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Brain interactions with RF/microwave fields generated by mobile phones

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Neither radiofrequency (30 kHz-300MHz) nor microwave fields (300-3000 MHz) exist as significant components of the natural terrestrial electromagnetic environment. In consequence, our human generation is the first to voluntarily expose itself to artificial RF/microwave fields that cover a wide spectrum of frequencies and intensities. In general suburban environments, these newly introduced fields now have average intensities around 1 $\mu W/cm^2$ (4V/m). Typical mobile phones radiate an average power of 0.2-0.6 W. When hand-held and operated close to the head, background levels are sharply distorted, with 40 percent of radiated phone energy absorbed in the hand and the head ([Kuster et al., 1997]). In this mode of operation, a mobile phone may be regarded as a quite powerful radio transmitter. Its emission at the head surface is typically 10,000 times stronger than fields reaching the head of a user standing within 30 m of the base of a typical mobile phone relay transponder mounted on a tower 30m above ground.

1. Historical development of analog and digital mobile phone transmission systems

The rapid worldwide development of mobile phone communication systems over the past decade has involved an equally rapid technological progression. In consequence, the heads of many current phone users have been exposed to a sequence of microwave fields modulated in substantially different ways ([Adey, 1997]). Initially, voice information was universally signaled by frequency-modulation (FM) of the microwave carrier wave. In a biophysical perspective, the carrier wave remains constant in amplitude throughout the transmission epoch, all voice information being transmitted in the frequency domain. Although these FM (analog) systems are still in common use, radio engineering considerations, such as economy of power usage in phone operation, and optimal utilization of the limited available microwave spectrum, have led progressively to general adoption of digital transmission techniques ([Kuster et al., 1997]). Initial transmission systems utilized 400 MHz frequencies, but current systems generally transmit at 900 and 1800 MHz.

Two methods of digital modulation now widely used in mobile phone systems exemplify these techniques. The North American Digital Cellular (NADC) standard used in North America and Japan employs Time Division Multiple Access (TDMA) modulation with speech encoding at 50 pulses/sec. The Global System for Mobile Communication (GSM) system employed throughout Europe and in much of the rest of the world is encoded at 217 pulses/sec.

2. Influence of microwave phone fields on human cognitive performance

Changes in human cognitive performance have been reported during exposures to simulated or actual GSM phone fields, and to FM (analog) phone fields. With simulated GSM and FM fields, there was increased speed in choice reaction time, greater in FM exposures than GSM ([Preece et al., 1999]). Using six cognitive neuropsychological tests (digit-span and spatial-span forwards and backwards, serial subtraction and verbal fluency), performance was facilitated following 30 min exposure to a 900 MHz GSM mobile phone field in two tests of attentional capacity (digital span forwards and spatial span backwards), and processing speed (serial subtraction) ([Edelstyn and Oldershaw, 2002]).

3. Subjective symptoms reported from prolonged mobile phone use

A wide range of subjective symptoms has been reported with prolonged use of mobile phones. They include dizziness, discomfort, concentration and memory difficulties, fatigue, warmth on and behind the ear, and burning sensations in the face. Scandinavian studies of these symptoms have involved 6379 GSM phone users and 5613 NMT (analog) users in Sweden, and 2500 from each category in Norway ([Sandstrom et al., 2001]; [Wilen et al., 2003]). These studies took account of energy absorption (SAR) in head structures adjacent to the user's ear, and indicators of the amount of daily use, as determined from the calling time/day and the number of calls/day. They conclude that subjective symptoms, especially dizziness, discomfort and warmth behind the ear, correlate with high SAR values (> 0.5 W/kg) and longer call times/day.

4. Alterations in EEG records and cerebral blood flow during and following mobile phone field exposure

GSM mobile phone fields are reported to alter EEG patterns during and following exposure, with evidence for concomitant changes in cerebral blood flow. During cognitive processing of a visual sequential letter task, 902 MHz digital fields altered event-related EEG desynchronization/synchronization responses in the 6-8 and 8-10 Hz bands, but only when examined as a function of memory load, and depending also on whether the presented stimulus was a target or not ([Krause et al., 2000]). Positron emission tomography (PET) after unilateral 30 min head exposure increased relative cerebral blood flow in the dorsolateral prefrontal cortex on the exposed side. These pulsed GSM fields also enhanced EEG power in the alpha (8-13 Hz) range prior to sleep onset and in the spindle frequency range during Stage 2 sleep. Importantly, exposure to unmodulated (CW) fields at the same average power density as the GSM fields did not enhance power in the waking or sleeping EEGs, supporting concepts that pulse-modulation is necessary to induce waking and sleeping EEG changes ([Adey, 1997]; Huber et al., 2002]).

5. Modification of blood-brain-barrier permeability by mobile phone and other microwave fields

In an historical perspective, initial observations of possible disruption of the blood-brain-barrier (BBB) by microwave fields used 3 GHz radar fields at presumed nonthermal incident levels

(3 mw/cm^2) ([Oscar and Hawkins,1977]). They reported increased brain uptake of mannitol and inulin through the BBB in rats, but not of dextran. This pioneering observation was overshadowed by subsequent collaborative studies in which Oscar participated, with findings of no BBB permeability change to sucrose ([Oscar et al., 1982]; Gruenau et al., 1982]). The original study using mannitol and inulin was not repeated at that time.

More extensive studies since 1988 by Salford and colleagues have reported significant leakage of albumen through the BBB in rats exposed once to GSM phone fields for 2 h at whole body average energy absorption rates of 2 mW/kg, 20 mW/kg, and 200 mW/kg ([Salford et al., 2003]). All field levels would be consistent with nonthermal exposures. Exposed animals were allowed to survive for about 50 days. Albumen antibodies displayed positive foci around finer blood vessels in gray and white matter. Damaged neurons, as revealed by cresyl violet staining, were found amongst normal neurons in cerebral cortex, hippocampus and basal ganglia., with a maximum incidence around 2%, but in some restricted areas, dominated the picture. Scores differed significantly between the groups, with evidence for a dose-dependence ($P<0.002$). The authors conclude that "the time between the last exposure and sacrifice is of great importance for detection of foci of leakage, since extravasated albumen rapidly diffuses below concentrations possible to demonstrate accurately immunohistologically. However, the initial leakage may start a secondary BBB opening, leading to a vicious circle – as we demonstrate albumen leakage even 8 weeks after the exposure…..We and others have pointed out that when such a relatively large molecule as albumen may pass the BBB, many other smaller molecules, including toxic ones, may also escape into the brain due to RF exposure."

At the cellular level, a model of the BBB can be achieved *in vitro*, in a co-culture of rat astrocytes and porcine brain capillary endothelial cells ([Schirmacher et al., 2000]). The existence of a BBB formed by these capillary endothelial cells was confirmed by the presence of the *zona occludens* protein as a marker of intercellular tight junctions, and also by the close contacts between these cells, together with an absence of intercellular clefts. Permeability measurements with radiolabeled sucrose also correlated with a physiological "tightness." Exposure to GSM phone fields at 1800 MHz for 4 days significantly increased permeability to radiolabeled sucrose in comparison to unexposed controls.

6. See also: Search Neuroscion

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