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Cellular telephones and effects on the brain: The head as an antenna and brain tissue as a radio receiver

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Summary Headache and other neuropsychological symptoms occur in users of cellular telephones, and controversy exists concerning risks for brain cancer. We hypothesize these effects result from the head serving as an antenna and brain tissue as a radio receiver. The frequencies for transmission and reception by cellular telephones, about 900 MHz for analog and 1800 MHz for digital transmission, have wavelengths of 33–35 and 16–17 cm, respectively. Human heads are oval in shape with a short axis about 16 to 17 cm in length. Near the ear there will be a cross-section in the head with an axis half the wavelength of RF/MW transmissions of 900 MHz and equal to the wavelength of RF/MW transmissions at 1800 MHz.

Therefore, the human head can serve as a lossy resonator for the electromagnetic radiation emitted by the cellular telephone, absorbing much of the energy specifically from these wavelengths. Brain cells and tissues demodulate the cell-phone's audio frequencies from the radio frequency carrier. Low audio frequencies in the ranges of α and β waves affect these waves and thereby influence brain function. These effects state the case for a precautionary policy. © 2002 Published by Elsevier Science Ltd.

HYPOTHESIS

There have been case reports of headache, nausea, dizziness, sleep disturbance, short-term memory problems, and fatigue in users of cellular telephones (1,2). Laboratory studies have reported alterations in permeability of the blood brain barrier, brain electrical activity, membrane permeability, and DNA breaks (3). Three epidemiologic studies have not found excess prior use of cell phones in persons with brain cancer (4–6), but their negative findings reflect short periods of follow-up and small numbers of individuals with cancer who actually had prior cell phone use (7). So far, there is absence of consensus as to a plausible mechanism to explain reported adverse health effects (8) from sub-thermal exposures to electromagnetic radiation at microwave frequencies (RF/MW) of cellular telephones.

The reason for the absence of a consensus is that the energy potential of cellular telephone frequencies is low compared to potentials from ionizing radiation. Local heating (estimated to be 0.11 °C rise in brain) due to the non-ionizing radiation from cellular telephones absorbed in the head is too weak to account for the health effects (2).

Frohlich has suggested that brain cells are far from being in a state of equilibrium, so that even low energy non-ionizing radiation at appropriate frequencies can trigger non-trivial effects in brain function (9). We postulate that the size and shape of the head acts as an

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antenna for the MW frequencies of mobile telephones. We also postulate that un-modulated MW frequencies will not affect perturbations in brain function but modulated RF/MW frequencies will. This bio-resonance may be the mechanism underlying sub-thermal effects (8,9).

The frequencies for transmission and reception by cellular telephones (800–900 MHz and 1800 MHz) include wavelengths of 33–35 cm and 16–17 cm, respectively. Human heads are oval in shape, and near the ear there will be a cross-section in the head with an axis either half the wavelength of RF/MW transmissions at 900 MHz or equal to the wavelength in the case of frequencies at 1800 MHz. Therefore, the human head can serve as a lossy resonator for the electromagnetic radiation emitted by the cellular telephone, as illustrated in Fig. 1. Joines and Spiegel have, in fact, analyzed the possibility of resonance absorption of microwaves of human skull at frequencies ranging from 100 MHz to 3000 GHz, but without addressing the specific effects of cellular telephone's wavelengths at multiples of the diameter of the human skull (10). Their mathematical analysis, in 1974, focused on resonance from frequencies 'near' 2100 MHz from leakage from microwave ovens, but not from resonance from cellular telephones, which did not then exist commercially. Their results lend support to the first hypothesis.

A more recent numerical analysis of absorption by model human heads performed by Schornborn et al. (11) also verifies the hypothesis. Model heads of adults and children based on MRI scans of an adult and, two children were digitized using averaged values of the electric properties of white and gray brain tissue. The results of their numerical analysis are that at 900 MHz the adult head absorbs 80% of the radiation emitted by a cellular telephone, whereas the head of a seven-year-old child absorbs only 69% of the radiation. We attribute this

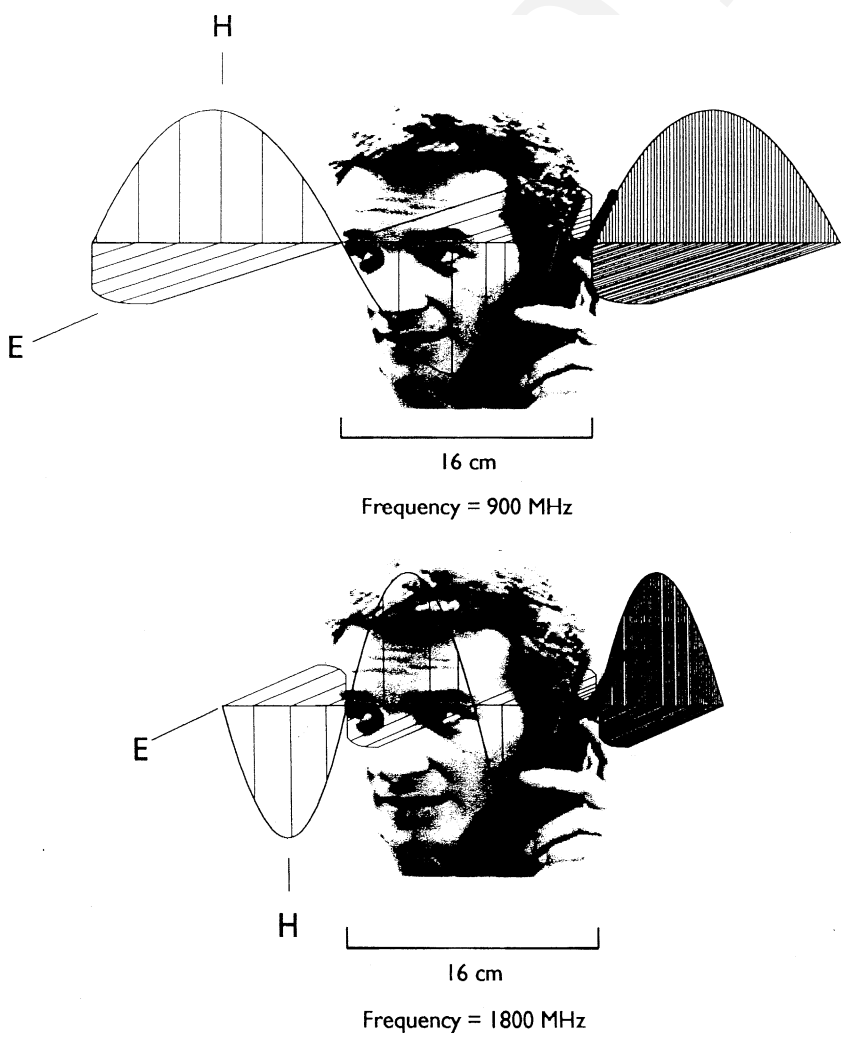

Fig. 1 Wavelengths of cellular telephones in relation to diameter of head for 900 and 1800 MHz: E, plane of electrical field; H, plane of magnetic field.

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difference in absorption efficiencies to the difference in size between the adult head and the child's. A 900 MHz frequency implies a half-wavelength of about 16–17 cm. The adult head will resonate at this wavelength, whereas the child's head may not have resonance at this wavelength because of smaller head dimensions.

These facts suggest the hypothesis that the head itself serves as an antenna and receiver for RF/MW from cellular telephones and will absorb much of the energy radiated by the cellular telephone.

We now consider our second hypothesis. Bawin et al. have shown that chicken and cat brain tissue act to demodulate square wave RF radiation in the same way that a radio receiver acts to demodulate carrier radio frequency waves to audio frequencies (12). Calcium efflux from brain sections is strongly influenced by modulation frequencies in the 6–20 Hz band, e.g., low audio frequencies, but not by un-modulated frequencies. If so, then adverse health effects from cellular telephones could result from bio-resonance in brain cells and tissue specifically by absorption of the radio-frequency transmission signals in the near field and their demodulation to audio frequencies. We suggest that the audio frequencies mediate the reported effects on α waves (8–14 cycles per second) and β waves (14–60 cycles per second). Von Klitzing has reported that EEG brain α waves (8–14 cycles per second) and β waves (14–60 cycles per second) are altered when exposed to cellular phone signals at field strengths as low as $0.1\,uW/cm^2$ (13), a level substantially lower than field strengths in the near field of cellular telephones (14). If our hypotheses are true, then laboratory studies based on exposures of small animals with small heads to un-modulated transmission frequencies used by cellular telephones cannot predict risks for neurobehavioral and possibly other effects in humans with larger head sizes from 'low' (i.e., sub-thermal) exposures. The same qualification applies to assessments of risks and standards based on simple linear models of relationships between wave frequency and energy potential.

We can test functional disturbances of brain function by modulated and un-modulated RF/MW on primates by using transmission frequencies in the range of 1850–1990 MHz. The half-wavelengths of these frequencies are between 7.5 and 8 cm, e.g., the head size of small monkeys.

In summary, since mobile phones broadcast specifically at frequencies at which the head serves as an antenna and brain tissue serves as a demodulating radio receiver, then it is reasonable to expect effects—adverse and otherwise—from bio-resonance at field strengths and specific absorption rates well below current thresholds. We call for reexamination of the assumptions underlying the US FCC's statement that 'permitted exposure levels based on past studies carried out at frequencies both higher and lower than those used for r cellular and PCS phones have led expert organizations to conclude that typical RF exposures from these devices are safe' (15). We suggest that past studies of higher and lower frequencies are not applicable to the frequencies of present cellular telephones for which the head, because of its size and shape, behaves as a lossy resonator.

These effects state the case for a precautionary policy.

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