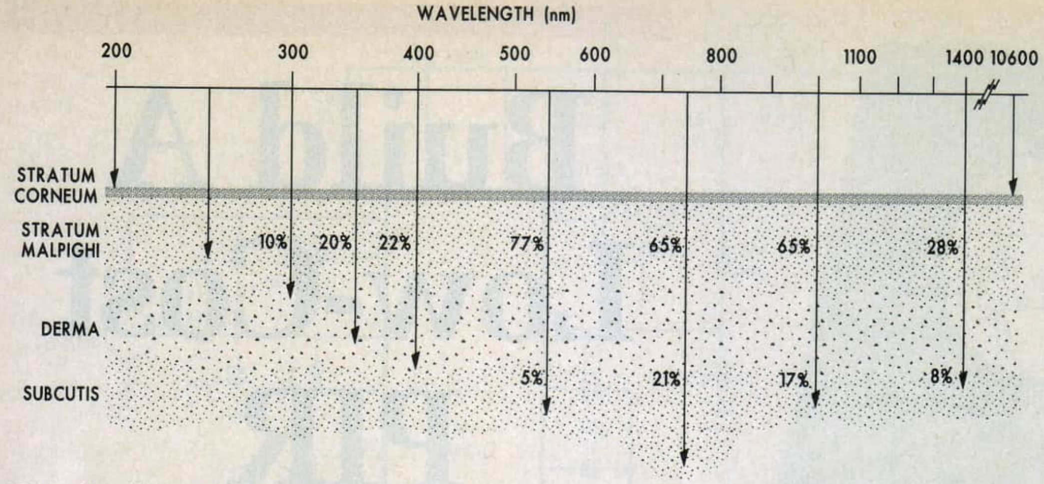

Fig.2: this diagram shows that UV-B frequencies around 700nm have the deepest penetration into your skin.

mechanism or where pooling occurs. Among these spots are the lens of the eye, the necrotic centre of tumours, the splanchnic region and above the spinal cord.

Exposure of animals to high levels of radiation has caused various injuries ranging from local lesions and necrosis (death of tissue) to gross thermal stress from hyperthermia. Death from overheating has been induced with power densities of a few hundred to several thousand watts per square metre.

Some animals died of hot spots due to non-uniform energy absorption and some of these died showing no signs of distress. I can recall an accident in which a technician left off an inspection panel from a radar waveguide and sat in front of the opening during a prolonged test. He died as a result of his kidneys overheating. The kidneys have poor heat dissipation due to the fat around them.

The cornea and crystalline lens are very susceptible to injury within the range of 1-300GHz; the cornea between 10-300GHz and the lens between 1-10GHz. Exposure within the range of 1.5-2kW/m^2 lasting from one hour to 24 hours, or for a few hours per day repeated for a few days per week, can result in cataracts. The formation of retinal lesions is also possible.

Behavioural changes

One of the most obvious effects are behavioural changes and some small animals have been observed showing signs of decreased endurance and convulsive activity. Both ANSI (1982) and INIRC/IRPA (1984) considered this behavioural sensitivity to be the lower limit of harm from exposure to RF fields and have based their exposure limits on these effects.

Studies on the health effects in humans have been inadequate, for various reasons. The most obvious is that it is not wise to use human guinea pigs.

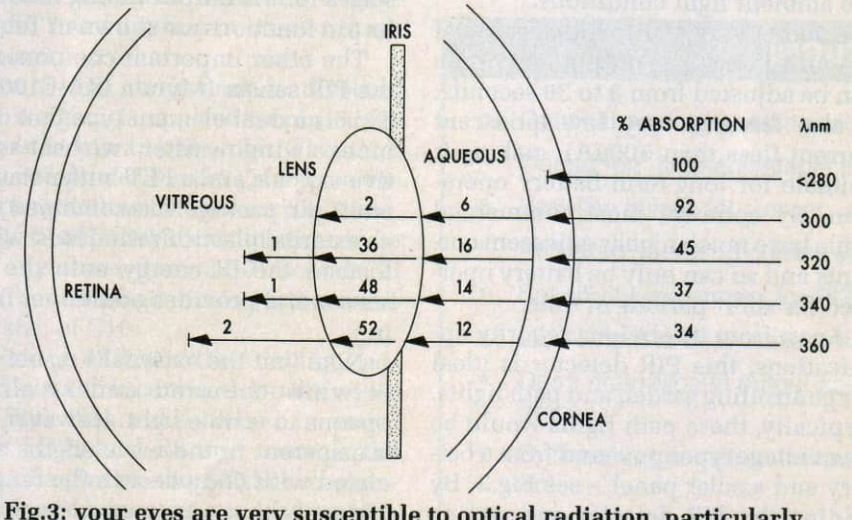

Fig.3: your eyes are very susceptible to optical radiation, particularly ultraviolet. Excessive exposure can lead to the formation of cataracts.

Surveys of personnel exposed to RF accidentally have been conducted but since the exposure levels and times are not known accurately, the results are inconclusive.

Early studies conducted in Czechoslovakia, Poland and the Soviet Union reported that some subjective complaints such as headaches, irritability, sleep disturbances, weakness, decreased sexual activity (libido) and generally poorly defined feelings of ill health were experienced. However later studies conducted in the USA and Poland with better controls indicated there was no relationship between exposure up to 60W/m^2 and the incidence of functional disturbances, morbidity, reproductive performance and the health of children.

Power densities required for the formation of cataracts appears to be above 1kW/m^2 which agrees with the experimental data for rabbits.

Following a detailed study of all factors involved in RF exposure, the International Non-Ionising Radiation Committee of IRPA has published guidelines on limits of exposure to RF fields. The health risk assessment and exposure limits can be found in INIRC/IRPA (1984). Australian Standard AS 2772.1-1988 was based on this standard.

Now for the good news. AS 2772.1 does not concern itself with transmitters below 7W and 1GHz and sets the maximum occupational exposure at 10W/m^2 for transmitters in the range 30MHz-300GHz. In addition, the SAR is related to watts per kilogram, so the more kilograms you have, the more watts you can safely absorb. The non-occupational long term exposure rate is set at 0.4W/kg.

As most R/C transmitters run around 0.5W into a very inefficient antenna and most of us weigh more than 1.25kg there is little likelihood of any real danger. Here again, the truth is that nobody really knows. Keeping in mind Murphy's Law 743 which states that all things that are fun are bad for you, I am sure somebody will eventually come up with the proof that we should not use R/C transmitters at all.

However, be that as it may, probably the most serious health risk from R/C transmitters is getting poked in the eye by your mate's antenna! **SC**