

Studies published in 2003-2005 demonstrating biological effects from exposure to low-intensity radiofrequency radiation.

Citations and Abstracts

Ardoino L, Barbieri E, Vecchia P. Determinants of exposure to electromagnetic fields from mobile phones. *Radiat Prot Dosimetry*. 111(4):403-406, 2004.

In actual conditions of use, the power radiated from cellular phones changes during conversation depending on several factors. Upon request from the radio base station (RBS), the phone in fact, reduces, its power to a level that is deemed optimum for the quality of conversation. In this study, special phones, which had been modified to allow the continuous logging of power emitted during the calls have been used. Off-line processing of recorded data allowed the analysis of the behaviour of mobile phones under real-use conditions. Further data recorded by operators at selected base stations were used for the purposes of comparison and checking of the effectiveness of the experimental method. The results indicate a high proportion of use of the highest power levels, under any circumstance. Such behaviour is mainly due to frequent handovers requested by the control software to optimise the communication traffic.

Czyz J, Guan K, Zeng Q, Nikolova T, Meister A, Schönborn F, Schuderer J, Kuster N, Wobus AM, High frequency electromagnetic fields (GSM signals) affect gene expression levels in tumor suppressor p53-deficient embryonic stem cells. *Bioelectromagnetics* 25:296-307, 2004.

Effects of electromagnetic fields (EMF) simulating exposure to the Global System for Mobile Communications (GSM) signals were studied using pluripotent embryonic stem (ES) cells in vitro. Wild-type ES cells and ES cells deficient for the tumor suppressor p53 were exposed to pulse modulated EMF at 1.71 GHz, lower end of the uplink band of GSM 1800, under standardized and controlled conditions, and transcripts of regulatory genes were analyzed during in vitro differentiation. Two dominant GSM modulation schemes (GSM-217 and GSM-Talk), which generate temporal changes between GSM-Basic (active during talking phases) and GSM-DTX (active during listening phases thus simulating a typical conversation), were applied to the cells at and below the basic safety limits for local exposures as defined for the general public by the International Commission on Nonionizing Radiation Protection (ICNIRP). GSM-217 EMF induced a significant upregulation of mRNA levels of the heat shock protein, hsp70 of p53-deficient ES cells differentiating in vitro, paralleled by a low and transient increase of c-jun, c-myc, and p21 levels in p53-deficient, but not in wild-type cells. No responses were observed in either cell type after EMF exposure to GSM-Talk applied at similar slot-averaged specific absorption rates (SAR), but at lower time-averaged SAR values. Cardiac differentiation and cell cycle characteristics were not affected in embryonic stem and embryonic carcinoma cells after exposure to GSM-217 EMF signals. Our data indicate that the genetic background determines cellular responses to GSM modulated EMF.

de Pomerai DI, Smith B, Dawe A, North K, Smith T, Archer DB, Duce IR, Jones D, Candido EP. Microwave radiation can alter protein conformation without bulk heating. *FEBS Lett* 22;543(1-3):93-97, 2003.

Exposure to microwave radiation enhances the aggregation of bovine serum albumin in vitro in a time- and temperature-dependent manner. Microwave radiation also promotes amyloid fibril formation by bovine insulin at 60 degrees C. These alterations in protein conformation are not accompanied by measurable temperature changes, consistent with estimates from field modelling of the specific absorbed radiation (15-20 mW kg⁻¹). Limited denaturation of cellular proteins could explain our previous observation that modest heat-shock responses are induced by microwave exposure in *Caenorhabditis elegans*. We also show that heat-shock responses both to heat and microwaves are suppressed after RNA interference ablating heat-shock factor function.

D'Costa H, Trueman G, Tang L, Abdel-rahman U, Abdel-rahman W, Ong K, Cosic I. Human brain wave activity during exposure to radiofrequency field emissions from mobile phones. *Australas Phys Eng Sci Med.* 26(4):162-167, 2003.

The aim of this study was to determine whether there is an effect of mobile phone electromagnetic field emissions on the human electroencephalograph (EEG). EEG recordings from ten awake subjects were taken during exposure to radiofrequency (RF) emissions from a mobile phone positioned behind the head. Two experimental trials were conducted. In the first trial, RF exposures were generated by a GSM mobile phone with the speaker disabled and configured to transmit at full-radiated power. During the second trial, exposures were generated by a non-modified GSM mobile phone in active standby mode. For each trial, subjects were exposed in five minute intervals to a randomized, interrupted sequence of five active and five sham exposures. The experiment was conducted under single-blind conditions. The average EEG band power in active exposure recordings was compared to corresponding sham recordings. Statistical tests indicated significant difference in the full-power mode trial within the EEG alpha (8-13 Hz) and beta (13-32 Hz) bands. A subsequent statistical analysis of median spectral power in discrete EEG rhythms revealed significant differences in 7 of the 32 distinct frequencies overall. In conclusion, the results of this study lend support to EEG effects from mobile phones activated in talk-mode.

Gadhia PK, Shah T, Mistry A, Pithawala M, Tamakuwala D. A Preliminary Study to Assess Possible Chromosomal Damage Among Users of Digital Mobile Phones. *Electromag Biol Med* 22:149-159, 2003.

In a preliminary study to examine possible lymphocyte chromosomal damage, we have tested two cytogenetic endpoints, namely, chromosomal aberrations (CA) and sister chromatid exchange frequencies (SCE), in 24 mobile phone users (12 nonsmoker–nonalcoholic subjects and 12 smoker–alcoholics), who used digital mobile phones for at least 2 years, employing Gaussian Minimum Shift Keying modulations with uplink frequencies at 935–960 MHz. and downlinks at 890–915 MHz. For comparison, the control study group included another 24 individuals, matched according to their age, sex, drinking and smoking habits, as well as similar health status, working habits, and professional careers; but did not use mobile phones. Blood samples of 12 mobile users (6 smoker–alcoholic and 6 nonsmoker–nonalcoholic) and 12 controls (identical to mobile users in every respect) were further treated with a known mutagen Mitomycin-C (MMC) to find out comutagenic/synergistic effect. A complete blood picture for each individual was assessed with an automatic particle cell counter.

There was a significant increase ($P < 0.05$) in dicentric chromosomes among mobile users who were smoker–alcoholic as compared to nonsmoker–nonalcoholic; the same held true for controls of both types. After MMC treatment, there was a significant increase in dicentrics ($P < 0.05$) and ring chromosomes ($P < 0.001$) in both smoker–alcoholic and nonsmoker–nonalcoholic mobile users when compared with the controls. Although SCEs showed a significant increase among mobile users, no change in cell cycle progression was noted. The hematological picture showed only minor variations between mobile users and controls.

Hallberg , Johansson O, "Malignant melanoma of the skin - not a sunshine story!", *Med Sci Monit* 2004; 10: CR336-340

Background: In an earlier study on malignant melanoma incidence in Sweden, Norway, Denmark and the USA, we found a strong association between the introduction of FM radio broadcasting at full-body resonant frequencies and increasing melanoma incidence. The purpose of the current study was to review mortality and incidence data for malignant melanoma of the skin in Sweden and its temporal relation to increased "sun-traveling", and to the introduction of FM and TV broadcasting networks.

Results: A good correlation in time was found for the rollout of FM/TV broadcasting networks while the increased amount of "sun travel" by air (charter) did not start until 7 years after the melanoma trend break in 1955. Counties that did not roll out their FM-

broadcasting network until several years after 1955 continued to have a stable melanoma mortality during the intervening years.

Conclusions: The increased incidence and mortality of melanoma of skin cannot solely be explained by increased exposure to UV-radiation from the sun. We conclude that continuous disturbance of cell repair mechanisms by body-resonant electromagnetic fields seems to amplify the carcinogenic effects resulting from cell damage caused e.g. by UV-radiation.

Hamblin DL, Wood AW, Croft RJ, Stough C. Examining the effects of electromagnetic fields emitted by GSM mobile phones on human event-related potentials and performance during an auditory task. *Clin Neurophysiol.* 115(1):171-178, 2004.

OBJECTIVE: Due to the widespread use of mobile phones (MP), it is important to determine whether they affect human physiology. The aim of this study was to explore the sensitivity of auditory event-related potentials to electromagnetic emissions. METHODS: Twelve participants attended two sessions, 1 week apart. Participants performed an auditory oddball task while they were exposed to an active MP during one session and sham exposure during the other. Each condition lasted 1 h and order was counterbalanced. N100 and P200 latencies and amplitudes were analysed for non-target waveforms, and N200 and P300 latencies and amplitudes were analysed for target waveforms. RESULTS: In real relative to sham exposure N100 amplitude and latency to non-targets were reduced, with the reduction larger over midline and right hemisphere sites. P300 latency to targets was delayed in the real exposure condition, however as this difference was greatest at left frontal and left central sites the interpretation of this result is unclear. Reaction time increased in the real relative to sham condition. No difference in accuracy was found. CONCLUSIONS: The results suggest that MP exposure may affect neural activity, particularly in proximity to the phone, however caution should be applied due to the small sample size.

Hinrikus H, Parts M, Lass J, Tuulik V. Changes in human EEG caused by low level modulated microwave stimulation. *Bioelectromagnetics.* 25(6):431-440, 2004.

This study focuses on the effect of low level microwave radiation on human EEG alpha and theta rhythms. During the experiment, 20 healthy volunteers were exposed to a 450 MHz microwaves with 7 Hz on-off modulation. The field power density at the scalp was 0.16 mW/cm². Signals from the following EEG channels were used: FP1, FP2, P3, P4, T3, T4, O1, and O2. The experimental protocol consisted of one cycle of short term photic and ten cycles of the repetitive microwave stimulation. The changes caused by photic as well as microwave stimulation were more regular on the alpha rhythm. In the majority of cases, photic stimulation caused changes in the EEG energy level in the occipital and microwave stimulation in the frontal region. Our experimental results demonstrated that microwave stimulation effects became apparent, starting from the third stimulation cycle. Changes varied strongly from subject to subject. Therefore, photic and microwave exposure did not cause statistically significant changes in the EEG activity level for the whole group. For some subjects, clear tendencies of changes in microwave on-off cycles were noticeable.

Huber R, Schuderer J, Graf T, Jutz K, Borbely AA, Kuster N, Achermann P. Radio frequency electromagnetic field exposure in humans: Estimation of SAR distribution in the brain, effects on sleep and heart rate. *Bioelectromagnetics* 24(4):262-276, 2003.

In two previous studies we demonstrated that radiofrequency electromagnetic fields (RF EMF) similar to those emitted by digital radiotelephone handsets affect brain physiology of healthy young subjects exposed to RF EMF (900 MHz; spatial peak specific absorption rate [SAR] 1 W/kg) either during sleep or during the waking period preceding sleep. In the first experiment, subjects were exposed intermittently during an 8 h nighttime sleep episode and in the second experiment, unilaterally for 30 min prior to a 3 h daytime sleep episode. Here we report an extended analysis of the two studies as well as the detailed dosimetry of the brain areas, including the assessment of the exposure variability and uncertainties. The latter enabled a more

in depth analysis and discussion of the findings. Compared to the control condition with sham exposure, spectral power of the non-rapid eye movement sleep electroencephalogram (EEG) was initially increased in the 9-14 Hz range in both experiments. No topographical differences with respect to the effect of RF EMF exposure were observed in the two experiments. Even unilateral exposure during waking induced a similar effect in both hemispheres. Exposure during sleep reduced waking after sleep onset and affected heart rate variability. Exposure prior to sleep reduced heart rate during waking and stage 1 sleep. The lack of asymmetries in the effects on sleep EEG, independent of bi- or unilateral exposure of the cortex, may indicate involvement of subcortical bilateral projections to the cortex in the generation of brain function changes, especially since the exposure of the thalamus was similar in both experiments (approx. 0.1 W/kg).

Ilhan A, Gurel A, Armutcu F, Kamisli S, Iraz M, Akyol O, Ozen S. Ginkgo biloba prevents mobile phone-induced oxidative stress in rat brain. *Clin Chim Acta.* 340(1-2): 153-162, 2004.

BACKGROUND: The widespread use of mobile phones (MP) in recent years has raised the research activities in many countries to determine the consequences of exposure to the low-intensity electromagnetic radiation (EMR) of mobile phones. Since several experimental studies suggest a role of reactive oxygen species (ROS) in EMR-induced oxidative damage in tissues, in this study, we investigated the effect of Ginkgo biloba (Gb) on MP-induced oxidative damage in brain tissue of rats. **METHODS:** Rats (EMR+) were exposed to 900 MHz EMR from MP for 7 days (1 h/day). In the EMR+Gb groups, rats were exposed to EMR and pretreated with Gb. Control and Gb-administrated groups were produced by turning off the mobile phone while the animals were in the same exposure conditions. Subsequently, oxidative stress markers and pathological changes in brain tissue were examined for each groups. **RESULTS:** Oxidative damage was evident by the: (i) increase in malondialdehyde (MDA) and nitric oxide (NO) levels in brain tissue, (ii) decrease in brain superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) activities and (iii) increase in brain xanthine oxidase (XO) and adenosine deaminase (ADA) activities. These alterations were prevented by Gb treatment. Furthermore, Gb prevented the MP-induced cellular injury in brain tissue histopathologically. **CONCLUSION:** Reactive oxygen species may play a role in the mechanism that has been proposed to explain the biological side effects of MP, and Gb prevents the MP-induced oxidative stress to preserve antioxidant enzymes activity in brain tissue.

Jarupat S, Kawabata A, Tokura H, Borkiewicz A. Effects of the 1900 MHz Electromagnetic Field Emitted from Cellular Phone on Nocturnal Melatonin Secretion. *J Physiol Anthropol Appl Human Sci* 22(1):61-63, 2003.

Exposure to cellular phone EMF caused a significant reduction in salivary melatonin in female human subjects.

Kramarenko AV, Tan U. EFFECTS OF HIGH-FREQUENCY ELECTROMAGNETIC FIELDS ON HUMAN EEG: A BRAIN MAPPING STUDY. *Int J Neurosci.* 113(7):1007-1019, 2003.

Cell phones emitting pulsed high-frequency electromagnetic fields (EMF) may affect the human brain, but there are inconsistent results concerning their effects on electroencephalogram (EEG). We used a 16-channel telemetric electroencephalograph (ExpertTM), to record EEG changes during exposure of human skull to EMF emitted by a mobile phone. Spatial distribution of EMF was especially concentrated around the ipsilateral eye adjacent to the basal surface of the brain. Traditional EEG was full of noises during operation of a cellular phone. Using a telemetric electroencephalograph (ExpertTM) in awake subjects, all the noise was eliminated, and EEG showed interesting changes: after a period of 10-15 s there was no visible change, the spectrum median frequency increased in areas close to antenna; after 20-40 s, a slow-wave activity (2.5-6.0 Hz) appeared in the contralateral frontal and temporal areas. These slow waves lasting for about one second repeated every 15-20 s at the same recording electrodes. After turning off the mobile phone, slow-wave activity progressively disappeared; local changes such as increased

median frequency decreased and disappeared after 15-20 min. We observed similar changes in children, but the slow-waves with higher amplitude appeared earlier in children (10-20 s) than adults, and their frequency was lower (1.0-2.5 Hz) with longer duration and shorter intervals. The results suggested that cellular phones may reversibly influence the human brain, inducing abnormal slow waves in EEG of awake persons.

Krause CM, Haarala C, Sillanmaki L, Koivisto M, Alanko K, Revonsuo A, Laine M, Hamalainen H. Effects of electromagnetic field emitted by cellular phones on the EEG during an auditory memory task: a double blind replication study. *Bioelectromagnetics*. 25(1): 33-40, 2004.

The effects of electromagnetic fields (EMF) emitted by cellular phones on the event related desynchronization/synchronization (ERD/ERS) of the 4-6, 6-8, 8-10, and 10-12 Hz electroencephalogram (EEG) frequency bands were studied in 24 normal subjects performing an auditory memory task. This study was a systematic replication of our previous work. In the present double blind study, all subjects performed the memory task both with and without exposure to a digital 902 MHz field in a counterbalanced order. We were not able to replicate the findings from our earlier study. All eight of the significant changes in our earlier study were not significant in the present double blind replication. Also, the effect of EMF on the number of incorrect answers in the memory task was inconsistent. We previously reported no significant effect of EMF exposure on the number of incorrect answers in the memory task, but a significant increase in errors was observed in the present study. We conclude that EMF effects on the EEG and on the performance on memory tasks may be variable and not easily replicable for unknown reasons.

Lee TM, Lam PK, Yee LT, Chan CC. The effect of the duration of exposure to the electromagnetic field emitted by mobile phones on human attention. *Neuroreport*. 14(10):1361-1364, 2003.

Previous findings suggested the facilitating effect of the electromagnetic field emitted by mobile phones on human attention. This study aimed to examine the relationship between the facilitating effect and the duration of exposure to the electromagnetic field emitted by mobile phones on human attention. Seventy-eight university students were randomly assigned to either an experimental or a control group. Their performance in the administered attention tasks was compared. Participants in the experimental group performed better on one of the two measures of attention only after they had been exposed to the electromagnetic field emitted by the mobile phone for some time. The results seem to suggest that attention functions may be differentially enhanced after exposing to the electromagnetic field emitted by mobile phones. Furthermore, this transient facilitation effect might be dose dependent.

Leszczynski D, Nylund R, Joenvaara S, Reivinen J. Applicability of discovery science approach to determine biological effects of mobile phone radiation. *Proteomics*. 4(2):426-431, 2004.

We argue that the use of high-throughput screening techniques, although expensive and laborious, is justified and necessary in studies that examine biological effects of mobile phone radiation. The "case of hsp27 protein" presented here suggests that even proteins with only modestly altered (by exposure to mobile phone radiation) expression and activity might have an impact on cell physiology. However, this short communication does not attempt to present the full scientific evidence that is far too large to be presented in a single article and that is being prepared for publication in three separate research articles. Examples of the experimental evidence presented here were designed to show the flow of experimental process demonstrating that the use of high-throughput screening techniques might help in rapid identification of the responding proteins. This, in turn, can help in speeding up of the process of determining whether these changes might affect human health.

Lonn S, Forssen U, Vecchia P, Ahlbom A, Feychting M. Output power levels from mobile phones in different geographical areas; implications for exposure assessment. *Occup Environ Med.* 61(9):769-772, 2004.

BACKGROUND: The power level used by the mobile phone is one of the most important factors determining the intensity of the radiofrequency exposure during a call. Mobile phone calls made in areas where base stations are densely situated (normally urban areas) should theoretically on average use lower output power levels than mobile phone calls made in areas with larger distances between base stations (rural areas). **AIMS:** To analyse the distribution of power levels from mobile phones in four geographical areas with different population densities. **METHODS:** The output power for all mobile phone calls managed by the GSM operator Telia Mobile was recorded during one week in four defined areas (rural, small urban, suburban, and city area) in Sweden. The recording included output power for the 900 MHz and the 1800 MHz frequency band. **RESULTS:** In the rural area, the highest power level was used about 50% of the time, while the lowest power was used only 3% of the time. The corresponding numbers for the city area were approximately 25% and 22%. The output power distribution in all defined urban areas was similar. **CONCLUSION:** In rural areas where base stations are sparse, the output power level used by mobile phones are on average considerably higher than in more densely populated areas. A quantitative assessment of individual exposure to radiofrequency fields is important for epidemiological studies of possible health effects for many reasons. Degree of urbanisation may be an important parameter to consider in the assessment of radiofrequency exposure from mobile phone use.

Lonn S, Ahlbom A, Hall P, Feychting M. Mobile Phone Use and the Risk of Acoustic Neuroma. *Epidemiology.* 15(6):653-659, 2004.

BACKGROUND:: Radiofrequency exposure from mobile phones is concentrated to the tissue closest to the handset, which includes the auditory nerve. If this type of exposure increases tumor risk, acoustic neuroma would be a potential concern. **METHODS::** In this population-based case-control study we identified all cases age 20 to 69 years diagnosed with acoustic neuroma during 1999 to 2002 in certain parts of Sweden. Controls were randomly selected from the study base, stratified on age, sex, and residential area. Detailed information about mobile phone use and other environmental exposures was collected from 148 (93%) cases and 604 (72%) controls. **RESULTS::** The overall odds ratio for acoustic neuroma associated with regular mobile phone use was 1.0 (95% confidence interval = 0.6-1.5). Ten years after the start of mobile phone use the estimates relative risk increased to 1.9 (0.9-4.1); when restricting to tumors on the same side of the head as the phone was normally used, the relative risk was 3.9 (1.6-9.5). **CONCLUSIONS::** Our findings do not indicate an increased risk of acoustic neuroma related to short-term mobile phone use after a short latency period. However, our data suggest an increased risk of acoustic neuroma associated with mobile phone use of at least 10 years' duration.

Maier R, Greter SE, Maier N. Effects of pulsed electromagnetic fields on cognitive processes - a pilot study on pulsed field interference with cognitive regeneration. *Acta Neurol Scand.* 110(1):46-52, 2004.

BACKGROUND: Due to the ubiquitous use of cellular phones much has been speculated on secondary effects of electromagnetic irradiation emitted by those. Additionally, several studies have reported vegetative alterations as well as effects on the neuronal and molecular levels in humans. Here, using a psycho-physiological test paradigm, we examined effects of exposure to pulsed electromagnetic fields on cognitive performance. **MATERIALS AND METHODS:** In 11 volunteers, we tested cognitive processing under field exposure (GSM standard) and under field-free conditions. To examine the hypothesized effect of pulsed fields, we applied an auditory discrimination task and determined the participant's current 'Order Threshold' value. Following a first test cycle, the volunteers had to relax for 50 min while being, or not, exposed to pulsed electromagnetic fields. Subsequently, the test was repeated. Data acquired before and after the resting phase were compared from both experimental conditions. **RESULTS:** We found that nine of the 11 test participants (81.8%) showed worse results in their auditory discrimination

performance upon field exposure as compared with control conditions. Group data comparison revealed a statistical significance of $P = 0.0105$. CONCLUSION: We could show that the participants' cognitive performance was impaired after exposure to pulsed electromagnetic fields. With regard to this finding, we recommend that the use of cellular phones should be restricted generally and in particular in respect of physical hazard of high-risk groups, e.g. elderly, children and ill people.

Mancinelli F, Caraglia M, Abbruzzese A, d'Ambrosio G, Massa R, Bismuto E. Non-thermal effects of electromagnetic fields at mobile phone frequency on the refolding of an intracellular protein: myoglobin. *J Cell Biochem.* 93(1):188-196, 2004.

Non-thermal effects induced by exposure to microwave electromagnetic field (MW-EMF) at 1.95 MHz, a frequency used in mobile communication, have been observed on the refolding kinetics of the heme binding site in an intracellular protein: tuna myoglobin, starting from acidic conditions. We have selected myoglobin because it can be considered a good model to study protein interactions with MW-EMF for its well-known high-resolution crystallographic structure. Myoglobin solutions at pH 3.0 were subjected to 3 h exposure to microwave field (with a specific absorption rate of 51 ± 1 mW/g); the heme site refolding has been followed by measuring the molecular absorption in the Soret spectral region and the data were fitted to a bi-exponential model. The kinetics of exposed samples appear to be slowed by MW-EMF action. Moreover, the tryptophanyl lifetime distribution of the exposed protein, as deduced by the analysis of the fluorescence emission decay from its single tryptophan, appears sharper if compared to non-exposed protein samples. This observation suggests that the presence of MW-EMF could affect the propensity of protein molecules to populate specific conformational substates among which myoglobin molecules fluctuate at acidic pH. Changes in the structural fluctuation caused by MW perturbation can affect differently the aggregation process that occurs competitively during the protein folding, so representing a potential risk for protein "misfolding." These data suggest that MW-EMF could have also biochemical and, consequently, biological effects on eukaryotic cells that are still under investigation.

Marinelli F, La Sala D, Ciccio G, Cattini L, Trimarchi C, Putti S, Zamparelli A, Giuliani L, Tomassetti G, Cinti C. Exposure to 900 MHz electromagnetic field induces an unbalance between pro-apoptotic and pro-survival signals in T-lymphoblastoid leukemia CCRF-CEM cells. *J Cell Physiol.* 198(2):324-332, 2004.

It has been recently established that low-frequency electromagnetic field (EMFs) exposure induces biological changes and could be associated with increased incidence of cancer, while the issue remains unresolved as to whether high-frequency EMFs can have hazardous effect on health. Epidemiological studies on association between childhood cancers, particularly leukemia and brain cancer, and exposure to low- and high-frequency EMF suggested an etiological role of EMFs in inducing adverse health effects. To investigate whether exposure to high-frequency EMFs could affect in vitro cell survival, we cultured acute T-lymphoblastoid leukemia cells (CCRF-CEM) in the presence of unmodulated 900 MHz EMF, generated by a transverse electromagnetic (TEM) cell, at various exposure times. We evaluated the effects of high-frequency EMF on cell growth rate and apoptosis induction, by cell viability (MTT) test, FACS analysis and DNA ladder, and we investigated pro-apoptotic and pro-survival signaling pathways possibly involved as a function of exposure time by Western blot analysis. At short exposure times (2-12 h), unmodulated 900 MHz EMF induced DNA breaks and early activation of both p53-dependent and -independent apoptotic pathways while longer continuous exposure (24-48 h) determined silencing of pro-apoptotic signals and activation of genes involved in both intracellular (Bcl-2) and extracellular (Ras and Akt1) pro-survival signaling. Overall our results indicate that exposure to 900 MHz continuous wave, after inducing an early self-defense response triggered by DNA damage, could confer to the survivor CCRF-CEM cells a further advantage to survive and proliferate.

Marino AA, Nilsen E, Frilot C. Nonlinear changes in brain electrical activity due to cell phone radiation. *Bioelectromagnetics* 24(5):339-346, 2003.

We studied the effect of an electromagnetic field from a cellular telephone on brain electrical activity, using a novel analytical method based on a nonlinear model. The electroencephalogram (EEG) from rabbits was embedded in phase space and local recurrence plots were calculated and quantified using recurrence quantitation analysis to permit statistical comparisons between filtered segments of exposed and control epochs from individual rabbits. When the rabbits were exposed to the radiation from a standard cellular telephone (800 MHz band, 600 mW maximum radiated power) under conditions that simulated normal human use, the EEG was significantly affected in nine of ten animals studied. The effect occurred beginning about 100 ms after initiation of application of the field and lasted approximately 300 ms. In each case, the fields increased the randomness in the EEG. A control procedure ruled out the possibility that the observations were a product of the method of analysis. No differences were found between exposed and control epochs in any animal when the experiment was repeated after the rabbits had been sacrificed, indicating that absorption of radiation by the EEG electrodes could not account for the observed effect. No effect was seen when deposition of energy in the brain was minimized by repositioning the radiating antenna from the head to the chest, showing that the type of tissue that absorbed the energy determined the observed changes in the EEG. We conclude that, in normal use, the fields from a standard cellular telephone can alter brain function as a consequence of absorption of energy by the brain.

Markkanen A, Penttinen P, Naarala J, Pelkonen J, Sihvonen A-P, Juutilainen J. Apoptosis induced by ultraviolet radiation is enhanced by amplitude modulated radiofrequency radiation in mutant yeast cells *Bioelectromagnetics* 25:127-133, 2004.

The aim of this study was to investigate whether radiofrequency (RF) electromagnetic field (EMF) exposure affects cell death processes of yeast cells. *Saccharomyces cerevisiae* yeast cells of the strains KFY417 (wild-type) and KFY437 (*cdc48*-mutant) were exposed to 900 or 872 MHz RF fields, with or without exposure to ultraviolet (UV) radiation, and incubated simultaneously with elevated temperature (+37°C) to induce apoptosis in the *cdc48*-mutated strain. The RF exposure was carried out in a special waveguide exposure chamber where the temperature of the cell cultures can be precisely controlled. Apoptosis was analyzed using the annexin V-FITC method utilizing flow cytometry. Amplitude modulated (217 pulses per second) RF exposure significantly enhanced UV induced apoptosis in *cdc48*-mutated cells, but no effect was observed in cells exposed to unmodulated fields at identical time-average specific absorption rates (SAR, 0.4 or 3.0 W/kg). The findings suggest that amplitude modulated RF fields, together with known damaging agents, can affect the cell death process in mutated yeast cells.

Mashevich M, Folkman D, Kesar A, Barbul A, Korenstein R, Jerby E, Avivi L, Exposure of human peripheral blood lymphocytes to electromagnetic fields associated with cellular phones leads to chromosomal instability. *Bioelectromagnetics* 24:82-90, 2003.

Whether exposure to radiation emitted from cellular phones poses a health hazard is at the focus of current debate. We have examined whether in vitro exposure of human peripheral blood lymphocytes (PBL) to continuous 830 MHz electromagnetic fields causes losses and gains of chromosomes (aneuploidy), a major "somatic mutation" leading to genomic instability and thereby to cancer. PBL were irradiated at different average absorption rates (SAR) in the range of 1.6-8.8 W/kg for 72 hr in an exposure system based on a parallel plate resonator at temperatures ranging from 34.5-37.5 °C. The averaged SAR and its distribution in the exposed tissue culture flask were determined by combining measurements and numerical analysis based on a finite element simulation code. A linear increase in chromosome 17 aneuploidy was observed as a function of the SAR value, demonstrating that this radiation has a genotoxic effect. The SAR dependent aneuploidy was accompanied by an abnormal mode of replication of the chromosome 17 region engaged in segregation (repetitive DNA arrays associated with the centromere),

suggesting that epigenetic alterations are involved in the SAR dependent genetic toxicity. Control experiments (i.e., without any RF radiation) carried out in the temperature range of 34.5-38.5 °C showed that elevated temperature is not associated with either the genetic or epigenetic alterations observed following RF radiation - the increased levels of aneuploidy and the modification in replication of the centromeric DNA arrays. These findings indicate that the genotoxic effect of the electromagnetic radiation is elicited via a non-thermal pathway. Moreover, the fact that aneuploidy is a phenomenon known to increase the risk for cancer, should be taken into consideration in future evaluation of exposure guidelines.

Moneda AP, Ioannidou MP, Chrissoulidis DP. Radio-wave exposure of the human head: analytical study based on a versatile eccentric spheres model including a brain core and a pair of eyeballs. *IEEE Trans Biomed Eng.* 50(6):667-676, 2003.

A versatile eccentric-spheres model of the human head is used in this paper to investigate radio-wave absorption. Numerical results, obtained by use of an exact analytical solution, are presented for the total, percentage, and gram-specific absorption. Interest is mainly in the brain and in the eyes of an adult or an infant head. Our model comprises a host sphere and several spherical inclusions, all concentrically stratified with respect to their own center. Any number of inclusions and any number of concentric layers for the host sphere and each one of the inclusions can be considered. Excitation is provided either by a plane-wave or by a nearby electric dipole. The analytical solution is obtained by use of the indirect-mode matching method. The theory of this paper and the accompanying computer code constitute a versatile tool for analytical studies of cellular-phone interactions with the human head. Specific absorption rate maps in a horizontal cross section of the head model manifest the existence of hot spots in the eyes and near the center of the brain.

Munoz S, Sebastian JL, Sancho M, Miranda JM. Transmembrane voltage induced on altered erythrocyte shapes exposed to RF fields. *Bioelectromagnetics.* 25(8):631-633, 2004.

In this article, the transmembrane voltage induced on erythrocyte, codocyte, ovalocyte and spherocyte cell models exposed to a linearly polarised electromagnetic plane wave of frequency 1800 MHz is calculated. For this purpose, a finite element (FE) numerical technique with adaptive meshing is used. The results show that the value of the induced voltage on the original erythrocyte shape is higher than the one observed on the rest of the altered cell geometries studied. The erythrocyte shape and the membrane electric permittivity are shown to play a fundamental role on the values of the induced transmembrane voltage.

Navarro EA, Sequra J, Portoles M, Gomez-Perretta de Mateo C. The Microwave Syndrome: A Preliminary Study in Spain. *Electromag Biol Med* 22:161-169, 2003.

A health survey was carried out in Murcia, Spain, in the vicinity of a Cellular Phone Base Station working in DCS-1800 MHz. This survey contained health items related to "microwave sickness" or "RF syndrome." The microwave power density was measured at the respondents' homes. Statistical analysis showed significant correlation between the declared severity of the symptoms and the measured power density. The separation of respondents into two different exposure groups also showed an increase of the declared severity in the group with the higher exposure.

Novoselova EG, Ogay VB, Sorokina OV, Glushkova OV, Sinotova OA, Fesenko EE. The production of tumor necrosis factor in cells of tumor-bearing mice after total-body microwave irradiation and antioxidant diet. *Electromag. Biol. Med.* 23:167-180, 2004.

The effects of repeated treatment with weak microwaves (MW) (8.15–18 GHz, 1 $\mu\text{W}/\text{cm}^2$, 1.5 h daily) and diet with antioxidants (AO) (β -carotene, α -tocopherol, and ubiquinone Q₉) on production of tumor necrosis factor (TNF) in macrophages and T lymphocytes of healthy and tumor-bearing mice (TBM) were studied. Tumor size and mortality of TBM were also followed.

Microwave radiation and antioxidant diet stimulated production of TNF in cells from healthy mice. At early stages, tumor growth induced TNF production in mouse cells; however, this effect decreased as tumors grew. In TBM exposed to MW, TNF production was higher than in unirradiated TBM. Oppositely, AO diet induced TNF production in healthy mice but did not affect TNF secretion in TBM. Accordingly, prolonged treatment of TBM to MW, but not to AO diet, decreased tumor growth rate and increased overall animal longevity. These results suggest that diminished tumor growth rate due to extremely low-level MW exposure of mice carrying tumors, at least in part, was caused by enhancement in TNF production and accumulation of plasma TNF.

Nylund R, Leszczynski D. Proteomics analysis of human endothelial cell line EA.hy926 after exposure to GSM 900 radiation. *Proteomics* 4:1359-1365, 2004.

The human endothelial cell line EA.hy926 was exposed to mobile phone radiation and the effect on protein expression was examined using two-dimensional electrophoresis (2-DE). Up to 38 various proteins have statistically significantly altered their expression levels following the irradiation. Four proteins were identified with matrix-assisted laser desorption/ionization-mass spectrometry (MALDI-MS). Two of the affected proteins were determined to be isoforms of cytoskeletal vimentin. This finding supports our earlier presented working hypothesis which indicated that the mobile phone radiation might affect the cytoskeleton and might have an effect on the physiological functions that are regulated by the cytoskeleton.

Papageorgiou CC, Nanou ED, Tsiafakis VG, Capsalis CN, Rabavilas AD. Gender related differences on the EEG during a simulated mobile phone signal. *Neuroreport*. 15(16):2557-2560, 2004.

The present study investigated the gender-related influence of electromagnetic fields (EMF), similar to that emitted by mobile phones, on brain activity. Ten women and nine men performed a short memory task (Wechsler test), both without (baseline) and with exposure to a 900 MHz signal. The EEG energy of the total waveform and the alpha, beta, delta and theta; rhythms were calculated from the recordings of 15 scalp electrodes. Baseline EEG energy of males was greater than that of females, while exposure to EMF decreased EEG energy of males and increased that of females. Memory performance was invariant to EMF exposure and gender influences. These findings indicate that EMF may exert a gender-related influence on brain activity.

Park SK, Ha M, Im H-J. Ecological study on residences in the vicinity of AM radio broadcasting towers and cancer death: preliminary observations in Korea. *International Archives of Occupational and Environmental Health* 77(6):387-394, 2004.

Abstract

Objectives Public health concern about the health effects of radio-frequency electromagnetic fields (RF-EMFs) has increased with the increase in public exposure. This study was to evaluate some health effect of RF exposure by the AM radio broadcasting towers in Korea.

Methods We calculated cancer mortality rates using Korean death certificates over the period of 1994–1995 and population census data in ten RF-exposed areas, defined as regions that included AM radio broadcasting towers of over 100 kW, and in control areas, defined as regions without a radio broadcasting tower inside and at least 2 km away from the towers.

Results All cancers-mortality was significantly higher in the exposed areas [direct standardized mortality rate ratio (MRR) =1.29, 95%CI=1.12–1.49]. When grouped by each exposed area and by electrical power, MRRs for two sites of 100 kW, one site of 250 kW and one site of 500 kW, for all subjects, and for one site of 100 kW and two sites of 250 kW, for male subjects, showed statistically significant increases without increasing trends according

to the groups of electric power. Leukemia mortality was higher in exposed areas (MRR=1.70, 95% CI=0.84–3.45), especially among young adults aged under 30 years (0–14 years age group, MRR=2.29, 95% CI=1.05–5.98; 15–29 age group, MRR=2.44, 95% CI=1.07–5.24). *Conclusions* We observed higher mortality rates for all cancers and leukemia in some age groups in the area near the AM radio broadcasting towers. Although these findings do not prove a causal link between cancer and RF exposure from AM radio broadcasting towers, it does suggest that further analytical studies on this topic are needed in Korea.

Paulraj R, Behari J. Radio frequency radiation effects on protein kinase C activity in rats' brain. *Mutat Res.* 545(1-2):127-130, 2004.

The present work describes the effect of amplitude modulated radio frequency (rf) radiation (112 MHz amplitude-modulated at 16 Hz) on calcium-dependent protein kinase C (PKC) activity on developing rat brain. Thirty-five days old Wistar rats were used for this study. The rats were exposed 2 h per day for 35 days at a power density of 1.0 mW/cm² (SAR = 1.48 W/kg). After exposure, rats were sacrificed and PKC was determined in whole brain, hippocampus and whole brain minus hippocampus separately. A significant decrease in the enzyme level was observed in the exposed group as compared to the sham exposed group. These results indicate that this type of radiation could affect membrane bound enzymes associated with cell signaling, proliferation and differentiation. This may also suggest an affect on the behavior of chronically exposed rats.

Pedersen W. [Mobile phones, web chat, and sex among Norwegian adolescents] *Tidsskr Nor Laegeforen.* 124(13-14):1756-1759, 2004.
[Article in Norwegian]

BACKGROUND: We investigated the associations between new interactive technology for communication, such as web chat or mobile phones, and sexual behaviour among Norwegian adolescents. **MATERIALS AND METHODS:** A representative sample of adolescents (age 13-18, N = 10,926) filled in a questionnaire during school hours; the response rate was 92%. **RESULTS:** Most adolescents have access to communication technology, but how much they use it varies. In particular with regard to mobile phones, a strong association to sexual behaviour was found. Among those who did not use the new technology, less than 10% reported having had intercourse while two out of three of the most active users reported intercourse. The associations remained significant when controls were made for age and a range of contextual, family, peer and individual factors. **INTERPRETATION:** Norwegian adolescents have changed their sexual behaviour over the last decade. The introduction and widespread use of new communication technology is one of the most salient changes over the same period. The findings suggest that this technology may in fact be of importance to teenagers' sexual socialisation.

Prohofsky EW. RF absorption involving biological macromolecules. *Bioelectromagnetics.* 25(6):441-451, 2004.

The fundamental intramolecular frequency of a globular protein can be obtained from the measurements of acoustic velocities of bulk protein matter. This lowest frequency for common size molecules is shown to be above several hundred GHz. All modes below this frequency would then be intermolecular modes or bulk modes of the molecule and surrounding matter or tissue. The lowest frequency modes of an extended DNA double helix are also shown to be bulk modes because of interaction with water. Only DNA modes, whose frequency is well above 4 GHz, can be intrahelical modes, that is, confined to the helix rather than in the helix plus surroundings. Near 4 GHz, they are heavily damped and, therefore, not able to resonantly absorb. Modes that absorb radio frequency (RF) below this frequency are bulk modes of the supporting matter. Bulk modes rapidly thermalize all absorbed energy. The implication of these findings for the possibility of athermal RF effects is considered. The applicability of these findings for other biological molecules is discussed.

Pyrpasopoulou A, Kotoula V, Cheva A, Hytiroglou P, Nikolakaki E, Magras IN, Xenos TD, Tsiboukis TD, Karkavelas G. Bone morphogenetic protein expression in newborn rat kidneys after prenatal exposure to radiofrequency radiation. *Bioelectromagnetics* 25(3):216-227, 2004.

Effects of nonthermal radiofrequency radiation (RFR) of the global system of mobile communication (GSM) cellular phones have been as yet mostly studied at the molecular level in the context of cellular stress and proliferation, as well as neurotransmitter production and localization. In this study, a simulation model was designed for the exposure of pregnant rats to pulsed GSM-like RFR (9.4 GHz), based on the different resonant frequencies of man and rat. The power density applied was 5 microW/cm², in order to avoid thermal electromagnetic effects as much as possible. Pregnant rats were exposed to RFR during days 1-3 postcoitum (p.c.) (embryogenesis, pre-implantation) and days 4-7 p.c. (early organogenesis, peri-implantation). Relative expression and localization of bone morphogenetic proteins (BMP) and their receptors (BMPR), members of a molecular family currently considered as major endocrine and autocrine morphogens and known to be involved in renal development, were investigated in newborn kidneys from RFR exposed and sham irradiated (control) rats. Semi-quantitative duplex RT-PCR for BMP-4, -7, BMPR-IA, -IB, and -II showed increased BMP-4 and BMPR-IA, and decreased BMPR-II relative expression in newborn kidneys. These changes were statistically significant for BMP-4, BMPR-IA, and -II after exposure on days 1-3 p.c. ($P < .001$ each), and for BMP-4 and BMPR-IA after exposure on days 4-7 p.c. ($P < .001$ and $P = .005$, respectively). Immunohistochemistry and in situ hybridization (ISH) showed aberrant expression and localization of these molecules at the histological level. Our findings suggest that GSM-like RFR interferes with gene expression during early gestation and results in aberrations of BMP expression in the newborn. These molecular changes do not appear to affect renal organogenesis and may reflect a delay in the development of this organ. The differences of relative BMP expression after different time periods of exposure indicate the importance of timing for GSM-like RFR effects on embryonic development.

Salford LG, Brun AR, Eberhardt JL, Malmgren L, Persson BRR, Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. *Environ Health Persp* 111:881-883, 2003.

The possible risks of radio-frequency electromagnetic fields for the human body is a growing concern for the society. We have earlier shown that weak pulsed microwaves give rise to a significant leakage of albumin through the blood-brain barrier (BBB). Now we have investigated whether a pathological leakage over the BBB might be combined with damage to the neurons. Three groups of each 8 rats were exposed for 2 hours to GSM mobile phone electromagnetic fields of different strengths. We found, and present here for the first time, highly significant ($p < 0.002$) evidence for neuronal damage in both the cortex, the hippocampus and the basal ganglia in the brains of exposed rats.

Sandrini L, Vaccari A, Malacarne C, Cristoforetti L, Pontalti R. RF dosimetry: a comparison between power absorption of female and male numerical models from 0.1 to 4 GHz. *Phys Med Biol*. 49(22):5185-5201, 2004.

Realistic numerical models of human subjects and their surrounding environment represent the basic points of radiofrequency (RF) electromagnetic dosimetry. This also involves differentiating the human models in men and women, possibly with different body shapes and postures. In this context, the aims of this paper are, firstly, to propose a female dielectric anatomical model (fDAM) and, secondly, to compare the power absorption distributions of a male and a female model from 0.1 to 4 GHz. For realizing the fDAM, a magnetic resonance imaging tomographer to acquire images and a recent technique which avoids the discrete segmentation of body tissues into different types have been used. Simulations have been performed with the FDTD method by using a novel filtering-based subgridding algorithm. The latter is applied here for the first time to dosimetry, allowing an abrupt mesh refinement by a factor of up to 7. The results show that the whole-body-averaged specific absorption rate (WBA-SAR) of the female model is higher than that

of the male counterpart, mainly because of a thicker subcutaneous fat layer. In contrast, the maximum averaged SAR over 1 g (1gA-SAR) and 10 g (10gA-SAR) does not depend on gender, because it occurs in regions where no subcutaneous fat layer is present.

Sarimov, R., [Malmgren, L.O.G.](#), [Markova, E.](#), [Persson, B.R.R.](#), [Belyaev, I.Y.](#) Nonthermal GSM microwaves affect chromatin conformation in human lymphocytes similar to heat shock. *IEEE Trans Plasma Sci* 32:1600-1608, 2004.

Here we investigated whether microwaves (MWs) of Global System for Mobile Communication (GSM) induce changes in chromatin conformation in human lymphocytes. Effects of MWs were studied at different frequencies in the range of 895-915 MHz in experiments with lymphocytes from seven healthy persons. Exposure was performed in transverse electromagnetic transmission line cell (TEM-cell) using a GSM test-mobile phone. All standard modulations included 2 W output power in the pulses, specific absorbed rate (SAR) being 5.4 mW/kg. Changes in chromatin conformation, which are indicative of stress response and genotoxic effects, were measured by the method of anomalous viscosity time dependencies (AVTD). Heat shock and treatment with the genotoxic agent camptothecin, were used as positive controls. 30-min exposure to MWs at 900 and 905 MHz resulted in statistically significant condensation of chromatin in lymphocytes from 1 of 3 tested donors. This condensation was similar to effects of heat shock within the temperature window of 40/spl deg/C-44/spl deg/C. Analysis of pooled data from all donors showed statistically significant effect of 30-min exposure to MWs. Stronger effects of MWs was found following 1-h exposure. In replicated experiments, cells from four out of five donors responded to 905 MHz. Responses to 915 MHz were observed in cells from 1 out of 5 donors, $p < 0.002$. Dependent on donor, condensation, 3 donors, or decondensation, 1 donor, of chromatin was found in response to 1-h exposure. Analysis of pooled data from all donors showed statistically significant effect of 1-h exposure to MWs. In cells from one donor, this effect was frequency-dependent ($p < 0.01$). Effects of MWs correlated statistically significantly with effects of heat shock and initial state of chromatin before exposure. MWs at 895 and 915 MHz affected chromatin conformation in transformed lymphocytes. The conclusion-GSM microwaves under specific conditions of exposure affected human lymphocytes similar to stress response. The data suggested that the MW effects differ at various GSM frequencies and vary between donors.

Simsek V, Sahin H, Akay AF, Kaya H, Bircan MK. The effects of cellular telephone use on serum PSA levels in men. *Int Urol Nephrol.* 35(2):193-196, 2003.

BACKGROUND: The increasing use of cellular telephones is known to have harmful effects on human health. The aim of this prospective study was to determine whether cellular telephone use affected serum PSA levels in men. **METHODS:** Participants included 20 men with ages ranging from 22 to 65 years who had never previously used cellular telephones. Blood samples were taken prior to and 30 days after the beginning of cellular telephone use. Serum was separated from the blood samples and stored in a deep freezer until the end of the study, at which time serum free and total PSA levels were determined by tandem radioimmunoassay. The results were statistically analyzed by the Wilcoxon Paired Signed Rank Test. **RESULTS:** Average free and total PSA values were 2.070 ng/ml and 0.500 ng/ml before the study, and 2.0 ng/ml and 0.505 ng/ml at the end of the study, respectively. No significant difference was determined between the initial and final values ($p > 0.05$). **CONCLUSIONS:** The results indicate that cellular telephone use does not significantly affect PSA values in the short term. Nevertheless, we think that there is a need for longer-term studies on this subject.

Smythe JW, Costall B. Mobile phone use facilitates memory in male, but not female, subjects. *Neuroreport* 14(2):243-246, 2003.

In the present study we report on the effects of mobile phone exposure on short- and long-term memory in male and female subjects. Subjects were university undergraduate students, and consisted of right-handed, males (= 33) and females (= 29). Individuals were randomly assigned to one of three experimental conditions: no phone exposure; inactive phone exposure; and active

phone exposure. They were provided with a series of words to learn, structured in a two-dimensional shape, and given 3 min to memorise the words. After a 12 min distraction task, they were then asked to draw the shape (spatial) and place the correct words (semantic) into the appropriate boxes. One week later the same subjects were brought back to again redraw the shape and words. Error scores were determined and analysed by non-parametric techniques. The results show that males exposed to an active phone made fewer spatial errors than those exposed to an active phone condition, while females were largely unaffected. These results further indicate that mobile phone exposure has functional consequences for human subjects, and these effects appear to be sex-dependent.

Tafforeau M, Verdus MC, Norris V, White GJ, Cole M, Demarty M, Thellier M, Ripoll C. Plant sensitivity to low intensity 105 GHz electromagnetic radiation. *Bioelectromagnetics*. 25(6):403-407, 2004.

Exposing seedlings of the flax, *Linum usitatissimum* L., to a variety of weak environmental stresses followed by a 2 day calcium deprivation, triggers the common response of production of epidermal meristems (actively dividing groups of cells) in the hypocotyl, which is the part of the stem between the root and the cotyledons (the pre-existing leaves in the embryo). This production reaches a plateau of 10-20 meristems after a month in the case of mechanical stimulation and cold shock. Recently, we have shown that radiation from a global system for mobile communication (GSM) telephone also triggers production of meristems with a plateau of around six meristems. Here, we show that a single 2 h exposure to radiation emitted at 105 GHz at non-thermal levels by a Gunn oscillator induces meristem production with kinetics similar to that induced by weak environmental stimuli and radiation from GSM telephone.

Trosic I, Busljeta I, Modlic B. Investigation of the genotoxic effect of microwave irradiation in rat bone marrow cells: in vivo exposure. *Mutagenesis*. 19(5):361-364, 2004.

An in vivo mammalian cytogenetic test (the erythrocyte micronucleus assay) was used to investigate the extent of genetic damage in bone marrow red cells of rats exposed to radiofrequency/microwave (RF/MW) radiation. Wistar rats (n = 40) were exposed to a 2.45 GHz continuous RF/MW field for 2 h daily, 7 days a week, at a power density of 5-10 mW/cm². The whole body average specific absorption rate (SARs) was calculated to be 1.25 +/- 0.36 (SE) W/kg. Four subgroups were irradiated for 4, 16, 30 and 60 h. Sham-exposed controls (n = 24) were included in the study. The animals of each treated subgroup were killed on the final day of irradiation. Bone marrow smears were examined to determine the extent of genotoxicity after particular treatment times. The results were statistically evaluated using non-parametric Mann-Whitney and Kruskal-Wallis tests. In comparison with the sham-exposed subgroups, the findings of polychromatic erythrocytes (PCE) revealed significant differences (P < 0.05) for experimental days 8 and 15. The frequency of micronucleated PCEs was also significantly increased on experimental day 15 (P < 0.05). Pair-wise comparison of data obtained after 2, 8 and 30 irradiation treatments did not reveal statistically significant differences between sham-exposed and treated subgroups. Under the applied experimental conditions the findings revealed a transient effect on proliferation and maturation of erythropoietic cells in the rat bone marrow and the sporadic appearance of micronucleated immature bone marrow red cells.

Troulis SE, Scanlon WG, Evans NE. Effect of a hands-free wire on specific absorption rate for a waist-mounted 1.8 GHz cellular telephone handset. *Phys Med Biol*. 48(12):1675-1684, 2003.

A common feature of cellular telephony is the use of a 'hands-free' audio extension lead connected to a waist-worn handset. Interaction between the transmitting antenna, the wire and the user's body can occur, with detrimental effects including polar pattern degradation, reduced efficiency and localized increases in specific absorption rate (SAR). Using a realistic full-body model of an adult male, finite difference time domain analysis was employed to investigate the coupling between a hip-mounted 1.8 GHz handset fitted with a monopole antenna and a 1 m long

wire representing a hands-free wire. Conduction current densities were computed for three identifiable coupling modes: magnetic-only, conductive-only and combined conductive-and-magnetic. Magnetic-only coupling was dominant. Without the lead, placing the handset at waist height led to a 42.8% increase in the total energy deposited in the body, compared to use at the head. Introducing the lead further increased the body loss, with a reduction in system radiation efficiency from 52% to 43.7%. Without the hands-free lead, the peak 1 g and 10 g SARs were 0.450 W kg⁽⁻¹⁾ and 0.265 W kg⁽⁻¹⁾, respectively, for 125 mW transmit power. With the hands-free lead connected, these values increased to 1.14 W kg⁽⁻¹⁾ and 0.430 W kg⁽⁻¹⁾, respectively.

Vorobyov V, Pesic V, Janac B, Prolic Z. Repeated exposure to low-level extremely low frequency-modulated microwaves affects baseline and scopolamine-modified electroencephalograms in freely moving rats. *Int J Radiat Biol.* 80(9):691-698, 2004.

PURPOSE: To compare in the electroencephalogram of rats the effects of scopolamine (an acetylcholine receptor antagonist) alone and after repeated exposure to low-level microwaves modulated at extremely low frequency. **MATERIALS AND METHODS:** Averaged frequency spectra (0.5-30 Hz) of the electroencephalogram were studied in freely moving rats with carbon electrodes implanted into the somatosensory cortex. The rats were repeatedly (3 days, 30 min day⁽⁻¹⁾) exposed to low-intensity (approximately = 0.3 mW cm⁽⁻²⁾) microwaves (915 MHz, 20-ms pulse duration), amplitude modulated (square-wave) at extremely low frequency (4 Hz). **RESULTS:** The exposure to extremely low frequency microwaves alone significantly enhanced the fast electroencephalographic rhythms (18-30 Hz). This effect was observed neither in subsequent sham-exposure experiment nor in radiation-naive animals. In the microwave-exposed rats, scopolamine (0.1 mg kg⁽⁻¹⁾, subcutaneously) did not cause a slowing in the electroencephalogram that was shown in non-exposed rats. A similarity between the scopolamine-induced electroencephalogram effect in the microwave-exposed rats and that of physostigmine (enhancing the acetylcholine level in the brain) in radiation-naive animals was noted. This paradoxical phenomenon stimulates new experimentation for understanding its mechanism(s). **CONCLUSIONS:** The data obtained provide additional evidence that repeated low-level exposure to extremely low frequency microwaves can modify an activity of cholinergic system in the brain. transient effect on proliferation and maturation of erythropoietic cells in the rat bone marrow and the sporadic appearance of micronucleated immature bone marrow red cells.

Weisbrot D, Lin H, Ye L, Blank M, Goodman R. Effects of mobile phone radiation on reproduction and development in *Drosophila melanogaster*. *J Cell Biochem* 89(1):48-55, 2003.

In this report we examined the effects of a discontinuous radio frequency (RF) signal produced by a GSM multiband mobile phone (900/1,900 MHz; SAR approximately 1.4 W/kg) on *Drosophila melanogaster*, during the 10-day developmental period from egg laying through pupation. As found earlier with low frequency exposures, the non-thermal radiation from the GSM mobile phone increased numbers of offspring, elevated hsp70 levels, increased serum response element (SRE) DNA-binding and induced the phosphorylation of the nuclear transcription factor, ELK-1. The rapid induction of hsp70 within minutes, by a non-thermal stress, together with identified components of signal transduction pathways, provide sensitive and reliable biomarkers that could serve as the basis for realistic mobile phone safety guidelines.

Wilén J, Sandström M, Hansson Mild K. Subjective symptoms among mobile phone users-A consequence of absorption of radiofrequency fields? *Bioelectromagnetics* 24(3):152-159, 2003.

In a previous epidemiological study, where we studied the prevalence of subjective symptoms among mobile phone (MP) users, we found as an interesting side finding that the prevalence of many of the subjective symptoms increased with increasing calling time and number of calls per day. In this extrapolative study, we have selected 2402 people from the epidemiological study who used any of the four most common GSM MP. We used the information about the prevalence of symptoms, calling time per day, and number of calls per day and combined it with

measurements of the Specific Absorption Rate (SAR). We defined three volumes in the head and measured the maximum SAR averaged over a cube of 1 g tissue (SAR(1g)) in each volume. Two new exposure parameters Specific Absorption per Day (SAD) and Specific Absorption per Call (SAC) have been devised and are obtained as combinations of SAR, calling time per day, and number of calls per day, respectively. The results indicates that SAR values >0.5 W/kg may be an important factor for the prevalence of some of the symptoms, especially in combination with long calling times per day.

Yeolekar ME, Sharma A. Use of mobile phones in ICU--why not ban? J Assoc Physicians India. 52:311-313, 2004. (C-P, I-F)

Due to the rapid growth of mobile telecommunications it is predicted that by 2005 there will be 1.6 billion mobile phone users worldwide. The usage of cellphones in Intensive Care Units carries with it a high incidence of interference with a number of medical devices like implantable defibrillators, cardioverters, pacemakers, monitors and other important devices like ventilators. It is in this context that this article will throw a light on complications of cellphones use in the Intensive Care Units and various strategies that can be taken to restrict their use in the Intensive Care Units