RADIO FREQUENCY RADIATION (RFR) EXPOSURES FROM MOBILE PHONES

K.H. Joyner, V. Lubinas, M.P. Wood, J. Saribalas and J.A. Adams*

Telecom Australia Research Laboratories
770 Blackburn Road, Clayton Victoria
***Department of Physics,**
University of Canterbury, Christchurch, New Zealand.

ABSTRACT

Measurements of the free space levels of radio frequency radiation (RFR) around a hand-held mobile phone and the specific absorption rate (SAR) induced in the ocular region of a phantom head exposed to RFR from a mobile phone are presented. The level of RFR measured 5 cm from the antenna of a mobile phone transmitting 600 mW was 0.27 mW/cm^2. The average SAR level measured in the nearside eye of the phantom head containing tissue equivalent jellies was 0.7 W/kg for a 600 mW transmit power which is very much less than the spatial peak limit of 8 W/kg underlying the Australian and other national and international RFR exposure standards.

INTRODUCTION

In Australia the Telecom cellular mobile phone network is expanding rapidly with the total number of customers exceeding 300,000. The hand-held mobile phone transmits on frequencies between 825 and 845 MHz and has an output power of 600 mW. Questions associated with RFR exposure have been raised in the media and, in one report, the use of a mobile phone was likened to placing one's head in a microwave oven. Clearly such a claim is ludicrous as the hand held mobile phone has a transmit power of 600 mW and radiates into all space, whereas a microwave oven operates at around 600 W and radiates into a confined space.

Australian and IRPA Standards for Mobile Phones

Both the Australian [1] and IRPA [2] Standards contain exclusions for devices with output powers of less than 7W and transmission frequencies of less than 1000 MHz. The exclusions, although not explicitly stated in the Standards, are based upon a spatial peak limit for the specific absorption rate (SAR) of 8 W/kg averaged over any 1 gram of tissue. As stated earlier, the hand-held mobile phones in use in Australia have maximum radiated power of 600 mW and transmission frequencies of between 825 and 845 MHz and as such are excluded from compliance with both the Standards. If these exclusions did not appear in the Standards then for members of the general public, the appropriate limits of RFR exposure to be observed at 835 MHz would be 0.2 mW/cm^2 for the Australian Standard and 0.42 mW/cm^2 for the IRPA Standard.

EXPERIMENTAL MEASUREMENTS

Measurements were made of the free space levels of RFR in the vicinity of the antenna of a mobile phone. These measurements were conducted in a semi anechoic chamber with the mobile phone mounted in a vertical position on a wooden support 1.75 m above the ground. The mobile phone was configured to transmit a full 600 mW of continuous power. A Narda 8616 broadband monitor and Narda 8621C isotropic broadband probe (0.3 to 26 GHz), mounted on a wooden support 1.75 m above the ground, were used to measure the levels of RFR at various distances from the antenna. The following levels were recorded:

Distance From Antenna (cm)	**Power Density (mW/cm^2)**
0	0.39
1.0	0.33
2.5	0.32
5.0	0.27
7.5	0.21
15.0	0.10

Within distances of 7.5 cm from the antenna, the level of 0.2 mW/cm^2 recommended in the Australian Standard [1] for members of the general public is exceeded. However, in the normal mode of operation the antenna is unlikely to be closer than 7.5 cm to the eye. In any case exposures within 7.5 cm would only be of concern if there was no exclusion clause. The free space levels of RFR are not of concern for the IRPA Standard because they are below the limit values irrespective of the exclusion clause.

Energy Absorption in Eye of Phantom Head

In the Australian context it is possible for confusion to exist between the exclusion clause in the Standard [1] and the observation that the free space levels of RFR close to the antenna of a mobile phone exceed the recommended limit for members of the general public. Therefore, it was decided to conduct a series of measurements on a phantom head and actually measure the SAR in the ocular area. The ocular area was chosen as the primary site of investigation because of the limited ability of the eye to dissipate heat relative to the brain, and the possibility of local field enhancement in the orbit due to resonance.

The phantom head was fabricated to simulate as closely as possible the electrical characteristics of a real head. Consequently, artificial tissues for eye, muscle, brain, skin and fat were developed having the same conductivity and relative permittivity as their real counterparts. The tissues were applied to a plastic replica skull which, was found to have electrical properties closer to living bone than a dried human skull. The following electrical properties corresponding to the various tissue types were used in the experiment.

Tissue		**Relative Permittivity**	**Conductivity (mS/m)**
eye	[3]	70	1900
muscle	[4]	59	1190
brain	[5]	44	940
skin	[6]	35	590
fat	[7]	5.7	60

In order to measure the electrical properties of these mixtures at 835 MHz a technique has been adapted which relies on measuring the input admittance of a monopole antenna inserted into the medium under test. The complex permitivity and hence relative permittivity and conductivity are obtained from the measured admittance as they are functionally related according to the antenna modelling theorem [8].

Both an electric (E) field probe and a temperature probe were used in the experiment. The E-field probe was manufactured specifically for the task. It consisted of an 11 mm (tip-to-tip) dipole and an HP 2207 diode mounted across the centre gap. The dipole was angled at 54.7° to the probe handle such that when the probe handle was rotated through each of three 120° sectors an isotropic response was achieved. The dipole elements of the E-field probe were encased in a 4 mm coating of epoxy. This was to physically protect the dipole and to reduce any artificial enhancement of the probe output when inserted in tissue due to increased capacitive coupling between the dipole elements. The probe was then calibrated in air. The temperature probe used was a Luxtron Fluoroptic probe model 1000A which has a 0.1°C resolution.

During the experiment the mobile phone was placed along side the head in a normal manner and measurements made in the nearside eye. The SAR was calculated from the measured E-field level using the relationship SAR = $\sigma E^2/\rho$ where σ is the conductivity and ρ the density of wet tissue (1000 kg/m^3).

A number of measurements of the SAR were made and the average value obtained was 0.7 W/kg for a transmit power of 600 mW. If we scale up from 600 mW to the figure of 7 W which is used in the exclusion clause [1, 2] we find the scaled SAR corresponds to 8.2 W/kg which is in very good agreement with the spatial peak limit of 8 W/kg underlying the exclusion clause.

No temperature increases could be measured in the phantom with the Fluoroptic probe which indicates that any rise in a real head must be less than 0.1° C. An interesting point is that a 3mm sheet of polystyrene foam had to be used as a thermal barrier in order to shield the phantom head from heat generated by the electronic circuitry of the phone.

Temperature rises in the eye corresponding to the induced SAR were numerically calculated by applying the well known bioheat equation to a finite element model of the eyeball. The model was axisymetric about the optic axis and consisted of 64 triangular and 166 quadrilateral elements. The thermal conductivities used for the major structures of the eyeball were 0.58 W/m/°C for the cornea, sclera, aqueous humour, iris and ciliary body 0.40 W/m/°C for the lens and 0.603 W/m/°C for the vitreous humour [7]. The external heat loads to the anterior surface of the eyeball exposed to air were evaporation at 60 W/m^2 and convection and radiation to an ambient temperature of 20°C at a combined heat transfer coefficient of 16 W/m/°C. Convective heat transfer from the posterior surface of the eyeball to the blood flow of the choroid was set at a heat transfer coefficient of 67 $W/m^2/°C$ to a blood temperature of 37°C. Internally the respective blood flow in the iris and ciliary body was characterised as transferring 270 X 10^3 and 416 X 10^3 W/m^3 per degree C difference from the blood temperature of 37°C, as per the heat sink term in the bioheat equation.

Steady state analyses were conducted on the model when the eyeball was uniformally loaded at 0.75 W/kg SAR and on the normal unirradiated eye. The maximum temperature difference between the two conditions was 0.07°C in the vitreous humour. The maximum temperature rise in the lens was 0.05°C around the posterior pole.

CONCLUSIONS

The level of RFR measured 5 cm from the antenna of a mobile phone transmitting 600 mW was 0.27 mW/cm^2. This level of RFR has been shown to produce and average SAR of 0.7 W/kg in the ocular region of a fabricated skull. The subsequent maximum temperature rise in the eye has been calculated to be 0.07° C. On the basis of these results the general exclusion for devices operating at less than 7 W and with transmission frequencies of less than 1000 MHz is justified. It can also be concluded that the use of hand-held mobile phone does not present a health risk.

REFERENCES

1. AS2772.1, 1990. Standards Australia, North Sydney, NSW.
2. IRPA/INIRC. Health Physics, 1988:54;115-123.
3. Guy, A.W. IEEE Trans. Microwave Theory Tech., 1971:MTT-19(2);205-214.
4. Kraszewski, A. et al. Bioelectromagnetics, 1982:3;421-432.
5. Thurai, M. et al. Bioelectromagnetics, 1985:6;235-242.
6. Grant, J.P. et al. Phys. Med. Biol., 1988:33(5);607-612.
7. Cleveland, R.F. and Athey, T.W. Bioelectromagnetics, 1989:10;173-186.
8. Pham, A. Telecom Aust. Res. Labs. Rep. RLR 8078, 1991.
9. Scott, J.A. Phys, Med. Biol., 1988:33(2);227-241.

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