

Recent studies (1995-2000) on the biological effects of radiofrequency and cell phone radiation

Adey WR, Byus CV, Cain CD, Higgins RJ, Jones RA, Kean CJ, Kuster N, MacMurray A, Stagg RB, Zimmerman G, Phillips JL, Haggren W, Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats chronically exposed to 836 MHz modulated microwaves. *Radiat Res* 152(3):293-302, 1999.

We have tested an 836.55 MHz field with North American Digital Cellular (NADC) modulation in a 2-year animal bioassay that included fetal exposure. In offspring of pregnant Fischer 344 rats, we tested both spontaneous tumorigenicity and the incidence of induced central nervous system (CNS) tumors after a single dose of the carcinogen ethylnitrosourea (ENU) in utero, followed by intermittent digital-phone field exposure for 24 months. Far-field exposures began on gestational day 19 and continued until weaning at age 21 days. Near-field exposures began at 35 days and continued for the next 22 months, 4 consecutive days weekly, 2 h/day. SAR levels simulated localized peak brain exposures of a cell phone user. Of the 236 original rats, 182 (77%) survived to the termination of the whole experiment and were sacrificed at age 709-712 days. The 54 rats (23%) that died during the study ("preterm rats") formed a separate group for some statistical analyses. There was no evidence of tumorigenic effects in the CNS from exposure to the TDMA field. However, some evidence of tumor-inhibiting effects of TDMA exposure was apparent. Overall, the TDMA field-exposed animals exhibited trends toward a reduced incidence of spontaneous CNS tumors ($P < 0.16$, two-tailed) and ENU-induced CNS tumors ($P < 0.16$, two-tailed). In preterm rats, where primary neural tumors were determined to be the cause of death, fields decreased the incidence of ENU-induced tumors ($P < 0.03$, two-tailed). We discuss a possible approach to evaluating with greater certainty the possible inhibitory effects of TDMA-field exposure on tumorigenesis in the CNS.

Adey WR, Byus CV, Cain CD, Higgins RJ, Jones RA, Kean CJ, Kuster N, MacMurray A, Stagg RB, Zimmerman G, Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats exposed to frequency-modulated microwave fields. *Cancer Res* 60(7):1857-1863, 2000.

In a 2-year bioassay, we exposed Fischer 344 rats to a frequency-modulated (FM) signal (836.55 MHz \pm 12.5 KHz deviation) simulating radiofrequency exposures in the head of users of hand-held mobile phones. We tested for effects on spontaneous tumorigenicity of central nervous system (CNS) tumors in the offspring of pregnant rats and also for modified incidence of primary CNS tumors in rats treated with a single dose of the neurocarcinogen ethylnitrosourea (ENU) in utero. ENU dosage (4 mg/kg) was selected to give an expected brain tumor incidence of 10-15% over the mean life span of 26 months. Pregnant dams ($n = 102$) were randomly assigned to six groups. Their offspring were treated as cohorts in each of the six groups ($n = 90$ per group; total, $n = 540$): Sham ENU/Sham Field,

Sham ENU/Field Exposed, ENU/Sham Field, ENU/Field Exposed, ENU/Cage Control, and Sham ENU/Cage Control. Intermittent field exposures began on gestation day 19 and continued until weaning at 21 days, resuming thereafter at 31 days and continuing until experiment termination at 731-734 days. Energy absorption rates (SARs) in the rats' brains were similar to localized peak brain exposures of a phone user (female, 236 g, 1.0 W/kg; male, 450 g, 1.2 W/kg). Of the original 540 rats, 168 died before the termination of the experiment. In these rats, ENU significantly reduced survival from a mean of 708 days in three groups without ENU treatment to 645 days in three groups treated with ENU ($P < 0.0005$). There were no effects on survival attributable to FM field exposure in either ENU-treated or in sham-treated groups. Spontaneous CNS tumor incidence in control groups was 1.1-4.4% but sharply higher in rats receiving ENU (14.4-22.2%; $P < 0.0001$). No FM field-mediated changes were observed in number, incidence, or histological type of either spontaneous or ENU-induced brain tumors, nor were gender differences detected in tumor numbers. These negative findings with FM fields contrast with our study using standard digital phone fields pulsed on and off at 50/se, where a trend was noted toward reduced incidence of both spontaneous and ENU-induced CNS tumors (W. R. Adey et al., *Radiat. Res.*, 152: 293-302, 1999). Although consistent but not attaining significance in the experiment overall (spontaneous CNS tumors, $P < 0.08$ one-tailed; $P < 0.16$ two-tailed; ENU-induced CNS tumors, $P < 0.08$ one-tailed, $P < 0.16$ two-tailed), the trend was significant ($P < 0.015$ one-tailed, $P < 0.03$, two-tailed) in rats that received ENU and died prior to experiment termination, with a primary brain tumor as the cause of death. We discuss differences in the signaling structure of digital and FM fields. Certain bioeffects induced by either amplitude-modulated or pulsed radiofrequency fields at athermal levels have not been seen with fields of similar average power but unvarying in intensity (continuous wave or frequency-modulated fields).

Afromeev VI, Tkachenko VN, [Change in the percent of lactate dehydrogenase isoenzyme level in testes of animals exposed to superhigh frequency radiation]. *Biofizika* 44(5):931-932, 1999.
[Article in Russian]

The content of six lactate dehydrogenase isoenzymes in testes of rats exposed to electromagnetic field of 3-cm wavelength range was studied. The changes in their percent contents were found to be inhomogeneous compared with control. It is assumed that electromagnetic radiation affects the organs of the human urinogenital system. The results can be used for estimating the safety of persons professionally exposed to electromagnetic radiation of the industrial frequency range and in the therapy of diseases of the urinogenital system.

Altamura G, Toscano S, Gentilucci G, Ammirati F, Castro A, Pandozi C, Santini M, Influence of digital and analogue cellular telephones on implanted pacemakers. *Eur Heart J* 18(10):1632-4161, 1997.

The aim of this study was to find out whether digital and analogue cellular

'phones affect patients with pacemakers. The study comprised continuous ECG monitoring of 200 pacemaker patients. During the monitoring certain conditions caused by interference created by the telephone were looked for: temporary or prolonged pacemaker inhibition; a shift to asynchronous mode caused by electromagnetic interference; an increase in ventricular pacing in dual chamber pacemakers, up to the programmed upper rate. The Global System for Mobile Communications system interfered with pacing 97 times in 43 patients (21.5%). During tests on Total Access of Communication System telephones, there were 60 cases of pacing interference in 35 patients (17.5%). There were 131 interference episodes during ringing vs 26 during the on/off phase; ($P < 0.0001$); 106 at maximum sensitivity level vs 51 at the 'base' value; $P < 0.0001$). Prolonged pacing inhibition (> 4 s) was seen at the pacemaker 'base' sensing value in six patients using the Global system but in only one patient using Total Access. CONCLUSION: Cellular 'phones may be dangerous for pacemaker patients. However, they can be used safely if patients do not carry the 'phone close to the pacemaker, which is the only place where high risk interference has been observed.

Aniolczyk H, Electromagnetic field pattern in the environment of GSM base stations. *Int J Occup Med Environ Health* 1999;12(1):47-58

Three mobile phone systems are used in Poland: analog, operated at the 450 MHz frequency range, and two digital systems operated at 900 MHz and 1800 MHz. The GSM--Global System for Mobile Communication meets all relevant requirements, and it is most widely used throughout the world. According to the mobile phone concept, the whole communication area is divided into sub-areas (cells) where base stations are located. The base stations are provided with the transmitter units mounted on free-standing masts, high chimneys and building roofs, including those of the residential buildings. The transmitter antennas of the base stations constitute a source of 935-960 EMF radiation. This work analyses the essential characteristics of the base station antennas from the point of view of radiation intensity. The analysis is based on the results of EMF measurements performed by experts of two relevant research institutes. For inaccessible antennas, the measurements were performed at the accredited laboratory.

Antonopoulos A, Eisenbrandt H, Obe G, Effects of high-frequency electromagnetic fields on human lymphocytes in vitro. *Mutat Res* 395(2-3): 209-214, 1997.

Human peripheral lymphocytes were incubated in the presence of high-frequency electromagnetic fields of 380, 900 and 1800 MHz. The measured endpoints were cell cycle progression and the frequencies of sister-chromatid exchanges. No differences between treated and control cultures could be found.

Balode, Z, Assessment of radio-frequency electromagnetic radiation by the micronucleus test in bovine peripheral erythrocytes. *Sci Total Environ* 180(1):81-85, 1996.

Previous bioindicative studies in the Skrunda Radio Location Station area have focused on the somatic influence of electromagnetic radiation on plants, but it is also important to study genetic effects. We have chosen cows as test animals for cytogenetical evaluation because they live in the same general exposure area as humans, are confined to specific locations and are chronically exposed to radiation. Blood samples were obtained from female Latvian Brown cows from a farm close to and in front of the Skrunda Radar and from cows in a control area. A simplified alternative to the Schiff method of DNA staining for identification of micronuclei in peripheral erythrocytes was applied. Microscopically, micronuclei in peripheral blood erythrocytes were round in shape and exhibited a strong red colour. They are easily detectable as the only coloured bodies in the uncoloured erythrocytes. From each individual animal 2000 erythrocytes were examined at a magnification of x 1000 for the presence of micronuclei. The counting of micronuclei in peripheral erythrocytes gave low average incidences, 0.6 per 1000 in the exposed group and 0.1 per 1000 in the control, but statistically significant ($P < 0.01$) differences were found in the frequency distribution between the control and exposed groups.

Barbaro V, Bartolini P, Donato A, Militello C, Electromagnetic interference of analog cellular telephones with pacemakers. *Pacing Clin Electrophysiol* 19(10):1410-1418, 1996.

The aim of this study was to verify whether there is a public health risk from the interference of analog cellular telephones with pacemakers. We used a human trunk simulator to reproduce an actual implant, and two cellular telephones working with the TACS (Total Access Communication System) standard. Results showed that the electromagnetic field radiated from the analog cellular telephones interfered with a large number of the pacemakers tested (10/25). When the telephone antenna was in close proximity to the pacemaker head, pacemaker desensitizing and sensitizing and pulse inhibition was detected at the moment of an incoming call and throughout ringing. In the worst case of pulse inhibition, the pacemaker skipped three nonconsecutive beats and then resumed its normal pacing, while the desensitizing and sensitizing phenomena persisted as long as the interfering signal was on. Pulse inhibition was also observed when the connection did not succeed. Maximum sensing threshold variation was about 186% (increase) and 62% (decrease) for desensitizing and sensitizing phenomena, respectively. It was also demonstrated that the signal emitted by analog cellular telephones during the crossing of contiguous cells could induce pacemaker pulse inhibition, but under our experimental conditions this event did not seem to pose a risk for the pacemaker patient.

Bassen HI, Moore HJ, Ruggera PS, Cellular phone interference testing of implantable cardiac defibrillators in vitro. *Pacing Clin Electrophysiol* 21(9): 1709-1715, 1998.

An in vitro study was undertaken to investigate the potential for cellular telephones to interfere with representative models of presently used ICDs. Digital cellular phones (DCPs) generate strong, amplitude modulated fields with pulse repetition rates near the physiological range sensed by the ICD as an arrhythmia. DCPs with Time Division Multiple Access (TDMA) pulsed amplitude modulation caused the most pronounced effect--high voltage firing or inhibition of pacing output of the ICDs. This electromagnetic interference (EMI) occurred only when the phones were within 2.3-5.8 cm of the ICD pulse generator that was submerged 0.5 cm in 0.18% saline. ICD performance always reverted to baseline when the cellular phones were removed from the immediate proximity of the ICD. Three models of ICDs were subjected to EMI susceptibility testing using two types of digital phones and one analog cellular phone, each operating at their respective maximum output power. EMI was observed in varying degrees from all DCPs. Inhibition of pacemaker output occurred in one ICD, and high voltage firing occurred in the two other ICDs, when a TDMA-11 Hz DCP was placed within 2.3 cm of the ICD. For the ICD that was most sensitive to delivering unintended therapy, inhibition followed by firing occurred at distances up to 5.8 cm. When a TDMA-50 Hz phone was placed at the minimum test distance of 2.3 cm, inhibition followed by firing was observed in one of the ICDs. EMI occurred most frequently when the lower portion of the monopole antenna of the cellular phone was placed over the ICD header.

Belousova TE, Kargina-Terent'eva RA, [Adrenergic nerve plexuses of heart and adrenal and myocardial catecholamines of spontaneously hypertensive rats under the influence of electromagnetic irradiation in the millimeter range]. *Morfologija* 115(1):16-18, 1999. [Article in Russian]

Condition of adrenergic cardiac and adrenal nervous plexuses of Kyoto-Wistar Rats (WKY) and spontaneously hypertensive rats (SHR) was examined by quantitative neurohistochemical methods before and after extremely high frequency field (EHF field) influence of "Bayur" microwave therapy apparatus in mode 1 (42,194 MHz frequency, 7.1 mm wavelength) and in mode 3 (53,534 MHz frequency, 5.6 mm wavelength). Reduction of myocardial nervous plexus density and catecholamine luminescence intensity were detected in SHR, as well as decrease of adrenal glands relative weight and catecholamine luminescence intensity in adrenal medulla of SHR, that is indicative of suppression of sympatho-adrenal system of hypertensive animals by EHF field influence in medical operating modes.

Belyaev IY, Shcheglov VS, Alipov YD, Polunin VA, Resonance effect of millimeter waves in the power range from 10(-19) to 3 x 10(-3) W/cm² on Escherichia coli cells at different concentrations. *Bioelectromagnetics* 17(4):312-321, 1996.

The effect of millimeter waves (MMWs) on the genome conformational state (GCS)

of *E. coli* AB1157 cells was studied by the method of anomalous viscosity time dependencies (AVTD) in the frequency range of 51.64-51.85 GHz. The 51.755 GHz resonance frequency of the cell reaction to MMWs did not depend on power density (PD) in the range from 10^{-19} to 3×10^{-3} W/cm². The half-width of the resonant reaction of cells showed a sigmoid dependence on PD, changing from 3 MHz to 100 MHz. The PD dependence of the half-width had the same shape for different concentrations of exposed cells (4×10^7 and 4×10^8 cells/ml), whereas the magnitude of the 51.755 GHz resonance effect differed significantly and depended on the PD of MMW exposure. Sharp narrowing of the 51.755 GHz resonance in the PD range from 10^{-4} to 10^{-7} W/cm² was followed by an emergence of new resonance frequencies. The PD dependence of the MMW effect at one of these resonance frequencies (51.674 GHz) differed markedly from the corresponding dependence at the 51.755 GHz resonance, the power window occurring in the range from 10^{-16} to 10^{-8} W/cm². The results obtained were explained in the framework of a model of electron-conformational interactions. The frequency-time parameters of this model appeared to be in good agreement with experimental data.

Bielski J, Sikorski M, [Disturbances of glucose tolerance in workers exposed to electromagnetic radiation]. *Med Pr* 47(3):227-231, 1996. [Article in Polish]

The study group was composed of 50 workers exposed to electromagnetic radiation (radiowaves). Out of them 31 persons (62%), employed mostly in the risk zone, showed irregular glycaemia after oral administration of 75 g of glucose. At normal blood sugar before breakfast, the glycaemia level was high following administration of glucose and it did not return to starting values after 2 hours. After 30 min from glucose administration the level accounted for 155 mg%, after 60 min-180 mg%, after 90 min-153 mg% and after 120 min-124 mg%, on average. In 10 persons (32%) with glucose tolerance disturbances, disorders in bioelectric activity of the brain (abnormal EEG record) were observed.

Blick DW, Adair ER, Hurt WD, Sherry CJ, Walters TJ, Merritt JH, Thresholds of microwave-evoked warmth sensations in human skin. *Bioelectromagnetics* 18(6):403-409, 197.

We measured thresholds for microwave-evoked skin sensations of warmth at frequencies of 2.45, 7.5, 10, 35, and 94 GHz. In the same subjects, thresholds of warmth evoked by infrared radiation (IR) were also measured for comparison. Detection thresholds were measured on the skin in the middle of the back in 15 adult male human subjects at all microwave (MW) frequencies and with IR. Long duration (10-s), large area (327-cm²) stimuli were used to minimize any differential effects of temporal or spatial summation. Sensitivity increased monotonically with frequency throughout the range of microwave frequencies tested. The threshold at 94 GHz (4.5 ± 0.6 mW/cm²) was more than an order of magnitude less than at 2.45 GHz (63.1 ± 6.7 mW/cm²), and it was comparable to

the threshold for IR (5.34 +/- 1.07 mW/cm²).

Bohr, H, Bohr, J, Microwave enhanced kinetics observed in ORD studies of a protein. *Bioelectromagnetics* 21(1):68-72, 2000.

Microwaves are shown to affect the kinetics of conformational changes of the protein beta-lactoglobulin. Microwaves can accelerate conformational changes in the direction towards the equilibrium state. This applies both for the folding and the unfolding processes. Cold denaturing thermal unfolding of the proteins is accelerated by negative temperature gradients. Microwave irradiation of the protein solution heated it by about 0.3 degree, and hence the observed acceleration of denaturing is therefore non-thermal.

Borbely, AA, Huber, R, Graf, T, Fuchs, B, Gallmann, E, Achermann, P, Pulsed high-frequency electromagnetic field affects human sleep and sleep electroencephalogram. *Neurosci Lett* 275(3):207-210, 1999.

To investigate whether the electromagnetic field (EMF) emitted by digital radiotelephone handsets affects the brain, healthy, young subjects were exposed during an entire night-time sleep episode to an intermittent radiation schedule (900 MHz; maximum specific absorption rate 1 W/kg) consisting of alternating 15-min on-15-min off intervals. Compared with a control night with sham exposure, the amount of waking after sleep onset was reduced from 18 to 12 min. Spectral power of the electroencephalogram in non-rapid eye movement sleep was increased. The maximum rise occurred in the 10-11 Hz and 13.5-14 Hz bands during the initial part of sleep and then subsided. The results demonstrate that pulsed high-frequency EMF in the range of radiotelephones may promote sleep and modify the sleep EEG.

Bortkiewicz A, Zmyslony M, Gadzicka E, Szymczak W, [Evaluation of selected parameters of circulatory system function in various occupational groups exposed to high frequency electromagnetic fields. II. Electrocardiographic changes]. *Med Pr* 47(3):241-252, 1996. [Article in Polish]

The effect of electromagnetic fields (EMF) on the circulatory and nervous systems has been the subject of great interest for many years, since electric impulses generated in these systems by outer electric and magnetic fields can theoretically disturb their functions. The only data on chronic effect of weak EMFs on the human body come from the studies carried out in the Soviet Union between the fifties and the seventies. In view of a growing number of persons exposed to EMF, there is an urgent need for verifying those data by means of modern diagnostic methods. That is the reason why our study of the EMF effect on the circulatory system has been initiated. It covered 71 workers at four AM broadcast stations, 40 workers at ten radio link stations and 42 workers at three radioservices. Workers' exposure to EMF was evaluated (see part I). Subjective and objective medical examinations were performed in all workers in order to assess their state of health, then resting electrocardiogram, Holter

measurements, and high intensity ECG were taken, and variation in cardiac rhythm was analysed by a long-term recording of blood pressure. The results of the analysis of the questionnaire survey as well as the Holter and resting ECG examinations are presented. The study indicated that exposure to EMF in parameters found in AM broadcast station increased risk for electrographic disturbances (detected by means of resting ECG and a 24-hour Holter recording) by six times in comparison with that in radio link station workers not exposed to medium wave EMF. In radioservice workers this risk was twice as high as that in link station workers. It seems that in AM broadcast station workers, resting ECG should be complemented by a 24-hour Holter measurements, particularly, if workers complain of the circulatory system disturbances.

Bortkiewicz, A, Zmyslony, M, Gadzicka, E, Palczynski, C, Szmigielski, S, Ambulatory ECG monitoring in workers exposed to electromagnetic fields. *J Med Eng Technol* 21(2):41-46, 1997.

The aim of this study was to evaluate the function of the circulatory system in workers occupationally exposed to medium frequency electromagnetic fields. The subjects were 71 workers at four AM broadcast stations [0.738-1.503 MHz] aged 20-68 (mean 46.9 +/- 13.1) years and 22 workers at radio link stations aged 23-67 (mean 48.2 +/- 17.4) years. Workers at AM broadcast stations experienced 2-40 (mean 18.6 +/- 12.1) years' exposure to electromagnetic fields (average daily exposure dose about 115 Vh m⁻¹, maximum exposure levels during shift about 165 V m⁻¹), workers at radio link stations had no history of regular exposure to electromagnetic fields. In all the subjects a general medical examination, resting ECG and 24 h Holter monitoring were performed. The work organization, work period structure, age, lifestyle, nutritional habits and health status in both groups remained fairly similar. The electrocardiographic abnormalities detected in the resting and/ or 24 h ECG were significantly more frequent ($p = 0.006$) in workers exposed to electromagnetic fields than in non-exposed subjects (75% versus 25%). A clear tendency for a higher number of rhythm disturbances (mostly ExV) was observed in AM broadcast station workers.

Braune, S, Wrocklage, C, Raczek, J, Gailus, T, Lucking, CH, Resting blood pressure increase during exposure to a radio-frequency electromagnetic field. *Lancet* 351(9119):1857-1858, 1998.

Exposure of the right hemisphere to a radiofrequency EMF for 35 min causes in human subjects an increase in sympathetic efferent activity with increases the resting blood pressure between 5-10 mm Hg. The effect is likely caused by vasoconstriction.

Burch, JB, Reif, JS, Pitrat, CA, Keele, TJ, Yost, MG, Cellular telephone use and excretion of a urinary melatonin metabolite. Abstract of the Annual Review of

Research on Biological Effects of Electric and Magnetic Fields from the Generation, delivery & Use of Electricity, San Diego, CA, 1997, pp.110.

Subjects that reported frequent (more than one a day) to occasional (daily or several times a day) cellular telephone use had significantly lower mean urinary melatonin metabolite levels compared to those who reported infrequent (less than one per week) or no cell phone use. Results suggest that occupational cellular telephone use may be associated with reduced daytime melatonin production.

Cain CD, Thomas DL, Adey WR, Focus formation of C3H/10T1/2 cells and exposure to a 836.55 MHz modulated radiofrequency field.

***Bioelectromagnetics* 18(3):237-243, 1997.**

Disruption of communication between transformed cells and normal cells is involved in tumor promotion. We have tested the hypothesis that exposures to radiofrequency (RF) fields using a form of digital modulation (TDMA) and a chemical tumor promoter, 12-O-tetradecanoylphorbol-13-acetate (TPA), are copromoters that enhance focus formation of transformed cells in coculture with parental C3H/10T1/2 murine fibroblasts. RF field exposures did not influence TPA's dose-dependent promotion of focus formation in coculture. Cell cultures were exposed to an 836.55 MHz TDMA-modulated field in TEM transmission line chambers, with incident energies that simulated field intensities at a user's head. Specific absorption rates (SARs) of 0.15, 1.5, and 15 $\mu\text{W/g}$ were used during each digital packet, and the packet frequency was 50/s. The TEM chambers were placed in a commercial incubator at 37 degrees C and 95% humidity/5% CO₂. The RF field exposures were in a repeating cycle, 20 min on, 20 min off, 24 h/day for 28 days. At 1.5 $\mu\text{W/g}$, TPA-induced focus formation (at 10, 30, and 50 ng/ml) was not significantly different in RF-exposed cultures compared to parallel sham-exposed cultures in ten independent experiments in terms of the number, density, and area of foci. Similarly, at 0.15 and 15.0 $\mu\text{W/g}$, in two and four experiments, respectively, RF exposure did not alter TPA-induced focus formation. The findings support a conclusion that repeated exposures to this RF field do not influence tumor promotion in vitro, based on the RF field's inability to enhance TPA-induced focus formation.

Chagnaud JL, Veyret B In vivo exposure of rats to GSM-modulated microwaves: flow cytometry analysis of lymphocyte subpopulations and of mitogen stimulation. *Int J Radiat Biol* 75(1):111-113, 1999.

The effects of GSM-modulated microwaves on lymphocyte sub-populations of Sprague-Dawley rats and their normal mitogenic responses were investigated using flow cytometry analysis and a colorimetric method. No alterations were found in the surface phenotype of splenic lymphocytes or in their mitogenic activity, indicating that low-level pulsed microwaves do not seem to affect the integrity of the immune system.

Chagnaud, JL, Moreau, JM, Veyret, B, No effect of short-term exposure to GSM-modulated low-power microwaves on benzo(a)pyrene-induced tumours in rat. *Int J Radiat Biol* 75(10):1251-1256, 1999.

PURPOSE: In view of current interest in the biological effects of amplitude-modulated microwaves arising from the rapid development of mobile communications, the effects of low-level microwaves on cancer development were investigated using a rat sarcoma model. **MATERIALS AND METHODS:** Two-month-old female Sprague-Dawley rats were treated by injection of benzo(a)pyrene and irradiated with GSM (Global System for Mobile)-modulated 900-MHz microwaves in an anechoic chamber at 55 or 200 microW cm⁻² (75 and 270 mW kg⁻¹) average whole-body SAR, 2h daily for 2 weeks). Rats were exposed from day 20, 40 or 75 after carcinogen injection. Additional groups of rats were sham-exposed in a second anechoic chamber. Anti-phosphatidylinositol autoantibody levels were evaluated in sera to monitor malignant transformation. **RESULTS:** Microwave exposure had no effect on the development of tumours. No acceleration or delays in tumour onset were observed. Animal survival was not modified and serum autoantibody levels were similar in exposed and sham-exposed groups.

CONCLUSION: Low-level GSM microwave exposure of rat bearing benzo(a)pyrene-induced tumours had no effect on auto-antibody levels, tumour appearance and survival. The low exposure levels used here correspond to exposure limits for whole-body exposure of humans.

Chattopadhyay SK, Toews KA, Butt S, Barlett R, Brown HD, Reverse-micelle model: pH, electromagnetic field and inhibitor enzyme interaction. *Cancer Biochem Biophys* 15:245-255, 1997.

The reverse micelle is one of many models thought to have properties more nearly resembling the biological cellular environment, than does the traditional dilute-solution biochemical reaction system. In order to evaluate the results of EMF perturbation of enzyme-catalyzed reactions, the description of the AOT reverse-micelle model, with respect to its internal pH, effect of chemical inhibitors, temperature, and electromagnetic-field perturbation has herein been extended. Acetylcholinesterase and NADPH cytochrome-P450 reductase, reacting within the AOT reverse-micelle, exhibit a temperature vs. activity profile equivalent to the same reaction in a buffered dilute-solution environment. In reverse micelles, some inhibitors of AChE (propidium, and d-tubocurarine) have much less effect upon indophenol-acetate hydrolysis than they do in a dilute solution environment. Other inhibitors act in the same manner within the structured environment of the reverse micelle as in the conventional dilute solution reaction model. These differences are explicable in terms of mechanism of action of the individual inhibitors. Perturbation by low-intensity microwave fields has a similar inhibitory effect upon dilute-solution reactions, as those in the 'low-water-activity' environment of the reverse micelle. However, the interactions between physical and chemical perturbants are differently limited by the structure of the aqueous phase of the reverse micelle. pH of the 'internal' reverse-micelle

environment is a function of the availability of H-ions supplied by system components. Use of indicator dyes show that the low-molarity buffers which are compatible with reverse-micelle stability, are often insufficient to maintain a constant pH. Too, in the reverse micelle, reaction rate, for proton yielding reactions, is dramatically greater than the rate of the same reaction in dilute solution at the same acidic pH.

Chen WH, Lau CP, Leung SK, Ho DS, Lee IS, Interference of cellular phones with implanted permanent pacemakers. *Clin Cardiol* 19(11):881-886, 1996.

BACKGROUND AND HYPOTHESIS: Occasional reports have suggested that cellular phones may interfere with permanent pacemakers. Our investigation sought to determine systematically the effects of commercially available cellular phones on the performances of different pacing modes and sensing lead configurations of permanent implanted pacemakers. **METHODS:** We conducted the study in 29 patients implanted with single- or dual-chamber bipolar rate-adaptive permanent pacemakers (a total of nine different models and six different sensors: minute ventilation, activity sensing using either accelerometer or piezoelectric crystal, QT and oxygen saturation sensing) from four different manufacturers. Three different cellular phones with analog or digital coding with maximum power from 0.6 to 2 W were used to assess the effect of pacemaker interference. Each cellular phone was positioned at (1) above the pacemaker pocket, (2) the ear level ipsilateral to the pacemaker pocket, and (3) the contralateral ear level. Surface electrocardiograms, intracardiac electrograms, and marker channels were recorded where possible during the following maneuvers at each position: (1) calls made by a stationary phone to cellular phone, and (2) calls made from the cellular phone to a stationary phone. A total of eight different pacing modes [DDD(R), VDD(R), AAI(R) and VVI(R)] in both unipolar and bipolar sensing configurations was tested. **RESULTS:** Interference was demonstrated during cellular phone operation in 74 of 2,418 (3.1%) episodes in eight patients. Three types of interference were observed: inhibition of pacing output, rapid ventricular tracking in DDD(R) or VDD(R) mode, and asynchronous pacing. All were observed only with the cellular phone positioned above the pacemaker pocket. Interference occurred prior to and after the termination of the ringing tone of the cellular phone in 57% of cases. Cellular phones with either digital or analog technology could cause interference. Unipolar atrial lead was most susceptible to interference (relative frequency of interference: unipolar 1.8%, bipolar 0.4%, $p < 0.05$; atrial 2.9%, ventricular 1%, $p < 0.05$). There was no sensor-driven rate acceleration during all tests. In all patients, reprogramming of the sensitivity level successfully prevented cellular phone interference. **CONCLUSIONS:** Commercially available cellular phones can cause reversible interference to implanted single- or dual-chamber permanent pacemakers. The effect is maximal with high atrial unipolar sensitivity, especially in single pass VDD(R) systems. Both digital and analog cellular phones can lead to interference. Pacemaker interference can occur prior to a warning sign (ringing tone) of the phone and may have significant implications

in patient safety.

Chiang H, Microwave and ELF electromagnetic field effects on intercellular communication, *Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society* 20:2798-2801, 1998.

Gap junctional intercellular communication (GJIC) plays an essential role in regulation of cell growth, differentiation and wound healing. Microwave irradiation may down-regulate GJIC and the effect is strongly influenced by modulation frequency. Many studies have demonstrated that GJIC could be suppressed by ELF magnetic field (MF) and the suppression is related to the intensity of magnetic flux density and the exposure duration. Pulsed MF is more effective than sinusoidal MF in inhibiting GJIC. Inhibiting GJIC by electromagnetic field in some cases could be beneficial or detrimental. The mechanism of GJIC inhibition by ELF MF has also been studied and found that the inhibition may be mainly due to hyperphosphorylation of gap junctional connexins by PKC rather than its transcriptional or translational dysregulation.

Cleary, SF, Cao, G, Liu, LM, Egle, PM, Shelton, KR, Stress proteins are not induced in mammalian cells exposed to radiofrequency or microwave radiation. *Bioelectromagnetics* 18(7):499-505, 1997.

The induction of stress proteins in HeLa and CHO cells was investigated following a 2 h exposure to radiofrequency (RF) or microwave radiation. Cells were exposed or sham exposed in vitro under isothermal (37 +/- 0.2 degrees C) conditions. HeLa cells were exposed to 27- or 2450 MHz continuous wave (CW) radiation at a specific absorption rate (SAR) of 25 W/kg. CHO cells were exposed to CW 27 MHz radiation at a SAR of 100 W/kg. Parallel positive control studies included 2 h exposure of HeLa or CHO cells to 40 degrees C or to 45 microM cadmium sulfate. Stress protein induction was assayed 24 h after treatment by electrophoresis of whole-cell extracted protein labeled with [35S]-methionine. Both cell types exhibited well-characterized responses to the positive control stresses. Under these exposure conditions, neither microwave nor RF radiation had a detectable effect on stress protein induction as determined by either comparison of RF-exposed cells with sham-exposed cells or comparison with heat-stressed or Cd⁺⁺ positive control cells.

Cleary, SF, Du, Z, Cao, G, Liu, LM, McCrady, C, Effect of isothermal radiofrequency radiation on cytolytic T lymphocytes. *FASEB J* 10(8):913-919. 1996.

Previous in vitro studies provide evidence that RF electromagnetic radiation modulates proliferation of human glioma, lymphocytes, and other cell types. The mechanism of RF radiation cell proliferation modulation, as well as mechanisms for effects on other cell physiologic endpoints, are not well understood. To obtain insight regarding interaction mechanisms, we investigated effects of RF radiation exposure on interleukin 2 (IL-2) -dependent proliferation of cytolytic T lymphocytes (CTL-2).

After exposure to RF radiation in the presence or absence of IL-2 cells were cultured at various physiological concentrations of IL-2. Treatment effects on CTLL-2 proliferation were determined by tritiated thymidine incorporation immediately or 24 h after exposure. Exposure to 2450 MHz RIF radiation at specific absorption rates (SARs) of greater than 25 W/kg (induced E-field strength 98.4 V/m) induced a consistent, statistically significant reduction in CTLL-2 proliferation, especially at low IL-2 concentrations. At lower SARs, 2450 MHz exposure increased CTLL-2 proliferation immediately after exposure but reduced 24 h postexposure proliferation. RF radiation effects depended on the mitotic state of the cells at the time of exposure. Comparison of the effects of temperature elevation and RF radiation indicated significant qualitative and quantitative differences.

Daniells, C, Duce, I, Thomas, D, Sewell, P, Tattersall, J, de Pomerai, D, Transgenic nematodes as biomonitors of microwave-induced stress. *Mutat Res* 399:55-64, 1998.

Transgenic nematodes (*Caenorhabditis elegans* strain PC72), carrying a stress-inducible reporter gene (*Escherichia coli* beta-galactosidase) under the control of a *C. elegans* hsp16 heat-shock promoter, have been used to monitor toxicant responses both in water and soil. Because these transgenic nematodes respond both to heat and toxic chemicals by synthesising an easily detectable reporter product, they afford a useful preliminary screen for stress responses (whether thermal or non-thermal) induced by microwave radiation or other electromagnetic fields. We have used a transverse electromagnetic (TEM) cell fed from one end by a source and terminated at the other end by a matched load. Most studies were conducted using a frequency of 750 MHz, at a nominal power setting of 27 dBm. The TEM cell was held in an incubator at 25 degrees C inside a shielded room; corresponding controls were shielded and placed in the same 25 degrees C incubator; additional baseline controls were held at 15 degrees C (worm growth temperature). Stress responses were measured in terms of beta-galactosidase (reporter) induction above control levels. The time-course of response to continuous microwave radiation showed significant differences from 25 degrees C controls both at 2 and 16 h, but not at 4 or 8 h. Using a 5 x 5 multiwell plate array exposed for 2 h, the 25 microwaved samples showed highly significant responses compared with a similar control array. The wells most strongly affected were those in the rows closest to the source, whereas the most distant row did not rise above control levels, suggesting a shadow effect. These differential responses are difficult to reconcile with general heating effects, although localised power absorption affords a possible explanation. Experiments in which the frequency and/or power settings were varied suggested a greater response at 21 than at 27 dBm, both at 750 and 300 MHz, although extremely variable responses were observed at 24 dBm and 750 MHz. Thus, lower power levels tended, if anything, to induce larger responses (with the above-mentioned exception), which is opposite to the trend anticipated for any simple heating effect. These results are reproducible and data acquisition is both rapid and simple. The evidence accrued to date suggests that microwave radiation causes measurable stress to transgenic nematodes, presumably reflecting increased levels of protein damage within cells

(the common signal thought to trigger hsp gene induction). The response levels observed are comparable to those observed with moderate concentrations (ppm) of metal ions such as Zn²⁺ and Cu²⁺. We conclude that this approach deserves further and more detailed investigation, but that it has already demonstrated clear biological effects of microwave radiation in terms of the activation of cellular stress responses (hsp gene induction).

Dasdag, S, Ketani, MA, Akdag, Z, Ersay, AR, Sar, i I, Demirtas ,OC, Celik, MS, Whole-body microwave exposure emitted by cellular phones and testicular function of rats. *Urol Res* 27(3):219-223, 1999.

This study investigated whether there are adverse effects due to microwave exposure emitted by cellular phones in male rats. Eighteen Wistar Albino rats were separated into three groups, a sham group and two experimental groups. The rats were confined in Plexiglas cages and cellular phones were placed 0.5 cm under the cages. In the first experimental group, cellular phones were in standby position for 2 h. In the second experimental group, phones were turned to the speech position three times each for 1 min duration over 2 h. Rats in the first and second experimental groups were exposed to microwaves emitted by phones for 2 h/day for a duration of 1 month. After the last exposure the rats were killed. Brain, eyes, ears, liver, heart, lungs, stomach, kidneys, testes, small and large intestines and skin of the rats were observed histologically. The decrease of epididymal sperm counts in the speech groups were not found to be significant ($P > 0.05$). Differences in terms of normal and abnormal sperm forms were not observed ($P > 0.05$). Histological changes were especially observed in the testes of rats of the speech groups. Seminiferous tubular diameter of rat testes in the standby and speech groups was found to be lower than the sham group ($P < 0.05$). Rectal temperatures of rats in the speech group were found to be higher than the sham and standby groups ($P < 0.05$). The rectal temperatures of rats before and after exposure were also found to be significantly higher in the speech group ($P < 0.05$). Specific absorption rate (SAR) was determined as 0.141 W/kg.

de Pomerai, DI, Daniells, C, Barker, SL, Scott, S, Duce, IR, Thomas, DW, Sewell, PD, Tattersall, JEH, Effects of stress-inducing microwave radiation on life-cycle parameters in the nematode *Caenorhabditis elegans*. Presented at the Twentieth Annual Meeting of the Bioelectromagnetics Society, St. Pete Beach, FL, June 1999.

Overnight exposure to microwave radiation (750 MHz, 0.5 W) shifted the worm size distribution markedly towards the larger size ranges. The size increase was correlated with a faster rate of progression through the stages of larval development.

de Pomerai D, Daniells C, David H, Allan J, Duce I, Mutwakil M, Thomas D, Sewell P, Tattersall J, Jones D, Candido P, Non-thermal heat-shock response to microwaves, *Nature* May 25, 2000.

Nematode worms (*C. elegans*) exposed overnight to 750-MHz microwaves at a SAR of 0.001 W/kg showed an increase in heat shock proteins (HSPs). (Heat shock proteins are induced in most organisms by adverse conditions (such as heat or toxins) that cause damage to cellular proteins, acting as molecular chaperones to rescue damaged proteins). The authors give several arguments that the microwave-induced effect on HSPs is non-thermal and suggest that 'current exposure limits for microwave equipment may need to be reconsidered.'

de Seze R, Ayoub J, Peray P, Miro L, Touitou Y, Evaluation in humans of the effects of radiocellular telephones on the circadian patterns of melatonin secretion, a chronobiological rhythm marker. *J Pineal Res* 27(4):237-242, 1999.

A decrease in melatonin secretion has been observed in small mammals under exposure to extremely low frequency electromagnetic fields. As there is some concern about possible health effects of the increasing use of radiocellular telephones emitting radiofrequency electromagnetic fields, we examined whether such fields would alter melatonin levels in the human. Volunteers were two groups totalling 38 men, 20-32 yr old. Exposures were to commercially available cellular telephones of the GSM 900 type (Global System for Mobile communication at 900 MHz) or DCS 1800 type (Digital Communication System at 1800 MHz), for 2 hr/day, 5 days/wk, for 4 wk, at their maximum power. Attention of the volunteers was sustained by TV projection of movies. Blood samples were collected hourly during the night and every 3 hr in the daytime. Four sampling sessions were performed at 15-day intervals: before the beginning of the exposure period, at the middle and the end of the exposure period, and 15 days later to evaluate the persistence or late appearance of potential effects. Evaluated parameters were the maximum serum concentration, the time of this maximum, and the area under the curve of the hormone profile. Melatonin circadian profile was not disrupted in 37 young male volunteers submitted to a typical pattern of exposure to the electromagnetic fields generated by two common types of cell phones.

de Seze R, Fabbro-Peray P, Miro L, GSM radiocellular telephones do not disturb the secretion of antepituitary hormones in humans. *Bioelectromagnetics* 19(5):271-278, 1998.

It is known that the endocrine system of experimental animals is susceptible to perturbation by radiofrequency (RF) radiation. Because of the recent interest in health and safety issues of cellular telephones, an experiment was designed to evaluate the effect of a 900 MHz RF radiation emitted by a Global System for Mobile radiotelephone (217 Hz impulses, one-eighth duty cycle, 2 W peak power) on human endocrine functions. Twenty healthy male volunteers aged from 19 to 40 were included in the present experiment. Each subject was exposed to RF radiation through the use of a cellular phone 2 h/day, 5 days/wk, for 1 month. Subjects were their own control. End points were serum adrenocorticotropin, thyrotropin, growth hormone, prolactin, luteinizing hormone, and follicle stimulating hormone concentrations. These end points were determined in nine weekly blood samples obtained starting 3 weeks before the commencement of the exposure and

ending 2 weeks after exposures. All but one blood sample was drawn 48 h after each weekly session. The seventh drawing was performed the morning after the last weekly exposure. Within each individual, the preexposure hormone concentration was used as a control. Results indicated that all hormone concentrations remained within normal physiologic ranges. A difference was not noted among the nine weekly samples in five of six hormones studied. There was a significant change only in thyrotropin concentration, showing a 21% decrease on the seventh sampling. Because this change recovered fully during the postexposure period, it is concluded that 1 month of intermittent exposures to RF radiation from a cellular telephone does not induce a long-lasting or cumulative effect on the hormone secretion rate of the anterior pituitary gland in humans.

Detlavs I, Dombrovska L, Turauska A, Shkirmante B, Slutskii L, Experimental study of the effects of radiofrequency electromagnetic fields on animals with soft tissue wounds. *Sci Total Environ* 180(1):35-42, 1996.

The effect of radio frequency electromagnetic fields (RF EMF) was studied on Wistar rats with excised full-thickness dermal wounds in the interscapular region. The wounded regions of experimental animals were subjected to EMF for 30 min daily during the first 5 days after wound infliction. Control animals received no treatment. We used RF EMF with (1) frequency 53.53 GHz without modulation; (2) frequency 42.19 GHz without modulation; (3) frequency 42.19 GHz, but with a frequency modulation band 200-MHz wide. On the 7th day the animals were terminated and the granulation-fibrous tissue (GFT) developed in the wounds was subjected to complex quantitative biochemical analysis. RF EMF without frequency modulation decreased the amounts of glycoprotein macromolecules, diminishing the inflammatory exudation. In striking contrast, under the influence of RF EMF with frequency modulation, hexoses and especially sialic acid concentrations were significantly elevated ($P < 0.001$). This indicated intensification of exudative phenomena. As a consequence of inflammation inhibition in the treatment without frequency modulation, the total collagen accumulation was lowered. However, when frequency was modulated, the inflammatory phenomena were intensified, and pronounced accumulation of collagenous proteins was noted. Thus, our experiments confirm the effects of non-thermal EMF on the reparative-proliferative processes of animals with soft tissue wounds.

Ding G, Xie X, Zhang L et al. Changes of nitric oxide synthase in hippocampus and cerebellum of the rat following exposure to electromagnetic pulse. *Chin J Phys Med* 20:81-83, 1998.

Objective: In order to explore the role of nitric oxide in the obstruction of learning and memory of the rat caused by exposing to electromagnetic pulses (EMP), the distribution of nitric oxide synthase (NOS) expression was studied in hippocampus and cerebellum of the rat following exposure to EMP. Methods: SP immunohistochemical staining was employed to detect the distribution of NOS expression. Results: The number of NOS positive neurons and the intensity of

positive staining in hippocampus were decreased at 1.5 and 24 h after exposure to EMP. At 48 h, the number of NOS positive neurons reversed to control level but the intensity of positive staining was still low. the expression of NOS in cerebellum had no obvious changes. Conclusion: Decrease of NOS expression in hippocampus relates to the obstruction of learning and memory of the rat after exposure to EMP.

Donnellan M, McKenzie DR, French PW, Effects of exposure to electromagnetic radiation at 835 MHz on growth, morphology and secretory characteristics of a mast cell analogue, RBL-2H3. *Cell Biol Int* 21:427-439, 1997.

A mast cell line, RBL-2H3, was exposed to 835 MHz for 20 minutes, three times per day for 7 days at a power density of 8.1 +/- 3 mW/cm². From day 4 onwards, it was observed that the rate of DNA synthesis and cell replication increased, that actin distribution and cell morphology became altered, and the amount of beta-hexosaminidase (a marker of granule secretion) released in response to a calcium ionophore was significantly enhanced, in comparison to unexposed cultures. There were no effects seen on levels of cytoskeletal protein synthesis or of beta-actin mRNA. Morphological changes persisted following subculture for at least 7 days in the absence of further exposure. It is hypothesized that effects of exposure to an electromagnetic field at 835 MHz may be mediated via a signal transduction pathway.

Duan L, Shan Y, Yu X, [Observations of changes in neurobehavioral functions in workers exposed to high-frequency radiation]. *Chung Hua Yu Fang I Hsueh Tsa Chih* 32(2):109-111, 1998.
[Article in Chinese]

OBJECTIVE: To study the effects of exposure to high-frequency radiation on neurobehavioral function of the exposed workers and its measurement in evaluating occupational hazards caused by it. **METHODS:** Four neurobehavioral functions were tested for the workers exposed to high-frequency radiation with Neurobehavioral Core Tests Battery recommended by WHO. **RESULTS:** Scores for various indicators in exposed workers were significantly lower than those in controls, and correlated to the detection of neurasthenia in the exposed workers, to certain extent. **CONCLUSION:** Changes in neurobehavioral function in workers exposed to high-frequency radiation can reflect its important adverse effects.

Dreyer NA, Loughlin JE, Rothman KJ, Cause-specific mortality in cellular telephone users. *JAMA* 282(19):1814-1816, 1999.

A survey of standardized mortality rates (from cancer, circulatory diseases, and motor vehicle collisions) of 285,561 analog telephone users with known age, sex, and telephone type, showed that the only category of cause of death for which there was an indication of increasing risk with increasing minutes of phone use was motor vehicle collisions. Similar results were found for number of telephone calls per day.

collision were particularly hazardous (relative risk, 4.8 for calls placed within 5 minutes of the accident, as compared with 1.3 for calls placed more than 15 minutes before the accident; $P < 0.001$); and units that allowed the hands to be free (relative risk, 5.9) offered no safety advantage over hand-held units (relative risk, 3.9; P not significant). Thirty-nine percent of the drivers called emergency services after the collision, suggesting that having a cellular telephone may have had advantages in the aftermath of an event. **CONCLUSIONS:** The use of cellular telephones in motor vehicles is associated with a quadrupling of the risk of a collision during the brief time interval involving a call. Decisions about regulation of such telephones, however, need to take into account the benefits of the technology and the role of individual responsibility.

Elekes, E, Thuroczy, G, Szabo, LD, Effect on the immune system of mice exposed chronically to 50 Hz amplitude-modulated 2.45 GHz microwaves. *Bioelectromagnetics* 17(3):246-248, 1996.

The effect of continuous (CW; 2.45 GHz carrier frequency) or amplitude-modulated (AM; 50 Hz square wave) microwave radiation on the immune response was tested. CW exposures (6 days, 3 h/day) induced elevations of the number of antibody-producing cells in the spleen of male Balb/c mice (+37%). AM microwave exposure induced elevation of the spleen index (+15%) and antibody-producing cell number (+55%) in the spleen of male mice. No changes were observed in female mice. It is concluded that both types of exposure conditions induced moderate elevation of antibody production only in male mice.

Eulitz, C, Ullsperger, P, Freude, G, Elbert, T, Mobile phones modulate response patterns of human brain activity. *Neuroreport* 9(14):3229-3232, 1998.

Mobile phones emit a pulsed high-frequency electromagnetic field (PEMF) which may penetrate the scalp and the skull. Increasingly, there is an interest in the interaction of this pulsed microwave radiation with the human brain. Our investigations show that these electromagnetic fields alter distinct aspects of the brain's electrical response to acoustic stimuli. More precisely, our results demonstrate that aspects of the induced but not the evoked brain activity during PEMF exposure can be different from those not influenced by PEMF radiation. This effect appears in higher frequency bands when subjects process task-relevant target stimuli but was not present for irrelevant standard stimuli. As the induced brain activity in higher frequency bands has been proposed to be a correlate of coherent high-frequency neuronal activity, PEMF exposure may provide means to systematically alter the pattern fluctuations in neural mass activity.

Fesenko EE, Geletyuk VI, Kazachenko VN, Chemeris NK Preliminary microwave irradiation of water solutions changes their channel-modifying activity. *FEBS Lett* 366(1):49-52, 1995.

Earlier we have shown that millimetre microwaves (42.25 GHz) of non-thermal

power, upon direct admittance into an experiment bath, greatly influence activation characteristics of single Ca(2+)-dependent K⁺ channels (in particular, the channel open state probability, P_o). Here we present new data showing that similar changes in P_o arise due to the substitution of a control bath solution for a preliminary microwave irradiated one of the same composition (100 mmol/l KCl with Ca²⁺ added), with irradiation time being 20-30 min. Therefore, due to the exposure to the field the solution acquires some new properties that are important for the channel activity. The irradiation terminated, the solution retains a new state for at least 10-20 min (solution memory). The data suggest that the effects of the field on the channels are mediated, at least partially, by changes in the solution properties.

Fesenko EE, Novoselova EG, Semiletova NV, Agafonova TA, Sadovnikov VB, [Stimulation of murine natural killer cells by weak electromagnetic waves in the centimeter range]. *Biofizika* 44(4):737-741, 1999. [Article in Russian]

Irradiation with electromagnetic waves (8.15-18 GHz, 1 Hz within, 1 microW/cm²) in vivo increases the cytotoxic activity of natural killer cells of rat spleen. In mice exposed for 24-72 h, the activity of natural killer cells increased by 130-150%, the increased level of activity persisting within 24 h after the cessation of treatment. Microwave irradiation of animals in vivo for 3.5 and 5 h, and a short exposure of splenic cells in vitro did not affect the activity of natural killer cells.

Fesenko, EE, Makar, VR, Novoselova, EG, Sadovnikov, VB, Microwaves and cellular immunity. I. Effect of whole body microwave irradiation on tumor necrosis factor production in mouse cells. *Bioelectrochem Bioenerg* 49(1):29-35, 1999.

Whole body microwave sinusoidal irradiation of male NMRI mice with 8.15-18 GHz (1 Hz within) at a power density of 1 microW/cm² caused a significant enhancement of TNF production in peritoneal macrophages and splenic T lymphocytes. Microwave radiation affected T cells, facilitating their capacity to proliferate in response to mitogenic stimulation. The exposure duration necessary for the stimulation of cellular immunity ranged from 5 h to 3 days. Chronic irradiation of mice for 7 days produced the decreasing of TNF production in peritoneal macrophages. The exposure of mice for 24 h increased the TNF production and immune proliferative response, and these stimulatory effects persisted over 3 days after the termination of exposure. Microwave treatment increased the endogenously produced TNF more effectively than did lipopolysaccharide, one of the most potential stimuli of synthesis of this cytokine. The role of microwaves as a factor interfering with the process of cell immunity is discussed.

Fetter JG, Ivans V, Benditt DG, Collins J, Digital cellular telephone interaction with implantable cardioverter-defibrillators. *J Am Coll Cardiol* 31(3):623-628, 1998.

OBJECTIVES: This study sought to determine, *in vivo*, whether electromagnetic interference (EMI), generated by North American Digital Communications (NADC)/Time Division Multiple Access-50-Hz (TDMA-50) mobile cellular digital telephone model AT&T 6650, disturbs normal implantable cardioverter-defibrillator (ICD) operation and to verify these observations *in vitro* by testing a selection of telephones representing worldwide systems. **METHODS:** The effects of cellular phone interference on the operation of various models of market-released ICDs from a single manufacturer, Medtronic, Inc., were tested. The *in vivo* clinical test was undertaken in 41 patients using the AT&T 6650 digital telephone with the NADC/TDMA-50 technology. The *in vitro* component of the study was examined twofold: 1) antenna generated far field; and 2) analog/digital cellular telephone near field. **RESULTS:** None of the ICDs tested in 41 patients were affected by oversensing of the EMI field of the cellular telephones during the *in vivo* study. Therefore, the binomial upper 95% confidence limit for the failure rate of 0% is 7%. The *in vitro* antenna-generated field testing showed that telephone modulation frequencies used in the international Global System Mobile and TDMA-50 cellular telephone technologies did not result in ICD sensing interference at the predicted electric field intensity. The *in vitro* near field tests were performed using both analog and digital cellular telephones in service, or in the test mode, and indicated no interaction with normal operation. However, the static magnetic field generated by the cellular telephone placed over the ICD at a distance $< \text{or} = 0.5 \text{ cm}$ will activate the internal reed switch, resulting in temporary suspension of ventricular tachycardia and fibrillation detection. **CONCLUSIONS:** We conclude that TDMA-50 cellular telephones did not interfere with these types of ICDs. However, we recommend that the patient not carry or place the digital cellular telephone within 15 cm (6 in.) of the ICD.

Fink JM, Wagner JP, Congleton JJ, Rock JC, Microwave emission from police radar. *Am Ind Hyg Assoc J* 60(6):770-76, 1999.

This study evaluated police officers' exposures to microwaves emitted by traffic radar units. Exposure measurements were taken at approximated ocular and testicular levels of officers seated in patrol vehicles. Comparisons were made of the radar manufacturers' published maximum power density specifications and actual measured power densities taken at the antenna faces of those units. Four speed-enforcement agencies and one transportation research institute provided 54 radar units for evaluation; 17 different models, encompassing 4 frequency bands and 3 antenna configurations, were included. Four of the 986 measurements taken exceeded the 5 mW/cm² limit accepted by the International Radiation Protection Association and the National Council on Radiation Protection and Measurement, though none exceeded the American Conference of Governmental Industrial Hygienists, American National Standards Institute, Institute of Electrical and Electronic Engineers, or Occupational Safety and Health Administration standard of 10 mW/cm². The four high measurements were maximum power density readings taken directly in front of the radar. Of the 812 measurements taken at the officers' seated ocular and testicular

positions, none exceeded 0.04 mW/cm²; the highest of these (0.034 mW/cm²) was less than 1% of the most conservative current safety standards. High exposures in the limited region directly in front of the radar aperture are easily avoided with proper training. Results of this study indicate that police officer exposure to microwave radiation is apparently minimal. However, because of uncertainty in the medical and scientific communities concerning nonionizing radiation, it is recommended that law enforcement agencies implement a policy of prudent avoidance, including purchasing units with the lowest published maximum power densities, purchasing dash/rear deck-mounted units with antennae mounted outside the patrol vehicle, and training police officers to use the "stand-by" mode when not actually using radar.

Frei, MR, Jauchem, JR, Dusch, SJ, Merritt, JH, Berger, RE, Stedham, MA, Chronic, low-level (1.0 W/kg) exposure of mice prone to mammary cancer to 2450 MHz microwaves. *Radiat Res* 150(5):568-576, 1998.

In a previous study (Frei et al., *Bioelectromagnetics* 19, 20-31, 1998), we showed that low-level (0.3 W/kg), long-term exposure of mice prone to mammary tumors to 2450 MHz radiofrequency (RF) radiation did not affect the incidence of mammary tumors, latency to tumor onset, tumor growth rate or animal survival when compared to sham-irradiated animals. In the current study, the specific absorption rate (SAR) was increased from 0.3 W/kg to 1.0 W/kg. The same biological end points were used. One hundred C3H/HeJ mice were exposed in circularly polarized waveguides for 78 weeks (20 h/day, 7 days/week) to continuous-wave, 2450 MHz RF radiation; 100 mice were sham-exposed. There was no significant difference between exposed and sham-exposed groups with respect to the incidence of palpated mammary tumors (sham-exposed = 30%; irradiated = 38%), latency to tumor onset (sham-exposed = 62.0 +/- 2.3 weeks; irradiated = 62.5 +/- 2.2 weeks) and rate of tumor growth. Histopathological evaluations revealed no significant difference in numbers of malignant, metastatic or benign neoplasms between the two groups. Thus long-term exposures of mice prone to mammary tumors to 2450 MHz RF radiation at SARs of 0.3 and 1.0 W/kg had no significant effects when compared to sham-irradiated animals.

French PW, Donnellan M, McKenzie DR, Electromagnetic radiation at 835 MHz changes the morphology and inhibits proliferation of a human astrocytoma cell line. *Bioelectrochem Bioenerg* 43:13-18, 1997.

A human astrocytoma cell line, U-87 MG, was exposed to 835 MHz electromagnetic radiation for 20 min, 3 times per day for 7 days, at a power density of either 40 ± 15 mWcm⁻² or 8.1 ± 3 mWcm⁻². At the low power density, it was observed that the rate of DNA synthesis decreased, and that the cells flattened and spread out in comparison to unexposed culture. At 40 mWcm⁻², there were no effects seen on cell proliferation, but alteration in cell morphology included increased cell spreading and also the appearance of actin-containing blebs at localized sites on the membrane. It

is hypothesised that 835 MHz radiation at low power density may be affecting a signal transduction pathway involved in cell proliferation.

Freude, G, Ullsperger, P, Eggert, S, Ruppe, I, Effects of microwaves emitted by cellular phones on human slow brain potentials. *Bioelectromagnetics* 19(6):384-387, 1998.

The influence of electromagnetic fields (EMF) emitted by cellular phones on preparatory slow brain potentials (SP) was studied in two different experimental tasks: In the first, healthy male human subjects had to perform simple self-paced finger movements to elicit a Bereitschaftspotential; in the second, they performed a complex and cognitive demanding visual monitoring task (VMT). Both tasks were performed with and without EMF exposure in counterbalanced order. Whereas subjects' performance did not differ between the EMF exposure conditions, SP parameters were influenced by EMF in the VMT: EMF exposure effected a significant decrease of SPs at central and temporo-parieto-occipital brain regions, but not at the frontal one. In the simple finger movement task, EMF did not affect the Bereitschaftspotential.

Freude, G, Ullsperger, P, Eggert, S, Ruppe, I, Microwaves emitted by cellular telephones affect human slow brain potentials. *Eur J Appl Physiol* 81(1-2):18-27, 2000.

The influence of electromagnetic fields (EMF) emitted by cellular telephones on preparatory slow brain potentials (SP) was studied in two experiments, about 6 months apart. In the first experiment, a significant decrease of SP was found during exposure to EMF in a complex visual monitoring task (VMT). This effect was replicated in the second experiment. In addition to the VMT, EMF effects on SP were analysed in two further, less demanding tasks: in a simple finger movement task to elicit a Bereitschaftspotential (BP) and in a two-stimulus task to elicit a contingent negative variation (CNV). In comparison to the VMT, no significant main EMF effects were found in BP and CNV tasks. The results accounted for a selective EMF effect on particular aspects of human information processing, but did not indicate any influence on human performance, well-being and health.

Frey AH, Headaches from cellular telephones: are they real and what are the implications? *Environ Health Perspect* 106(3):101-103, 1998.

There have been numerous recent reports of headaches occurring in association with the use of hand-held cellular telephones. Are these reported headaches real? Are they due to emissions from telephones? There is reason to believe that the answer is "yes" to both questions. There are several lines of evidence to support this conclusion. First, headaches as a consequence of exposure to low intensity microwaves were reported in the literature 30 years ago. These were observed during the course of microwave hearing research before there were cellular telephones.

Second, the blood-brain barrier appears to be involved in headaches, and low intensity microwave energy exposure affects the barrier. Third, the dopamine-opiate systems of the brain appear to be involved in headaches, and low intensity electromagnetic energy exposure affects those systems. In all three lines of research, the microwave energy used was approximately the same—in frequencies, modulations, and incident energies—as those emitted by present day cellular telephones. Could the current reports of headaches be the canary in the coal mine, warning of biologically significant effects?

Fritze K, Wiessner C, Kuster N, Sommer C, Gass P, Hermann DM, Kiessling M, Hossmann KA, Effect of global system for mobile communication microwave exposure on the genomic response of the rat brain. *Neuroscience* 81(3):627-639, 1997.

The acute effect of global system for mobile communication (GSM) microwave exposure on the genomic response of the central nervous system was studied in rats by measuring changes in the messenger RNAs of hsp70, the transcription factor genes c-fos and c-jun and the glial structural gene GFAP using in situ hybridization histochemistry. Protein products of transcription factors, stress proteins and marker proteins of astroglial and microglial activation were assessed by immunocytochemistry. Cell proliferation was evaluated by bromodeoxyuridine incorporation. A special GSM radiofrequency test set, connected to a commercial cellular phone operating in the discontinuous transmission mode, was used to simulate GSM exposure. The study was conducted at time averaged and brain averaged specific absorption rates of 0.3 W/kg (GSM exposure), 1.5 W/kg (GSM exposure) and 7.5 W/kg (continuous wave exposure), respectively. Immediately after exposure, in situ hybridization revealed slight induction of hsp70 messenger RNA in the cerebellum and hippocampus after 7.5 W/kg exposure, but not at lower intensities. A slightly increased expression of c-fos messenger RNA was observed in the cerebellum, neocortex and piriform cortex of all groups subjected to immobilization, but no differences were found amongst different exposure conditions. C-jun and GFAP messenger RNAs did not increase in any of the experimental groups. 24 h after exposure, immunocytochemical analysis of FOS and JUN proteins (c-FOS, FOS B, c-JUN JUN B, JUN D), of HSP70 or of KROX-20 and -24 did not reveal any alterations. Seven days after exposure, neither increased cell proliferation nor altered expression of astroglial and microglial marker proteins were observed. In conclusion, acute high intensity microwave exposure of immobilized rats may induce some minor stress response but does not result in lasting adaptive or reactive changes of the brain.

Fritze K, Sommer C, Schmitz B, Mies G, Hossmann KA, Kiessling M, Wiessner C, Effect of global system for mobile communication (GSM) microwave exposure on blood-brain barrier permeability in rat. *Acta Neuropathol (Berl)* 94(5):465-470, 1997.

We investigated the effects of global system for mobile communication (GSM) microwave exposure on the permeability of the blood-brain barrier using a calibrated microwave exposure system in the 900 MHz band. Rats were restrained in a carousel of circularly arranged plastic tubes and sham-exposed or microwave irradiated for a duration of 4 h at specific brain absorption rates (SAR) ranging from 0.3 to 7.5 W/kg. The extravasation of proteins was assessed either at the end of exposure or 7 days later in three to five coronal brain slices by immunohistochemical staining of serum albumin. As a positive control two rats were subjected to cold injury. In the brains of freely moving control rats (n = 20) only one spot of extravasated serum albumin could be detected in one animal. In the sham-exposed control group (n = 20) three animals exhibited a total of 4 extravasations. In animals irradiated for 4 h at SAR of 0.3, 1.5 and 7.5 W/kg (n = 20 in each group) five out of the ten animals of each group killed at the end of the exposure showed 7, 6 and 14 extravasations, respectively. In the ten animals of each group killed 7 days after exposure, the total number of extravasations was 2, 0 and 1, respectively. The increase in serum albumin extravasations after microwave exposure reached significance only in the group exposed to the highest SAR of 7.5 W/kg but not at the lower intensities. Histological injury was not observed in any of the examined brains. Compared to other pathological conditions with increased blood-brain barrier permeability such as cold injury, the here observed serum albumin extravasations are very modest and, moreover, reversible. Microwave exposure in the frequency and intensity range of mobile telephony is unlikely to produce pathologically significant changes of the blood-brain barrier permeability.

Fry TL, Schlegel RE, Grant H, Impact of CDMA wireless phone power output and puncture rate on hearing aid interference levels. *Biomed Instrum Technol* 34(1):29-38, 2000

Interference between digital wireless phones and hearing aids occurs when the radiofrequency bursts from the phone transmission are demodulated by the hearing aid amplifier. The amplified interference signal is heard as a "buzz" or "static" by the hearing aid wearer. Most research and standards development activity has focused on worst-case scenarios with the phone operating at its maximum power. Since this power level is often not typical in urban and suburban settings, it is of value to determine the impact of lower power levels on the overall level of audible interference. Using a frequency analyzer, and several hearings aids and code division multiple access (CDMA) phones, the audio frequency spectrum of interference was recorded for each phone-aid combination and for a range of power levels producing from no interference to maximum interference. As phone power is increased, the interference signal becomes distinguishable from the ambient noise level and a linear response region is observed in which a specified increase in power output results in a proportional increase in the overall input referenced interference level (OIRIL). As power is increased beyond the linear region, the hearing aid enters a saturation region where an additional power increase results in a reduction or no increase in the OIRIL. The numeric differences in interference documented in this

study were used in conjunction with the results of a previous study by the authors to determine the impact of reduced power on speech intelligibility and annoyance. The amount of improvement for a given power reduction depends on the radiofrequency immunity of the hearing aid and is substantial for hearing aids with poor immunity. For high-immunity aids, the level of audible interference remains low even at high phone power levels.

Funch DP, Rothman KJ, Loughlin JE, Dreyer NA, Utility of telephone company records for epidemiologic studies of cellular telephones. *Epidemiology* 7(3):299-302, 1996.

We conducted a survey of over 5,000 telephone users who were customers of one large cellular telephone company covering four major geographical areas. Our primary goal was to assess the utility of ascertaining information on telephone use and type from telephone company records. We compared information from 3,949 respondents with corresponding data from company billing records. We found that 48% of the account holders were sole users, and 69% were the primary user, meaning that they accounted for at least 75% of the use. Respondent reports of amount of telephone use were highly correlated with data on the billing record ($r = 0.74$). Respondent reports of telephone type were similarly correlated with data from the manufacturer ($r = 0.92$). We also inquired about telephone holding patterns, since these have implications for exposure. Most users reported favoring one side of the head when using the telephone, but the side of the head used was not strongly associated with handedness.

Gadzicka E, Bortkiewicz A, Zmyslony M, Palczynski C, [Evaluation of selected functional circulation parameters of workers from various occupational groups exposed to electromagnetic fields of high frequency. III. 24-h monitoring of arterial blood pressure]. *Med Pr* 48(1):15-24, 1997. [Article in Polish]

The problem of blood pressure regulation in persons occupationally exposed to electromagnetic fields (EMF) has not as yet been elucidated, and most data come from studies carried out long time ago (1960-70) in the former Soviet Union. Our study was aimed at verifying the Soviet data by means of modern methods. Together with traditional methods, a 24-h monitoring of arterial blood pressure (ABP) using a Medilog ABP kit (Oxford) were employed. Measurements were taken automatically every 0.5 h during daily activities and every 1 h during the night rest (about 41 measurements/day). The mean systolic and diastolic blood pressure and heart rate were calculated over day (BPSD_{Over}, BPD_{Over}, HR_{Over}), during daily activities (HPDD, BPSD, HRD) and during the night rest (BPSN, BPDN, HRN). The subjective and objective examinations were carried out as well as resting ECG and a 24-h Holter were performed (the results have been published earlier). The study covered male workers of middlewave broadcast stations (71), radioservice (40) and radio line stations (42). The subjects

were aged 21-60 years and the duration of their work with devices generating high frequency EMF ranged between 1 and 42 years. The first group of workers was exposed to EFM at the frequency of 1 Mhz, the second at about 150 Mhz and the third group, not exposed, served as the control group. The study revealed that the mean arterial blood pressure and the day/night blood pressure variability indicator showed no significant differences between the groups, whereas the daily heart rate was significantly lower in the workers of middlewave broadcast stations in comparison with the controls despite similar type of work as far as physical effort and psychic burden are concerned, and similar non-occupational activities. The day/night heart rate variability indicator was significantly lower in the groups exposed. The decreased value of this indicator may suggest the occurrence of disorders in the neurovegetative regulation. In persons employed at radioservice stations a higher incidence of the increased arterial blood pressure, in comparison with the control group, was observed.

Galat VV, Mezhevikina LM, Zubin MN, Lepikhov KA, Khramov RN, Chailakhian LM, [Effect of millimeter waves on the early development of the mouse and sea urchin embryo]. *Biofizika* 44(1):137-140, 1999.
[Article in Russian]

The action of nonthermal electromagnetic radiation (EMR) of the millimeter range on the early development of murine and sea urchin embryos was investigated. An MRTA-01E-03 generator with a frequency of 54-78 GHz and radiation intensity of 0.06 mWt/cm² was used. The embryos were irradiated during 30 min at the stage of two blastomeres. The number of murine embryos that reached the blastocyst stage increased (up to 97.3% in comparison with 87.5% in control). The total time of cultivation up to the blastocyst stage was also shorter (72 h) than in control (96 h). The irradiation had effect on the development of sea urchin embryos only if embryos with a weakened viability were tested. The results indicate that millimeter electromagnetic radiation has a stimulating effect on the early development of embryos, increasing the resistance of embryos to unfavorable environmental conditions.

Gapeev AB, Iakushina VS, Chemeris NK, Fesenko EE [Modulated extremely high frequency electromagnetic radiation of low intensity activates or inhibits respiratory burst in neutrophils depending on modulation frequency]. *Biofizika* 42(5):1125-1134, 1997.
[Article in Russian]

The influence of low-intensity modulated electromagnetic radiation of extremely high frequencies (EHF EMR) on synergistic reaction of calcium ionophore A23187 and phorbol ester PMA in activation of the respiratory burst of the peritoneal neutrophils of mice line NMRI was investigated. The production of reactive oxygen species by the neutrophils was estimated by luminol-dependent chemiluminescence technique. The cells were irradiated in the far field zone of the channel radiator for 20 min in the presence of A23187 and then were activated by PMA after switching off the

irradiation. It was shown, that continuous EHF EMR (50 microW/cm²) inhibited quasi-resonantly the synergistic reaction. The maximum effect was about 25% at carrier frequency of 41.95 GHz. Modulated radiation with carrier frequency of 41.95 GHz and modulation frequency of 1 Hz activated the synergistic reaction, but at modulation frequencies of 0.1, 16 and 50 Hz inhibited one. At fixed modulation frequency of 1 Hz the nonlinear dependence of the effect on the carrier frequency was found. The synergistic reaction was activated in the frequency range of 41.95-42.05 GHz and was inhibited at the frequencies of 41.8-41.9 GHz. The effect was observed only at raised intracellular free calcium concentration and at calcium fluxes through plasma membrane. The obtained results prove the possibility of control over cell functioning by low-intensity modulated EHF EMR, presumably, manipulating by connected systems of enzyme reactions.

Gapeev AB, Safronova VG, Chemeris NK, Fesenko EE [Modification of the activity of murine peritoneal neutrophils upon exposure to millimeter waves at close and far distances from the emitter]. *Biofizika* 41(1): 205-219, 1996. [Article in Russian]

The comparison of horn, dielectric and channel antennae on their matching with various types of loads, including a biological object, is carried out. The channel antenna in contrast to dielectric and horn ones provides the uniform spatial distribution of specific absorbed rating in the frequency range used and wide-band matching with the object both in near field and far field zones of the radiator. It is shown, that low-intensity electromagnetic radiation of extremely high frequency in near field zone of the channel radiator modifies the activity of mouse peritoneal neutrophils on a quasi-resonance manner. The interaction of electromagnetic radiation with the biological object has been revealed in the narrow-band frequencies of 41.8-42.05 GHz and consists in inhibition of luminol-dependent chemiluminescence of neutrophils activated by opsonized zymosan. It is not found any frequency dependence of the electromagnetic radiation effects in the far field zone of the radiator. The results obtained suggest, that the quasi-resonance dependence of the biological effect on the frequency of the electromagnetic radiation in the near field zone is conditioned by structure and nature of the electromagnetic radiation in this zone.

Gapeev AB, Chemeris NK, [Modeling of the effect of modulated electromagnetic radiation on animal cells]. *Biofizika* 45(2):299-312, 2000.

Frequency-dependent modifications of intracellular free calcium concentration ([Ca²⁺]_i) in neutrophils exposures to modulated extremely high frequency electromagnetic radiation were analyzed using a special mathematical model for [Ca²⁺]_i oscillations. The model took into account the activation of Ca²⁺ influx into the cell by cytosolic Ca²⁺ and Ca(2+)-induced Ca²⁺ release from intracellular stores. The calcium channels of plasma membrane were chosen as a target for the influence of harmonic signal and additive noise in the model. The model simulation showed that in response to modulating signal, the rise in [Ca²⁺]_i, has frequency dependence and phase dependence in relation to the moment of chemical stimulation. The

phase-frequency dependence of the effect was observed at a certain sequence of delivery of chemical stimulus and modulating signal to the cell. At intensities of modulating signals exceeding the threshold, a rise in $[Ca^{2+}]_i$, reaching a level of more than 50% of the initial level, was observed at a frequency of about 1 Hz and in the phase range of 0.3-2.5 radians. The effect was found only at high intensities of chemical stimulus. The additive noise introduced into the system modified qualitatively and quantitatively the phase-frequency characteristics of the cell response to the modulating signal. An increase in noise intensity resulted in a displacement of the average frequency of the band of rise in $[Ca^{2+}]_i$, and then the emergence of a set of bands with a greater Q-factors. The analysis of dynamics of the nonlinear system in terms of the stability theory showed that, as the intensity of chemical stimulus increases, the system transits by means of a series of bifurcations from regular driving to chaotic, and then to oscillations, induced by a modulating harmonic signal. The boundary of the transition of oscillations from chaotic to induced ones corresponds to a specific "threshold" of the intensity of chemical stimulus for the significant rise in $[Ca^{2+}]_i$ in response to the modulating signal. The results of the model analysis are in good correspondence with the experimental data obtained earlier, namely, with the effects of modulated extremely high-frequency electromagnetic radiation on neutrophils, which were observed only in the presence of Ca^{2+} in extracellular medium and at high concentrations of calcium ionophore A23187. Thus, as the characteristic frequency of the quasi-periodic process of calcium signalling in the cell coincides with the frequency of external field, a narrow-band rise in $[Ca^{2+}]_i$ is observed, which can result in a modification of the functional activity of the cell.

Garaj-Vrhovac, V, Micronucleus assay and lymphocyte mitotic activity in risk assessment of occupational exposure to microwave radiation. *Chemosphere*;39(13):2301-2312, 1999.

The effects of radiofrequency electromagnetic radiation (RFR) on the cell kinetics and genome damages in peripheral blood lymphocytes were determined in lymphocytes of 12 subjects occupationally exposed to microwave radiation. Results showed an increase in frequency of micronuclei (MN) as well as disturbances in the distribution of cells over the first, second and third mitotic division in exposed subjects compared to controls. According to previous reports micronucleus assay can serve as a suitable indicator for the assessment of exposure to genotoxic agents (such as RFR) and the analysis of mitotic activity as an additional parameter for the efficient biomonitoring.

Geletyuk VI, Kazachenko VN, Chemeris NK, Fesenko EE Dual effects of microwaves on single Ca^{2+} -activated K^+ channels in cultured kidney cells *Vero*. *FEBS Lett* 359(1):85-88, 1995.

Using the patch voltage-clamp method, possible effects of millimetre microwaves (42.25 GHz) on single Ca^{2+} -activated K^+ channels in cultured kidney cells (*Vero*) were investigated. It was found that exposure to the field of non-thermal power

(about 100 microW/cm²) for 20-30 min greatly modifies both the Hill coefficient and an apparent affinity of the channels for Ca²⁺(i). The data suggest that the field alters both cooperativity and binding characteristics of the channel activation by internal Ca²⁺. The effects depend on initial sensitivity of the channels to Ca²⁺ and the Ca²⁺ concentration applied.

Gos, P, Eicher, B, Kohli, J, Heyer, WD, Extremely high frequency electromagnetic fields at low power density do not affect the division of exponential phase *Saccharomyces cerevisiae* cells. *Bioelectromagnetics* 18(2):142-155, 1997.

Exponentially growing cells of the yeast *Saccharomyces cerevisiae* were exposed to electromagnetic fields in the frequency range from 41.682 GHz to 41.710 GHz in 2 MHz increments at low power densities (0.5 microW/cm² and 50 microW/cm²) to observe possible nonthermal effects on the division of this microorganism. The electronic setup was carefully designed and tested to allow precise determination and stability of the electromagnetic field parameters as well as to minimize possible effects of external sources. Two identical test chambers were constructed in one exposure system to perform concurrent control and test experiments at every frequency step under well-controlled exposure conditions. Division of cells was assessed via time-lapse photography. Control experiments showed that the cells were dividing at submaximal rates, ensuring the possibility of observing either an increase or a decrease of the division rate. The data from several independent series of exposure experiments and from control experiments show no consistently significant differences (between) exposed and unexposed cells. This is in contrast to previous studies claiming nonthermal effects of electromagnetic fields in this frequency range on the division of *S. cerevisiae* cells. Possible reasons for this difference are discussed.

Goswami PC, Albee LD, Parsian AJ, Baty JD, Moros EG, Pickard WF, Roti Roti JL, Hunt CR, Proto-oncogene mRNA levels and activities of multiple transcription factors in C3H 10T 1/2 murine embryonic fibroblasts exposed to 835.62 and 847.74 MHz cellular phone communication frequency radiation. *Radiat Res* 151(3):300-309, 1999.

This study was designed to determine whether two differently modulated radiofrequencies of the type generally used in cellular phone communications could elicit a general stress response in a biological system. The two modulations and frequencies studied were a frequency-modulated continuous wave (FMCW) with a carrier frequency of 835.62 MHz and a code division multiple-access (CDMA) modulation centered on 847.74 MHz. Changes in proto-oncogene expression, determined by measuring Fos, Jun, and Myc mRNA levels as well as by the DNA-binding activity of the AP1, AP2 and NF-kappaB transcription factors, were used as indicators of a general stress response. The effect of radiofrequency exposure on proto-oncogene expression was assessed (1) in exponentially growing C3H 10T 1/2 mouse embryo fibroblasts during their transition to plateau phase and (2) during

transition of serum-deprived cells to the proliferation cycle after serum stimulation. Exposure of serum-deprived cells to 835.62 MHz FMCW or 847.74 MHz CDMA microwaves (at an average specific absorption rate, SAR, of 0.6 W/kg) did not significantly change the kinetics of proto-oncogene expression after serum stimulation. Similarly, these exposures did not affect either the Jun and Myc mRNA levels or the DNA-binding activity of AP1, AP2 and NF-kappaB in exponential cells during transit to plateau-phase growth. Therefore, these results suggest that the radiofrequency exposure is unlikely to elicit a general stress response in cells of this cell line under these conditions. However, statistically significant increases (approximately 2-fold, $P = 0.001$) in Fos mRNA levels were detected in exponential cells in transit to the plateau phase and in plateau-phase cells exposed to 835.62 MHz FMCW microwaves. For 847.74 MHz CDMA exposure, the increase was 1.4-fold ($P = 0.04$). This increase in Fos expression suggests that expression of specific genes could be affected by radiofrequency exposure.

Grayson JK, Radiation exposure, socioeconomic status, and brain tumor risk in the US Air Force: a nested case-control study. *Am J Epidemiol* 143(5):480-486, 1996.

A nested case-control study was used to investigate the relation between a range of electromagnetic field exposures and brain tumor risk in the US Air Force. Cumulative extremely low frequency and radiofrequency/microwave electromagnetic field potential exposures were estimated from a job-exposure matrix developed for this study. Ionizing radiation exposures were obtained from personal dosimetry records. Men who were exposed to nonionizing electromagnetic fields had a small excess risk for developing brain tumors, with the extremely low frequency and radiofrequency/microwave age-race-senior military rank-adjusted odds ratios being 1.28 (95% confidence interval (CI) 0.95-1.74) and 1.39 (95% CI 1.01-1.90), respectively. By contrast, men who were exposed to ionizing radiation had an age-race-senior military rank-adjusted odds ratio of 0.58 (95% CI 0.22-1.52). These results support a small association between extremely low frequency and radiofrequency/microwave electromagnetic field exposure and no association between ionizing radiation exposure and brain tumors in the US Air Force population. Military rank was consistently associated with brain tumor risk. Officers were more likely than enlisted men to develop brain tumors (age-race-adjusted odds ratio (OR) = 2.11, 95% CI 1.48-3.01), and senior officers were at increased risk compared with all other US Air Force members (age-race-adjusted OR = 3.30, 95% CI 1.99-5.45).

Grigor'ev IuG, Stepanov VS, [Forming of memory (imprinting) in chicks after prior low-level exposure to electromagnetic fields]. *Radiats Biol Radioecol* 38(2):223-231, 1998. [Article in Russian]

EMF of power density from 0.4 to 10 mW/cm² can influence forming the memory (imprinting). Showed the possibility to fix EMF modulated in embryonic brain

during the natal period and conservation of this information after birth.

Grigor'ev IuG, [Role of modulation in biological effects of electromagnetic radiation]. *Radiats Biol Radioecol* 36(5):659-670, 1996. [Article in Russian]

Data, describing a role of modulation of electromagnetic fields in development of biological effect, are considered. Outcomes of researches, indicating the dependence of a response of nervous and immune systems on a kind of modulation at low levels of effect, are represented. The necessity of the account of a role of modulation in an evaluation of electromagnetic danger is formulated.

Grigor'ev IuG, Luk'ianova SN, Makarov VP, Rynskov VV, [Total bioelectric activity of various structures of the brain in low-intensity microwave irradiation]. *Radiats Biol Radioecol* 35(1):57-65, 1995. [Article in Russian]

In experiments with thirty rabbits the influence of thirty-minute microwave irradiation (1.5 GHz, pulse intensity 0.3 mW/cm²; pulsed modes: 0.12 Hz, 16 ms or 1000 Hz, 0.4 ms; pack-pulsed mode: pulse frequency 1000 Hz, pack frequency 0.12 Hz) on the total bioelectrical activity of brain structures was studied. The reliable effect was detected only in hippocamp. The total bioelectrical activity of cortex, caudate nucleus, hypothalamus, amygdala and septum was not changed reliably in animal group studied. The reaction of hippocamp was displayed as amplification of theta-range in spectrum within of normal functioning.

Grigor'ev IuG, Luk'ianova SN, Makarov VP, Rynskov VV, Moiseeva NV, [Motor activity of rabbits in conditions of chronic low-intensity pulse microwave irradiation]. *Radiats Biol Radioecol* 35(1):29-35, 1995. [Article in Russian]

Motor activity of rabbits under daily thirty-minute irradiation (1.5 GHz, pulse duration 16 ms, pulse recurrence frequency 0.12 Hz, pulse intensity 0.3 mW/cm²) for one month was studied. From 14th day the reliable disadaptation changes such as an anxiety and alarm reaction were found. The importance of prolonged irradiation is noted.

Hanson Mild, K, Oftedal, G, Sandstrom, M, Wilen, J, Tynes, T, Haugsdal, B, Hauger E, Comparison of symptoms experienced by users of analogue and digital mobile phones: a Swedish-Norwegian epidemiological study. *Arbetslivsrapport* 1998:23.

Study of mobile phone users showed a statistically significant association between calling time/number of calls per day and the prevalence of warmth behind/around the ear, headaches, and fatigue.

Hardell, L, Reizenstein, J, Johansson, B, Gertzen, H, Mild, KH, Angiosarcoma of the scalp and use of a cordless (portable) telephone. *Epidemiology* 10(6):785-786, 1999.

This is a case study of a 57-year old woman who was diagnosed in January 1999 with an angiosarcoma of the scalp on the left side of her head (2 cm above her ear). Angiosarcoma is a rare type of soft tissue sarcoma (STS). Since 1988, the patient had, on a regular basis (1 hr per day), used a cordless (portable) phone, always using her left ear. Starting in 1994, she also used a GSM (digital) mobile phone on her left ear (a few minutes per week). The exposure to microwaves from a cordless phone in this patient is of interest because she had exposure on a daily basis starting 10 years before the first clinical signs of her angiosarcoma. Moreover, the tumor developed in the anatomical area with the highest exposure to microwaves on the same side of the head that she had used the phone. She also reported no exposure to other known risk factors for STS.

Hardell, L, Nasman, A, Pahlson, A, Hallquist, A, Hansson Mild, K, Use of cellular telephones and the risk for brain tumours: A case-control study. *Int J Oncol* 15(1):113-116, 1999.

The use of cellular telephones has increased dramatically during the 1990's in the world. In the 1980's the analogue NMT system was used whereas the digital GSM system was introduced in early 1990's and is now the preferred system. Case reports of brain tumours in users initiated this case-control study on brain tumours and use of cellular telephones. Also other exposures were assessed. All cases, both males and females, with histopathologically verified brain tumour living in Uppsala-Orebro region (1994-96) and Stockholm region (1995-96) aged 20-80 at the time of diagnosis and alive at start of the study were included, 233 in total. Two controls to each case were selected from the Swedish Population Register matched for sex, age and study region. Exposure was assessed by questionnaires supplemented over the phone. The analyses were based on answers from 209 (90%) cases and 425 (91%) controls. Use of cellular telephone gave odds ratio (OR) = 0.98 with 95% confidence interval (CI) = 0.69-1.41. For the digital GSM system OR = 0.97, CI = 0.61-1.56 and for the analogue NMT system OR = 0.94, CI = 0.62-1.44 were calculated. Dose-response analysis and using different tumour induction periods gave similar results. Non-significantly increased risk was found for tumour in the temporal or occipital lobe on the same side as a cellular phone had been used, right side OR = 2.45, CI = 0.78-7.76, left side OR = 2.40, CI = 0.52-10.9 Increased risk was found only for use of the NMT system. For GSM use the observation time is still too short for definite conclusions. An increased risk for brain tumour in the anatomical area close to the use of a cellular telephone should be especially studied in the future.

Hardell L, Nasman A, Pahlson A, Hallquist A, Case-Control Study on Radiology Work, Medical X-ray Investigations, and Use of Cellular Telephones as Risk Factors for Brain Tumors. *Medscape General Medicine* May 4, 2000.

Abstract

Context. Ionizing radiation is a well-established risk factor for brain tumors. During recent years, microwave exposure from the use of cellular telephones has been discussed as a potential risk factor.

Objective. To determine risk factors for brain tumors.

Design. A case-control study, with exposure assessed by questionnaires.

Participants. A total of 233 currently living men and women, aged 20 to 80 years, were included. The case patients had histopathologically verified brain tumors and lived in the Uppsala-Orebro region (1994-1996) or the Stockholm region (1995-1996). Two matched controls to each case were selected from the Swedish

Population Register.

Main Outcome Measures. Ionizing radiation and use of cellular telephones as risk factors for brain tumors.

Results. A total of 209 cases (90%) and 425 controls (91%) answered the questionnaire. Work as a physician yielded an odds ratio (OR) of 6.00, with a 95% confidence interval (CI) of 0.62 to 57.7. All three case patients had worked with fluoroscopy. Radiotherapy of the head and neck region yielded an OR of 3.61 (95% CI, 0.65-19.9). Medical diagnostic x-ray examination of the same area yielded an OR of 2.10 (95% CI, 1.25-3.53), with a tumor induction period of 5 years or more. Chemical industry work yielded an OR of 4.10 (95% CI, 1.25-13.4), and laboratory work yielded an OR of 3.21 (95% CI, 1.16-8.85). Ipsilateral use of cellular telephones increased the risk for tumors in the temporal, temporoparietal, and occipital lobes (OR, 2.42; 95% CI, 0.97-6.05), ie, the anatomic areas with highest exposure to microwaves from a mobile telephone. The result was further strengthened (OR, 2.62; 95% CI, 1.02-6.71) in a multivariate analysis that included laboratory work and medical diagnostic x-ray investigations of the head and neck.

Conclusion. Exposure to ionizing radiation, work in laboratories, and work in the chemical industry increased the risk of brain tumors. Use of a cellular telephone was associated with an increased risk in the anatomic area with highest exposure.

Harvey C, French PW, Effects on protein kinase C and gene expression in a human mast cell line, HMC-1, following microwave exposure. *Cell Biol Int* 23(11):739-748, 2000.

We used a resonant cavity which delivered a continuous wave exposure at 864.3 MHz at an average specific absorption rate (SAR) of 7 W/kg to determine non-thermal biological effects of microwave exposure. A human mast cell line, HMC-1, was used as the biological target. Cells were given three exposures each of 20-min duration daily for 7 days. The temperature of the cell culture medium during the exposure fell to 26.5 degrees C. Effects were seen on localization of protein kinase C, and expression of three genes of 588 screened. The affected genes included the proto-oncogene c-kit, the transcription factor Nucleoside diphosphate kinase B and the apoptosis-associated gene DAD-1. Stress response genes were variably upregulated. No significant effect on morphology or on F-actin distribution was detected. We conclude that low-power microwave exposure may act on HMC-1 cells

by altering gene expression via a mechanism involving activation of protein kinase C, and at temperatures well below those known to induce a heat shock response.

Hayes DL, Wang PJ, Reynolds DW, Estes M 3rd, Griffith JL, Steffens RA, Carlo GL, Findlay GK, Johnson CM, Interference with cardiac pacemakers by cellular telephones. *N Engl J Med* 336(21):1473-1479, 1997.

BACKGROUND: A growing body of evidence suggests that electromagnetic interference may occur between cardiac pacemakers and wireless hand-held (cellular) telephones, posing a potential public health problem. Electromagnetic interference may occur when the pacemaker is exposed to an electromagnetic field generated by the cellular telephone. **METHODS:** In this multicenter, prospective, crossover study, we tested 980 patients with cardiac pacemakers with five types of telephones (one analogue and four digital) to assess the potential for interference. Telephones were tested in a test mode and were programmed to transmit at the maximal power, simulating the worst-case scenario; in addition, one telephone was tested during actual transmission to simulate actual use. Patients were electrocardiographically monitored while the telephones were tested at the ipsilateral ear and in a series of maneuvers directly over the pacemaker. Interference was classified according to the type and clinical significance of the effect. **RESULTS:** The incidence of any type of interference was 20 percent in the 5533 tests, and the incidence of symptoms was 7.2 percent. The incidence of clinically significant interference was 6.6 percent. There was no clinically significant interference when the telephone was placed in the normal position over the ear. Interference that was definitely clinically significant occurred in only 1.7 percent of tests, and only when the telephone was held over the pacemaker. Interference was more frequent with dual-chamber pacemakers (25.3 percent) than with single-chamber pacemakers (6.8 percent, $P < 0.001$) and more frequent with pacemakers without feed-through filters (28.9 to 55.8 percent) than with those with such filters (0.4 to 0.8 percent, $P = 0.01$). **CONCLUSIONS:** Cellular telephones can interfere with the function of implanted cardiac pacemakers. However, when telephones are placed over the ear, the normal position, this interference does not pose a health risk.

Hietanen M, Kovala T, Hamalainen AM, Human brain activity during exposure to radiofrequency fields emitted by cellular phones. *Scand J Work Environ Health* 26(2):87-92, 2000.

OBJECTIVES: The aim of this study was to explore the possible influence of radiofrequency (RF) radiation exposure on human brain function. **METHODS:** The electroencephalographic (EEG) activity of 19 volunteers was quantitatively analyzed. Ten of the subjects were men (28-48 years of age) and 9 were women (32-57 years of age). The sources of exposure were 5 different cellular phones (analogue and digital models) operating at a frequency of 900 MHz or 1800 MHz. The EEG activity

was recorded in an awake, closed-eyes situation. Six 30-minute experiments, including 1 sham exposure, were made for each subject. The duration of a real exposure phase was 20 minutes. RESULTS: Exposure to one of the phones caused a statistically significant change in the absolute power at the delta band of the EEG recording. However, no difference was seen in the relative power of the same band, and no changes occurred during exposure to other phones at any frequency bands. CONCLUSIONS: The findings of this study suggest that exposure to radiofrequency fields emitted by cellular phones has no abnormal effects on human EEG activity. The observed difference in 1 parameter was probably caused by statistical chance.

Higashikubo R, Culbreth VO, Spitz DR, LaRegina MC, Pickard WF, Straube WL, Moros EG, Roti JL, Radiofrequency electromagnetic fields have no effect on the in vivo proliferation of the 9L brain tumor. *Radiat Res* 152(6):665-671, 1999.

The intracranial 9L tumor model was used to determine if exposure to a radiofrequency (RF) electromagnetic field similar to those used in cellular telephone has any effects on the growth of a central nervous system tumor. Fischer 344 rats implanted with different numbers of 9L gliosarcoma cells were exposed to 835.62 MHz frequency-modulated continuous wave (FMCW) or 847.74 MHz code division multiple access (CDMA) RF field with nominal slot-average specific absorption rates in the brain of 0.75 +/- 0.25 W/kg. The animals were exposed to the RF field for 4 h a day, 5 days a week starting 4 weeks prior to and up to 150 days after the implantation of tumor cells. Among sham-exposed animals injected with 2 to 10 viable cells (group 1), the median survival was 70 days, with 27% of the animals surviving at 150 days. The median survival length and final survival fraction for animals injected with 11 to 36 viable cells (group 2) were 52 days and 14%, respectively, while the values for those injected with 37 to 100 cells (group 3) were 45 days and 0%. The animals exposed to CDMA or FMCW had similar survival parameters, and the statistical comparison of the survival curves for each of the groups 1, 2 and 3 showed no significant differences compared to sham-exposed controls.

Hladky, A, Musil, J, Roth, Z, Urban, P, Blazkova, V, Acute effects of using a mobile phone on CNS functions. *Cent Eur J Public Health* 7(4):165-167. 1999.

Twenty volunteers participated in two experiments exploring the acute effects of using the mobile phone Motorola GSM 8700 on the functions of the CNS. When speaking (5 minutes reading a text from daily newspapers) the electromagnetic fields from the mobile apparatus did not affect the visual evoked potentials. Also a 6-min exposure did not reveal any effect of electromagnetic fields on the results in two tests (memory and attention) performed while speaking into the mobile. On the other hand the phone call itself strongly influenced the performance in a secondary task applying a test of switching attention which is a good model for driving a car. The response and decision speed were significantly worse. This is a proof that even a slight psychological stress involved in calling while driving can be a great risk.

Hocking, B, Preliminary report: symptoms associated with mobile phone use. *Occup Med (Lond)*;48(6):357-360, 1998.

Mobile phone use is ubiquitous, although the alleged health effects of low level radio-frequency radiation (RFR) used in transmission are contentious. Following isolated reports of headache-like symptoms arising in some users, a survey has been conducted to characterize the symptoms sometimes associated with mobile phone usage. A notice of interest in cases was placed in a major medical journal and this was publicized by the media. Respondents were interviewed by telephone using a structured questionnaire. Forty respondents from diverse occupations described unpleasant sensations such as a burning feeling or a dull ache mainly occurring in the temporal, occipital or auricular areas. The symptoms often began minutes after beginning a call, but could come on later during the day. The symptoms usually ceased within an hour after the call, but could last until evening. Symptoms did not occur when using an ordinary handset, and were different from ordinary headaches. There were several reports suggestive of intra-cranial effects. Three respondents reported local symptoms associated with wearing their mobile phone on their belts. There was one cluster of cases in a workplace. Seventy-five per cent of cases were associated with digital mobile phones. Most of the respondents obtained relief by altering their patterns of telephone usage or type of phone. Cranial and other diverse symptoms may arise associated with mobile phone usage. Physicians and users alike should be alert to this. Further work is needed to determine the range of effects, their mechanism and the possible implications for safety limits of RFR.

Hocking B, Gordon IR, Grain HL, Hatfield GE, Cancer incidence and mortality and proximity to TV towers. *Med J Aust* 165(11-12):601-605, 1996. (Published erratum appears in *Med J Aust* 166(2):80, 1997.)

OBJECTIVE: To determine whether there is an increased cancer incidence and mortality in populations exposed to radiofrequency radiations from TV towers.
DESIGN: An ecological study comparing cancer incidence and mortality, 1972-1990, in nine municipalities, three of which surround the TV towers and six of which are further away from the towers. (TV radiofrequency radiation decreases with the square of the distance from the source.) Cancer incidence and mortality data were obtained from the then Commonwealth Department of Human Services and Health. Data on frequency, power, and period of broadcasting for the three TV towers were obtained from the Commonwealth Department of Communications and the Arts. The calculated power density of the radiofrequency radiation in the exposed area ranged from 8.0 microW/cm² near the towers to 0.2 microW/cm² at a radius of 4km and 0.02 microW/cm² at 12 km. **SETTING:** Northern Sydney, where three TV towers have been broadcasting since 1956. **OUTCOME MEASURES:** Rate ratios for leukaemia and brain tumour incidence and mortality, comparing the inner with the outer areas. **RESULTS:** For all ages, the rate ratio for total leukaemia incidence was 1.24 (95% confidence interval [CI], 1.09-1.40). Among children, the rate ratio for leukaemia incidence was 1.58 (95% CI, 1.07-2.34) and for mortality it was 2.32 (95% CI, 1.35-4.01). The rate ratio for childhood lymphatic leukaemia (the most common type) was 1.55 (95% CI, 1.00-2.41) for incidence and 2.74 (95% CI, 1.42-5.27) for mortality.

Brain cancer incidence and mortality were not increased. CONCLUSION: We found an association between increased childhood leukaemia incidence and mortality and proximity to TV towers.

Hocking B, Gordon I, Decreased survival for childhood leukaemia in proximity to TV towers. Poster presented at the *Annual Scientific Meeting of the Royal Australasian College of Physicians* in Adelaide, SA, 2-5 May 2000

Objective: In a previous study we reported an increased risk of childhood leukaemia in municipalities proximate to TV towers in north Sydney compared with more distant ones (Hocking B Gordon I Hatfield G Grain H. Cancer incidence and proximity to TV towers *Med J Aust* 1996; 165: 601-605). The rate ratio for incidence, comparing the inner ring of municipalities to the outer ring, was 1.55 (95% confidence interval 1.00 – 2.41) and for mortality the rate ratio was 2.74 (95% confidence interval 1.42 – 5.27). The objective of the current study was to analyse the survival experience of the cases in detail, to determine whether there are differences between the two populations.

Design and Outcome Measures: Survival data on cases diagnosed from 1972-93 were analysed. Data on all cases who survived for less than one month were verified by the NSW cancer registry and one case diagnosed at autopsy excluded. Data were described by Kaplan-Meier curves. The log-rank and Wilcoxon tests were used to compare the two groups. Cox's proportional hazards model was used to adjust for confounders.

Results: There were 123 diagnosed cases of acute lymphatic leukaemia (ICD-9 204.0) of which 29 (16 deaths) were in the inner ring of municipalities and 94 (34 deaths) were in the outer ring. We found a significant difference in survival (log rank: $P = 0.03$; Wilcoxon: $P = 0.05$). The 5 year survival in the inner ring of municipalities was 55% and in the outer ring 71% (inner 23% worse); at 10 years the survival was 33% and 62% respectively (inner 47% worse). After adjustment for the potential confounders using Cox's model, the mortality rate ratio comparing the inner ring with the outer ring was found to be 2.1 (95% confidence interval: 1.1 – 4.0). We were not able to control for cytogenetic abnormalities.

Conclusion: There was an association between proximity to the TV towers and decreased survival, among cases of childhood leukaemia.

Hofgartner F, Muller T, Sigel H, [Could C- and D-network mobile phones endanger patients with pacemakers]? *Dtsch Med Wochenschr* 121(20):646-652, 1996. [Article in German]

OBJECTIVE: To investigate prospectively the extent of potentially harmful interference of cardiac pacemakers by mobile phones in the C (analog) and D (digital) networks in use in Germany. PATIENTS AND METHODS: 104 patients (54 men, 50 women; mean age 75.8 [40-100] years) with 58 different implanted

pacemaker models (43 one-chamber and 15 two-chamber systems) underwent uniform tests at various functional states with three different telephones (D1 portable 8 Watt, D1 Handy model 2 Watt, C Handy model 0.5 Watt). The distances between telephone aerial and pacemaker, as well as reception sensitivity and polarity of the pacemaker were varied. All tests were done during continuous ECG monitoring. RESULTS: 28 different pacemaker types (48.3%) in 43 patients (41.3%) showed interference in the form of pacemaker inhibition and switching to interference frequencies as well as triggering of pacemaker-mediated tachycardias in the DDD mode, as well as in the temperature-regulated frequency-adaptive function. D portables influenced pacemaker function more often and at greater distance than the D Handy model, which was little different from the c network hand phone. Reduction in pacemaker sensitivity as well as switching to bipolar reception only partly eliminated the interference. CONCLUSIONS: Patients with implanted pacemakers should if possible not use mobile phones in the C and D networks. Individual testing with suitable programming of pacemaker sensitivity and polarity can reduce the risk of interference.

Imaida, K, Taki, M, Watanabe, S, Kamimura, Y, Ito, T, Yamaguchi, T, Ito, N, Shirai, T, The 1.5 GHz electromagnetic near-field used for cellular phones does not promote rat liver carcinogenesis in a medium-term liver bioassay. *Jpn J Cancer Res* 89(10):995-1002, 1998.

We have recently established that local exposure to a 929.2 MHz electromagnetic near-field, used for cellular phones, does not promote rat liver carcinogenesis in a medium-term bioassay system. In the present study, a 1.439 GHz electromagnetic near-field (EMF), another microwave band employed for cellular phones in Japan, was similarly investigated. Time division multiple access (TDMA) signals for the Personal Digital Cellular (PDC) Japanese cellular telephone standard system were directed to rats through a quarter-wavelength monopole antenna. Numerical dosimetry showed that the peak SARs within the liver were 1.91-0.937 W/kg, while the whole-body average specific absorption rates (SARs) were 0.680-0.453 W/kg, when the time-averaged antenna radiation power was 0.33 W. Exposure was for 90 min a day, 5 days a week, over 6 weeks, to male F344 rats given a single dose of diethylnitrosamine (200 mg/kg, i.p.) 2 weeks previously. At week 3, all rats were subjected to a two-thirds partial hepatectomy. At week 8, the experiment was terminated and the animals were killed. Carcinogenic potential was scored by comparing the numbers and areas of the induced glutathione S-transferase placental form (GST-P)-positive foci in the livers of exposed (48) and sham-exposed rats (48). Despite increased serum levels of corticosterone, adrenocorticotrophic hormone (ACTH) and melatonin, the numbers and the areas of GST-P-positive foci were not significantly altered by the exposure. These findings clearly indicated that local body exposure to a 1.439 GHz EMF, as in the case of a 929.2 MHz field, has no promoting effect on rat liver carcinogenesis in the present model.

Irnich W, Tobisch R, [Effect of mobile phone on life-saving and life-sustaining systems]. [Article in German] *Biomed Tech (Berl)* 43(6):164-173, 1998.

Since the beginning of the nineties there have been warnings not to use mobile phones in the vicinity of medical devices. Functional failures of dialysis machines, respirators and defibrillators prompted the banning of their use in many hospitals in Scandinavia, and then in other countries. Since we believe that a general ban in hospitals is problematic, we decided to investigate the influence of mobile telephone on life-saving and/or life-support systems, with the aim of establishing rules for its use in hospitals. We investigated available phones of varying power of the C-, D- and E-net, as also of a cordless phone meeting the DECT standard. The aim was to identify the devices susceptible to interference and determine the minimum distances at which interference occurred. A total of 224 devices classified into 23 types of devices were examined. Nine different sets of transmission conditions were applied, giving a total of 2016 tests. Our results permit the conclusion that the ban on mobile phones in hospitals is based not on actual events, but on theoretical considerations in the absence of any practical information on the actual susceptibility of devices and their reaction to the electromagnetic fields involved. The fact that hazardous situations are very rare is due firstly to the need for the simultaneous occurrence of four coincidences, and the fail-safe feature of medical devices. We would therefore recommend that all life-saving and life-support systems that can also be used outside the hospital should be made mobile phone-proof. When apnoea monitors and respirators are protected from such interference, hazardous situations could be avoided by establishing the rule: "No portables, and mobile phones only at a distance of at least 1 metre from medical devices". With regard to emergency telephones, the minimum distance to medical devices should be at least 1.5 metres.

Irnich W, Batz L, Muller R, Tobisch R, electromagnetic interference of pacemakers by mobile phones. *Pacing Clin Electrophysiol* 19(10):1431-1446, 1996.

The topic of interference of pacemakers by mobile phones has evoked a surprisingly strong interest, not only in pacemaker patients, but also in the public opinion. The latter is the more surprising, as in the past, the problem of interference has scarcely found the attention that it deserves in the interest of the patient. It was the intention of our investigation to test as many pacemaker models as possible to determine whether incompatibility with mobile phones of different modes may exist, using an in vitro measuring setup. We had access to 231 different models of 20 manufacturers. During the measurements, a pulse generator together with a suitable lead was situated in a 0.9 g/L saline solution, and the antenna of a mobile phone was positioned as close as possible. If the pulse generator was disturbed, the antenna was elevated until interference ceased. The gap in which interference occurred was defined as "maximum interference distance." All three nets existing in Germany,

the C-net (450 MHz, analogue), the D-net (900 MHz, digital pulsed), and the E-net (1,800 MHz, digital pulsed) were tested in succession. Out of 231 pulse generator models, 103 pieces corresponding to 44.6% were influenced either by C- or D-net, if both results were totaled. However, this view is misleading as no patient will use C- and D-net phones simultaneously. Separated into C- or D-net interference, the result is 30.7% for C or 34.2% for D, respectively, of all models tested. The susceptible models represent 18.6% or 27% of today's living patients, respectively. All models were resistant to the E-net. With respect to D-net phones, all pacemakers of six manufacturers proved to be unaffected. Eleven other manufacturers possessed affected and unaffected models as well. A C-net phone only prolonged up to five pacemaker periods within 10 seconds during dialing without substantial impairment to the patient. Bipolar pacemakers are as susceptible as unipolar ones. The following advice for patients and physicians can be derived from our investigations: though 27% of all patients may have problems with D-net phones (not C- or E-net), the application should generally not be questioned. On the contrary, patients with susceptible devices should be advised that a distance of 20 cm is sufficient to guarantee integrity of the pacemaker with respect to hand held phones. Portables, on the other hand, should have a distance of about 0.5 m. Pacemaker patients really suffering from mobile phones are very rare unless the phone is just positioned in the pocket over the pulse generator. The contralateral pocket or the belt position guarantees, in 99% of all patients, undisturbed operation of the pacemaker. A risk analysis reveals that the portion of patients really suffering from mobile phones is about 1 out of 100,000. Nevertheless, it would be desirable in the future if implanting physicians would use only pacemakers with immunity against mobile phones as guaranteed by the manufacturers.

Ivaschuk OI, Jones RA, Ishida-Jones T, Haggren W, Adey WR, Phillips JL, Exposure of nerve growth factor-treated PC12 rat pheochromocytoma cells to a modulated radiofrequency field at 836.55 MHz: effects on c-jun and c-fos expression. *Bioelectromagnetics* 18(3):223-229, 1997.

Rat PC12 pheochromocytoma cells have been treated with nerve growth factor And then exposed to athermal levels of a packet-modulated radiofrequency field At 836.55 MHz. This signal was produced by a prototype time-domain multiple-access (TDMA) transmitter that conforms to the North American digital cellular telephone standard. Three slot average power densities were used: 0.09, 0.9, and 9 mW/cm². Exposures were for 20, 40, and 60 min and included an intermittent exposure regimen (20 min on/20 min off), resulting in total incubation times of 20, 60, and 100 min, respectively. Concurrent controls were sham exposed. After extracting total cellular RNA, Northern blot analysis was used to assess the expression of the immediate early genes, c-fos and c-jun, in all cell populations. No change in c-fos transcript levels were detected after 20 min exposure at each field intensity (20 min was the only time period at which c-fos message could be detected

consistently). Transcript levels for c-jun were altered only after 20 min exposure to 9 mW/cm² (average 38% decrease).

Jauchem, JR, Exposure to extremely-low-frequency electromagnetic fields and radiofrequency radiation: cardiovascular effects in humans. *Int Arch Occup Environ Health* 70(1):9-21, 1997.

Cardiovascular changes in humans exposed to nonionizing radiation [including extremely-low-frequency electromagnetic fields (ELF EMFs) and radiofrequency radiation (RFR)] are reviewed. Both acute and long-term effects have been investigated. In general, if heating does not occur during exposure, current flow appears to be necessary for major cardiovascular effects to ensue, such as those due to electric shock. Whereas most studies have revealed no acute effect of static or time-varying ELF EMFs on the blood pressure, heart rate, or electrocardiogram waveform, others have reported subtle effects on the heart rate. The possible health consequences of these results are unknown. Regarding long-term effects of ELF EMFs, reports from the former Soviet Union in the early 1960s indicated arrhythmias and tachycardia in high-voltage-switchyard workers. Subsequent studies in Western countries, however, did not confirm these findings. These studies are limited by uncertainties regarding exposure durations and appropriate control groups. Investigations of acute cardiovascular changes in humans purposely exposed to RFR have been limited to studies of magnetic resonance imaging (which, in addition to RFR, involves static and time-varying magnetic fields). It has been concluded that such exposures, as presently performed, are not likely to cause adverse cardiovascular effects. Reports of hypertension in workers potentially exposed to high levels of RFR during accidents are considered to be incidental (due to anxiety and posttraumatic stress). Soviet investigators have also indicated that long-term RFR exposure may result in hypotension and bradycardia or tachycardia. Other researchers, however, have been incapable of replicating these results, and some scientists have attributed the effects to chance variations and mishandling of data. In summary, studies have not yielded any obvious cardiovascular-related hazards of acute or long-term exposures to ELF EMFs or RFR at levels below current exposure standards.

Jauchem JR, Seaman RL, Lehnert HM, Mathur SP, Ryan KL, Frei MR, Hurt WD, Ultra-wideband electromagnetic pulses: lack of effects on heart rate and blood pressure during two-minute exposures of rats. *Bioelectromagnetics* 19(5):330-333, 1998.

Exposure to fast-rise-time ultra-wideband (UWB) electromagnetic pulses has been postulated to result in effects on biological tissue (including the cardiovascular system). In the current study, 10 anesthetized Sprague-Dawley rats were exposed to pulses produced by a Sandia UWB pulse generator (average values of exposures over three different pulse repetition rates: rise time, 174-218 ps; peak E field, 87-104 kV/m; pulse duration, 0.97-0.99 ns). Exposures to 50, 500 and 1000 pulses/s resulted in no significant changes in heart rate or mean arterial blood pressure

measured every 30 s during 2 min of exposure and for 2 min after the exposure. The results suggest that acute UWB whole-body exposure under these conditions does not have an immediate detrimental effect on these cardiovascular system variables in anesthetized rats.

Jauchem JR, Frei MR, Ryan KL, Merritt JH, Murphy MR, Lack of effects on heart rate and blood pressure in ketamine-anesthetized rats briefly exposed to ultra-wideband electromagnetic pulses. *IEEE Trans Biomed Eng* 46(1):117-120, 1999.

Fourteen Sprague-Dawley rats were exposed to pulses produced by a Bournlea ultra-wideband (UWB) pulse generator (rise time, 318-337 ps; maximum E field, 19-21 kV/m). Exposures at a repetition frequency of 1 kHz for 0.5 s or to repetitive pulse trains (2-s exposure periods alternating with 2 s of no exposure, for a total of 2 min) resulted in no significant changes in heart rate or mean arterial blood pressure. These results suggest that acute whole-body exposure to UWB pulses does not have a detrimental effect on the cardiovascular system.

Jauchem JR, Ryan KL, Freidagger MR, Cardiovascular and thermal effects of microwave irradiation at 1 and/or 10 GHz in anesthetized rats. *Bioelectromagnetics* 21(3):159-66, 2000.

Relatively large thermal gradients may exist during exposure of an animal to microwaves (MWs), particularly at high frequencies. Differences in thermal gradients within the body may lead to noticeable differences in the magnitude of cardiovascular changes resulting from MW exposure. This study compares the thermal distribution and cardiovascular effects of exposure to a single MW frequency with effects of simultaneous exposure to two frequencies. Ketamine-anesthetized male Sprague-Dawley rats (n = 58) were exposed individually to one of three conditions: 1-GHz, 10-GHz, or combined 1- and 10-GHz MWs at an equivalent whole-body specific absorption rate of 12 W/kg. The continuous-wave irradiation was conducted under far-field conditions with animals in E orientation (left lateral exposure, long axis parallel to the electric field) or in H orientation (left lateral exposure, long axis perpendicular to the electric field). Irradiation was started when colonic temperature was 37.5 degrees C and was continued until lethal temperatures were attained. Colonic, tympanic, left and right subcutaneous, and tail temperatures, and arterial blood pressure, heart rate, and respiratory rate were continuously recorded. In both E and H orientations, survival time (i.e., time from colonic temperature of 37.5 degrees C until death) was lowest in animals exposed at 1-GHz, intermediate in those exposed at 1- and 10-GHz combined, and greatest in the 10-GHz group (most differences statistically significant). At all sites (with the exception of right subcutaneous), temperature values in the 1- and 10-GHz combined group were between those of the single-frequency exposure groups in both E and H orientations. During irradiation, arterial blood pressure initially increased and then decreased until death. Heart rate increased throughout the exposure period. The general, overall patterns of these changes were similar in all groups. The results indicate that no

unusual physiological responses occur during multi-frequency MW exposure, when compared with results of single-frequency exposure.

Jimenez A, Hernandez Madrid A, Pascual J, Gonzalez Rebollo JM, Fernandez E, Sanchez A, Ortega J, Lozano F, Munoz R, Moro C, [Electromagnetic interference between automatic defibrillators and digital and analog cellular telephones]. *Rev Esp Cardiol* 51(5):375-382, 1998. [Article in Spanish]

BACKGROUND AND OBJECTIVES: Functional pacemaker interference by mobile telephones has been described with analogical systems and with possible greater influence, digital systems, including inhibition and inadequate pacing. The influence of both system has not been extensively studied in patients with implantable cardioverter defibrillators (ICD). **PATIENTS AND METHODS:** We studied the influence of mobile phones, both digital and analogic network, on the performance of several models of defibrillators, in a standardised test set up designed to provide high sensitivity. The purpose of our study was to establish whether there are any influences on ICD functions, both in vivo and in vitro models. Several mobile phones, with different transmission powers, were moved towards the defibrillator and the electrode, under continuous documentation of defibrillator sensing and interrogation afterwards. The experimental model was performed with the aid of an arrhythmia simulator (Intersim) and demo-defibrillators. The tests were repeated both in and out of a solution of saline water with an impedance within normal human limits. **RESULTS:** Partial loss of telemetry was found in 14 patients, 8 with analogical phones and 6 with digital phones. Fourteen patients showed alterations only on the surface electrocardiogram channel and five on the intracavitary channel. The same results were reproduced in the in vitro model. However, the in vitro test allowed us to simulate multiple ventricular arrhythmias, and demonstrate the normal sensing and functioning of the defibrillator during a "spontaneous" arrhythmia. After testing, we demonstrate that no real oversensing/undersensing was documented in any device. There was no evidence of ICD reprogramming or pacing inhibition. In particular, no inadequate therapies were delivered. **CONCLUSIONS:** a) in our series, we have not demonstrated clinically significant electromagnetic interferences with mobile phones of digital or analogical networks: b) the in vitro model allowed us to conclude that even if a spontaneous arrhythmia appears, the function of the defibrillator is not altered; c) the use of mobile phones seems to be safe for defibrillator patients, and d) however, some basic rules, such as to maintain the phone at least 15 cm away from the defibrillator, are advised.

Johnson EH, Chima SC, Muirhead DE, A cerebral primitive neuroectodermal tumor in a squirrel monkey (*Saimiri sciureus*). *J Med Primatol* 28(2):91-96, 1999.

An adult squirrel monkey with a history of long-term exposure to microwave

radiation was found at necropsy to have a malignant tumor of the right cerebral cortex. Gross examination revealed a mass with expanding borders in the right frontoparietal cortex with compression of the adjacent lateral ventricle. Microscopy revealed a tumor composed of sheets of moderate-sized cells, resembling an oligodendroglioma, with clear cytoplasm and central nuclei interrupted by delicate vasculature. Malignant features were present in the form of marked nuclear pleomorphism, frequent mitotic figures, and focal necrosis. A neuronal cell origin for this tumor was supported by immunohistochemical analysis, which revealed immunopositivity for neurofilament proteins and neuron-specific enolase. Staining for vimentin and glial fibrillary acid protein was negative, except in reactive astrocytes at the tumor margins and adjacent to intra-tumoral blood vessels. Antibody activity against Ki-67 antigen, a marker of rapidly proliferating tumor cells, and p53 oncoprotein was strongly positive, indicative of the aggressive and malignant nature of this tumor. The tumor was diagnosed as a cerebral primitive neuroectodermal tumor.

Johnson Liakouris AG, Radiofrequency (RF) sickness in the Lilienfeld Study: an effect of modulated microwaves? *Arch Environ Health* 53(3):236-238, 1998.

There is a controversy among professionals regarding whether radiofrequency radiation sickness syndrome is a medical entity. In this study, this controversy was evaluated with a methodology adapted from case studies. The author reviewed U.S. literature, which revealed that research results are sufficiently consistent to warrant further inquiry. A review of statistically significant health effects noted in the Lilienfeld Study provided evidence that the disregarded health conditions match the cluster attributed to the radiofrequency sickness syndrome, thus establishing a possible correlation between health effects and chronic exposure to low-intensity, modulated microwave radiation. The author discusses these health effects relative to (a) exposure parameters recorded at the U.S. Embassy in Moscow and (b) the Soviet 10-microwatt safety standard for the public. Given the evidence, new research-with current knowledge and technology-is proposed.

Kellenyi, L, Thuroczy, G, Faludy, B, Lenard, L, Effects of mobile GSM radiotelephone exposure on the auditory brainstem response (ABR). *Neurobiology* 7:79-81, 1999.

A 15-min exposure to GSM phone radiation caused an increase in auditory brainstem response in the exposed side of human subjects. Subjects also showed a hearing deficiency in the high frequency range (20 dB hearing deficiency from 2 KHz to 10 KHz).

Kemerov, S, Marinkev, M, Getova, D, Effects of low-intensity electromagnetic fields on behavioral activity of rats. *Folia Med (Plovdiv)* 41(3):75-80, 1999.

The present study aimed at comparative assessment of the changes in behavioral activity of rats after exposing them to low intensity electromagnetic fields (EMFs) in the meter, decimeter and centimeter ranges. The experiments were carried out on 24 Wistar rats divided into 4 groups (1 control and 3 experimental), treated with different EMFs. The rats were irradiated on the head area at power density of 10 mW/cm². Using a conventional shuttle box, the conditioned and non-conditioned responses and spontaneous motor activity of the rats were studied. The results suggest that exposure to EMFs in the three ranges can slow down the formation of conditioned responses--this was clearly marked in the rats exposed to meter EMFs, whereas the effects of centimeter EMFs were delayed in time. The behavioral effects were mild at athermal dosages and the animals adapted easily to exposure conditions. This study shows that determination of the effects of different EMFs should be done for each of the ranges separately; determination of the exact dosage of the electromagnetic fields can help to avoid their negative biological effects.

Khudnitskii, SS, Moshkarev, EA, Fomenko, TV, [On the evaluation of the influence of cellular phones on their users]. [Article in Russian] *Med Tr Prom Ekol* (9):20-24, 1999.

The authors studied influence of ultrahigh frequency radiation caused by cellular phones on functional state of central nervous, cardiovascular systems and local temperature changes in cellular phones users. The head area near the phone antenna appeared to be under the most intensive heating. Ultrahigh frequency radiation induces significant changes in local temperature and in physiologic parameters of central nervous and cardiovascular systems.

Klug S, Hetscher M, Giles S, Kohlsmann S, Kramer K, The lack of effects of nonthermal RF electromagnetic fields on the development of rat embryos grown in culture. *Life Sci* 61(18):1789-1802, 1997.

Rat embryos (9.5 days old) were exposed for up to 36 h to various radio frequency (RF) electric and magnetic fields (modulation frequency: 16, 60, 120 Hz; electric field strength: 60, 600 V/m; magnetic induction: 0.2, 2.0 microT). A resonator technique was used to generate standing waves thus fulfilling three conditions: The site of maximum electric and magnetic oscillations could be separated, the field strengths were known exactly and a high homogeneity over the sample volume was achieved. In each frequency region the transmitter power levels were set to give specific absorption rate (SAR) values spreading from far below to far above the values met in the field of telecommunication (0.2, 1.0 and 5.0 W/kg). The criteria used to examine the embryos on day 11.5 for possible structural effects consisted of a scoring system, photographs, histology using both light and electron microscopy and determination of the

protein content. All these data have been taken as sets of different intermediate frequency (IF) amplitude modulation of the RF carriers. Neither the electric nor the magnetic fields tested interfered significantly with the normal growth and differentiation of the embryos in vitro.

Koivisto, M, Revonsuo, A, Krause, C, Haarala, C, Sillanmaki, L, Laine, M, Hamalainen, H, Effects of 902 MHz electromagnetic field emitted by cellular telephones on response times in humans. *Neuroreport* 11(2):413-415, 2000.

The present study examined possible influences of a 902 MHz electromagnetic field emitted by cellular telephones on cognitive functioning in 48 healthy humans. A battery of 12 reaction time tasks was performed twice by each participant in a counterbalanced order: once with and once without the exposure to the field. The results showed that the exposure to the electromagnetic field speeded up response times in simple reaction time and vigilance tasks and that the cognitive time needed in a mental arithmetics task was decreased. The results suggest that exposure to the electromagnetic field emitted by cellular telephones may have a facilitatory effect on brain functioning, especially in tasks requiring attention and manipulation of information in working memory.

Koivisto M, Krause CM, Revonsuo A, Laine M, Hamalainen H, The effects of electromagnetic field emitted by GSM phones on working memory. *Neuroreport* 11(8):1641-1643, 2000.

The influence of pulsed radiofrequency (RF) electromagnetic fields of digital GSM mobile phones on working memory in healthy subjects were studied. Memory load was varied from 0 to 3 items in an n-back task. Each subject was tested twice within a single session, with and without the RF exposure (902MHz, 217Hz). The RF field speeded up response times when the memory load was three items but no effects of RF were observed with lower loads. The results suggest that RF fields have a measurable effect on human cognitive performance and encourage further studies on the interactions of RF fields with brain function.

Kolodynski AA, Kolodynska VV, Motor and psychological functions of school children living in the area of the Skrunda Radio Location Station in Latvia. *Sci Total Environ* 180(1):87-93, 1996.

This paper presents the results of experiments on school children living in the area of the Skrunda Radio Location Station (RLS) in Latvia. Motor function, memory and attention significantly differed between the exposed and control groups. Children living in front of the RLS had less developed memory and attention, their reaction time was slower and their neuromuscular apparatus endurance was decreased.

Krause CM, Sillanmaki L, Koivisto M, Haggqvist A, Saarela C, Revonsuo A, Laine M, Hamalainen H, Effects of electromagnetic field emitted by cellular phones on the EEG during a memory task. *Neuroreport* 11(4):761-764, 2000.

The effects of electromagnetic fields (EMF) emitted by cellular phones on the ERD/ERS of the 4-6 Hz, 6-8 Hz, 8-10 Hz and 10-12 Hz EEG frequency bands were studied in 16 normal subjects performing an auditory memory task. All subjects performed the memory task both with and without exposure to a digital 902 MHz EMF in counterbalanced order. The exposure to EMF significantly increased EEG power in the 8-10 Hz frequency band only. Nonetheless, the presence of EMF altered the ERD/ERS responses in all studied frequency bands as a function of time and memory task (encoding vs retrieval). Our results suggest that the exposure to EMF does not alter the resting EEG per se but modifies the brain responses significantly during a memory task.

Kues HA, D'Anna SA, Osiander R, Green WR, Monahan JC, Absence of ocular effects after either single or repeated exposure to 10 mW/cm(2) from a 60 GHz CW source. *Bioelectromagnetics* 20(8):463-473, 1999.

This study was designed to examine ocular effects associated with exposure to millimeter waves (60 GHz). Rabbits served as the primary experimental subjects. To confirm the results of the rabbit experiments in a higher species, the second phase of the study used nonhuman primates (*Macaca mulatta*). First, this study used time-resolved infrared radiometry to assess the field distribution patterns produced by different antennas operating at 60 GHz. These results allowed us to select an antenna that produced a uniform energy distribution and the best distance at which to expose our experimental subjects. The study then examined ocular changes after exposure at an incident power density of 10 mW/cm(2). Acute exposure of both rabbits and nonhuman primates consisted of a single 8 h exposure, and the repeated exposure protocol consisted of five separate 4 h exposures on consecutive days. One eye in each animal was exposed and the contralateral eye served as the sham-exposed control. After postexposure diagnostic examinations, animals were euthanized and the eyes were removed. Ocular tissue was examined by both light and transmission electron microscopy. Neither microscopic examinations nor the diagnostic procedures performed on the eyes of acute and repeatedly exposed rabbits found any ocular changes that could be attributed to millimeter-wave exposure at 10 mW/cm(2). Examination of the primates after comparable exposures also failed to detect any ocular changes due to exposure. On the basis of our results, we conclude that single or repeated exposure to 60 GHz CW radiation at 10 mW/cm(2) does not result in any detectable ocular damage.

Kwee, S, Raskmark, P, Radiofrequency electromagnetic fields and cell proliferation. Presented at the Second World Congress for Electricity and Magnetism in Biology and Medicine, Bologna, Italy, June, 1997.

Exposure to low-intensity (0.021-2.1 mW/kg) GSM mobile phone signals caused a decrease in cell proliferation in vitro.

Lagorio S, Rossi S, Vecchia P, De Santis M, Bastianini L, Fusilli M, Ferrucci A, Desideri E, Comba P, Mortality of plastic-ware workers exposed to radiofrequencies. *Bioelectromagnetics* 18(6):418-421, 1997.

The mortality experience of a cohort of Italian plastic-ware workers exposed to radiofrequency (RF)-electromagnetic fields generated by dielectric heat sealers was investigated. Follow-up extended from 1962 to 1992. The standardised mortality ratio (SMR) analysis was restricted to 481 women workers, representing 78% of the total person-years at risk. Mortality from malignant neoplasms was slightly elevated, and increased risks of leukemia and accidents were detected. The all-cancer SMR was higher among women employed in the sealing department, where exposure to RF occurred, than in the whole cohort. This study raises interest in a possible association between exposure to RF radiation and cancer risk. However, the study power was very small, and the possible confounding effects of exposure to solvents and vinyl chloride monomer (VCM) could not be ruled out. The hypothesis of an increased risk of cancer after radiofrequency exposure should be further explored by means of analytical studies characterised by adequate power and more accurate exposure assessment.

Lai, H, Singh, NP, Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. *Bioelectromagnetics* 18(6):446-454, 1997.

Effects of in vivo microwave exposure on DNA strand breaks, a form of DNA damage, were investigated in rat brain cells. In previous research, we have found that acute (2 hours) exposure to pulsed (2 microseconds pulses, 500 pps) 2450-MHz radiofrequency electromagnetic radiation (RFR) (power density 2 mW/cm², average whole body specific absorption rate 1.2 W/kg) caused an increase in DNA single- and double-strand breaks in brain cells of the rat when assayed 4 hours post exposure using a microgel electrophoresis assay. In the present study, we found that treatment of rats immediately before and after RFR exposure with either melatonin (1 mg/kg/injection, SC) or the spin-trap compound N-tert-butyl-alpha-phenylnitron (PBN) (100 mg/kg/injection, i.p.) blocks this effects of RFR. Since both melatonin and PBN are efficient free radical scavengers it is hypothesized that free radicals are involved in RFR-induced DNA damage in the brain cells of rats. Since cumulated DNA strand breaks in brain cells can lead to neurodegenerative diseases and cancer and an excess of free radicals in cells has been suggested to be the cause of various human diseases, data from this study could have important implications for the health effects of RFR exposure.

Lai, H, Carino, MA, Singh, NP, Naltrexone blocks RFR-induced DNA double strand breaks in rat brain cells. *Wireless Networks* 3:471-476, 1997.

Previous research in our laboratory has shown that various effects of radiofrequency electromagnetic radiation (RFR) exposure on the nervous system are mediated by endogenous opioids in the brain. We have also found that acute exposure to RFR

induced DNA strand breaks in brain cells of the rat. The present experiment was carried out to investigate whether endogenous opioids are also involved in RFR-induced DNA strand breaks. Rats were treated with the opioid antagonist naltrexone (1 mg/kg, IP) immediately before and after exposure to 2450-MHz pulsed (2 s pulses, 500 pps) RFR at a power density of 2 mW/cm² (average whole body specific absorption rate of 1.2 W/kg) for 2 hours. DNA double strand breaks were assayed in brain cells at 4 hours after exposure using a microgel electrophoresis assay. Results showed that the RFR exposure significantly increased DNA double strand breaks in brain cells of the rat, and the effect was partially blocked by treatment with naltrexone. Thus, these data indicate that endogenous opioids play a mediating role in RFR-induced DNA strand breaks in brain cells of the rat.

Lamble D, Kauranen T, Laakso M, Summala H, Cognitive load and detection thresholds in car following situations: safety implications for using mobile (cellular) telephones while driving. *Accid Anal Pre* ;31(6):617-623, 1999.

This study was aimed at investigating drivers' ability to detect a car ahead decelerating, while doing mobile phone related tasks. Nineteen participants aged between 20 and 29 years, (2000-125000 km driving experience) drove at 80 km/h, 50 m behind a lead car, on a 30 km section of motorway in normal traffic. During each trial the lead car started to decelerate at an average of 0.47 m/s² while the participant either looked at the car in front (control), continuously dialed series of three random integers on a numeric keypad (divided visual attention), or performed a memory and addition task (non-visual attention). The results indicated that drivers' detection ability was impaired by about 0.5 s in terms of brake reaction time and almost 1 s in terms of time-to-collision, when they were doing the non-visual task whilst driving. This impairment was similar to when the drivers were dividing their visual attention between the road ahead and dialing numbers on the keypad. It was concluded that neither a hands-free option nor a voice controlled interface removes the safety problems associated with the use of mobile phones in a car.

Li, JR, Chou, CK, McDougall, JA, Dasgupta, G, Wu, HH, Ren, RL, Lee, A, Han, J, Momand J TP53 tumor suppressor protein in normal human fibroblasts does not respond to 837 MHz microwave exposure. *Radiat Res* 151(6):710-716, 1999

The TP53 tumor suppressor protein (formerly known as p53) responds to a wide variety of environmental insults. To evaluate the safety of cellular telephones, TP53 responses in human fibroblast cells were studied after exposure to 837 MHz microwaves. Cells were exposed in a temperature-controlled transverse electromagnetic (TEM) chamber to a specific absorption rate (SAR) of 0.9 or 9.0 W/kg at 837 MHz continuous-wave (CW) microwave irradiation for 2 h. The TP53 protein levels were measured by Western blot at 2, 8, 24 and 48 h after treatment. The TP53 protein levels in microwave-treated cells, sham-treated cells, and untreated cells remained unchanged relative to each other at all times tested (Fisher

test and Student-Newman-Keuls test, $P > 0.05$). No morphological alterations were observed in microwave-treated cells compared to sham-treated cells. We conclude that TP53 protein expression levels in cultured human fibroblast cells do not change significantly during a 48-h period after exposure to 837 MHz continuous microwaves for 2 h at SAR levels of 0.9 or 9.0 W/kg.

Linz, KW, von Westphalen, C, Streckert, J, Hansen, V, Meyer, R, Membrane potential and currents of isolated heart muscle cells exposed to pulsed radio frequency fields. *Bioelectromagnetics* 20(8):497-511, 1999.

The influence of radio frequency (RF) fields of 180, 900, and 1800 MHz on the membrane potential, action potential, L-type Ca^{2+} current and potassium currents of isolated ventricular myocytes was tested. The study is based on 90 guinea-pig myocytes and 20 rat myocytes. The fields were applied in rectangular waveguides (1800 MHz at 80, 480, 600, 720, or 880 mW/kg and 900 MHz, 250 mW/kg) or in a TEM-cell (180 MHz, 80 mW/kg and 900 MHz, 15 mW/kg). Fields of 1800 and 900 MHz were pulsed according to the GSM-standard of cellular phones. The specific absorption rates were determined from computer simulations of the electromagnetic fields inside the exposure devices by considering the structure of the physiological test arrangement. The electrical membrane parameters were measured by whole cell patch-clamp. None of the tested electrophysiological parameters was changed significantly by exposure to RF fields. Another physical stimulus, lowering the temperature from 36 degrees C to 24 degrees C, decreased the current amplitude almost 50% and shifted the voltage dependence of the steady state activation parameter $d(\infty)$ and inactivation parameter $f(\infty)$ of L-type Ca^{2+} current by about 5 mV. However, at this lower temperature RF effects (900 MHz, 250 mW/kg; 1800 MHz, 480 mW/kg) on L-type Ca^{2+} current were also not detected.

Litovitz, TA, Penafiel, LM, Farrel, JM, Krause, D, Meister, R, Mullins, JM Bioeffects induced by exposure to microwaves are mitigated by superposition of ELF noise. *Bioelectromagnetics* 18(6):422-430, 1997.

We have previously demonstrated that microwave fields, amplitude modulated (AM) by an extremely low-frequency (ELF) sine wave, can induce a nearly twofold enhancement in the activity of ornithine decarboxylase (ODC) in L929 cells at SAR levels of the order of 2.5 W/kg. Similar, although less pronounced, effects were also observed from exposure to a typical digital cellular phone test signal of the same power level, burst modulated at 50 Hz. We have also shown that ODC enhancement in L929 cells produced by exposure to ELF fields can be inhibited by superposition of ELF noise. In the present study, we explore the possibility that similar inhibition techniques can be used to suppress the microwave response. We concurrently exposed L929 cells to 60 Hz AM microwave fields or a 50 Hz burst-modulated DAMPS (Digital Advanced Mobile Phone System) digital cellular phone field at levels known to produce ODC enhancement, together with band-limited 30-100 Hz ELF noise with root mean square amplitude of up to 10 microT. All exposures were

carried out for 8 h, which was previously found to yield the peak microwave response. In both cases, the ODC enhancement was found to decrease exponentially as a function of the noise root mean square amplitude. With 60 Hz AM microwaves, complete inhibition was obtained with noise levels at or above 2 microT. With the DAMPS digital cellular phone signal, complete inhibition occurred with noise levels at or above 5 microT. These results suggest a possible practical means to inhibit biological effects from exposure to both ELF and microwave fields.

Loscher W, Kas G, Extraordinary behavior disorders in cows in proximity to transmission stations. *Der Praktische Tierarz* 79:437-444, 1998. (Article in German)

In addition to reduction of milk yield and increased health problems, behavioral abnormalities were observed over a period of two years in a herd of dairy cows maintained in close proximity to a TV and cell phone transmitting antenna. Evaluation of possible factors which could explain the abnormalities in the live stock did not disclose any factors other than the high-frequency electromagnetic fields. An experiment in which a cow with abnormal behavior was brought to a stable 20 km away from the antenna resulted in a complete normalization of the cow within five days, whereas symptoms returned when the cow was brought back to the stable nearby the antenna. In view of the previous described effects of electromagnetic fields, it might be possible that the observed abnormalities in cows are related to electromagnetic field exposure. (power densities measured 0.02-7 mW/m²).

Lu ST, Mathur SP, Akyel Y, Lee JC, Ultrawide-band electromagnetic pulses induced hypotension in rats. *Physiol Behav* Jan 1-15;65(4-5):753-761, 1999; Corrected and republished in *Physiol Behav*;67(3):753-761, 1999.

The ultrawide-band (UWB) electromagnetic pulses are used as a new modality in radar technology. Biological effects of extremely high peak E-field, fast rise time, ultrashort pulse width, and ultrawide band have not been investigated heretofore due to the lack of animal exposure facilities. A new biological effects database is needed to establish personnel protection guidelines for these new type of radiofrequency radiation. Functional indices of the cardiovascular system (heart rate, systolic, mean, and diastolic pressures) were selected to represent biological end points that may be susceptible to the UWB radiation. A noninvasive tail-cuff photoelectric sensor sphygmomanometer was used. Male Wistar-Kyoto rats were subjected to sham exposure, 0.5-kHz (93 kV/m, 180 ps rise time, 1.00 ns pulse width, whole-body averaged specific absorption rate, SAR = 70 mW/kg) or a 1-kHz (85 kV/m, 200 ps rise time, 1.03 ns pulse width, SAR = 121 mW/kg) UWB fields in a tapered parallel plate GTEM cell for 6 min. Cardiovascular functions were evaluated from 45 min to 4 weeks after exposures. Significant decrease in arterial blood pressures (hypotension) was found. In contrast, heart rate was not altered by these exposures. The UWB radiation-induced hypotension was a robust, consistent, and persistent effect.

Maes A, Collier M, Van Gorp U, Vandoninck S, Verschaeve L, Cytogenetic effects of 935.2-MHz (GSM) microwaves alone and in combination with mitomycin C. *Mutat Res* 393(1-2):151-156, 1997.

This paper focuses on the genetic effects of microwaves from mobile communication frequencies (935.2 MHz) alone and in combination with a chemical DNA-damaging agent (mitomycin C). Three cytogenetic endpoints were investigated after in vitro exposure of human whole blood cells. These endpoints were the 'classical' chromosome aberration test, the sister chromatid exchange test and the alkaline comet assay. No direct cytogenetic effect was found. The combined exposure of the cells to the radiofrequency fields followed by their cultivation in the presence of mitomycin C revealed a very weak effect when compared to cells exposed to mitomycin C alone.

Magras, IN, Xenos, TD, RF radiation-induced changes in the prenatal development of mice. *Bioelectromagnetics* 18(6):455-461, 1997.

The possible effects of radiofrequency (RF) radiation on prenatal development has been investigated in mice. This study consisted of RF level measurements and in vivo experiments at several places around an "antenna park." At these locations RF power densities between 168 nW/cm² and 1053 nW/cm² were measured. Twelve pairs of mice, divided in two groups, were placed in locations of different power densities and were repeatedly mated five times. One hundred eighteen newborns were collected. They were measured, weighed, and examined macro- and microscopically. A progressive decrease in the number of newborns per dam was observed, which ended in irreversible infertility. The prenatal development of the newborns, however, evaluated by the crown-rump length, the body weight, and the number of the lumbar, sacral, and coccygeal vertebrae, was improved.

Malyapa RS, Ahern EW, Straube WL, Moros EG, Pickard WF, Roti Roti JL, Measurement of DNA damage after exposure to 2450 MHz electromagnetic radiation. *Radiat Res* 148(6):608-617, 1997.

Recent reports suggest that exposure to 2450 MHz electromagnetic radiation causes DNA single-strand breaks (SSBs) and double-strand breaks (DSBs) in cells of rat brain irradiated in vivo (Lai and Singh, *Bioelectromagnetics* 16, 207-210, 1995; *Int. J. Radiat. Biol.* 69, 513-521, 1996). Therefore, we endeavored to determine if exposure of cultured mammalian cells in vitro to 2450 MHz radiation causes DNA damage. The alkaline comet assay (single-cell gel electrophoresis), which is reportedly the most sensitive method to assay DNA damage in individual cells, was used to measure DNA damage after in vitro 2450 MHz irradiation. Exponentially growing U87MG and C3H 10T1/2 cells were exposed to 2450 MHz continuous-wave (CW) radiation in specially designed radial transmission lines (RTLs) that provided relatively uniform microwave exposure. Specific absorption rates (SARs) were calculated to be 0.7 and 1.9 W/kg. Temperatures in the RTLs were measured in real time and were maintained at 37 +/- 0.3 degrees C. Every experiment included sham

exposure(s) in an RTL. Cells were irradiated for 2 h, 2 h followed by a 4-h incubation at 37 degrees C in an incubator, 4 h and 24 h. After these treatments samples were subjected to the alkaline comet assay as described by Olive et al. (Exp. Cell Res. 198, 259-267, 1992). Images of comets were digitized and analyzed using a PC-based image analysis system, and the "normalized comet moment" and "comet length" were determined. No significant differences were observed between the test group and the controls after exposure to 2450 MHz CW irradiation. Thus 2450 MHz irradiation does not appear to cause DNA damage in cultured mammalian cells under these exposure conditions as measured by this assay.

Malyapa RS, Ahern EW, Bi C, Straube WL, LaRegina M, Pickard WF, Roti Roti JL, DNA damage in rat brain cells after in vivo exposure to 2450 MHz electromagnetic radiation and various methods of euthanasia. *Radiat Res* 149(6):637-645, 1998.

The present study was done to confirm the reported observation that low-intensity acute exposure to 2450 MHz radiation causes DNA single-strand breaks (Lai and Singh, Bioelectromagnetics 16, 207-210, 1995). Male Sprague-Dawley rats weighing approximately 250 g were irradiated with 2450 MHz continuous-wave (CW) microwaves for 2 h at a specific absorption rate of 1.2 W/kg in a cylindrical waveguide system (Guy et al., Radio Sci. 14, 63-74, 1979). There was no associated rise in the core body temperature of the rats. After the irradiation or sham treatments, rats were euthanized by either CO₂ asphyxia or decapitation by guillotine (eight pairs of animals per euthanasia group). After euthanasia the brains were removed and immediately immersed in cold Ames medium and the cells of the cerebral cortex and the hippocampus were dissociated separately and subjected to the alkaline comet assay. Irrespective of whether the rats were euthanized by CO₂ asphyxia or decapitated by guillotine, no significant differences were observed between either the comet length or the normalized comet moment of cells from either the cerebral cortex or the hippocampus of sham-treated rats and those from the irradiated rats. However, the data for the rats asphyxiated with CO₂ showed more intrinsic DNA damage and more experiment-to-experiment variation than did the data for rats euthanized by guillotine. Therefore, the guillotine method of euthanasia is the most appropriate in studies relating to DNA damage. Furthermore, we did not confirm the observation that DNA damage is produced in cells of the rat cerebral cortex or the hippocampus after a 2-h exposure to 2450 MHz CW microwaves or at 4 h after the exposure.

Malyapa RS, Bi C, Ahern EW, Roti Roti JL, Detection of DNA damage by the alkaline comet assay after exposure to low-dose gamma radiation. *Radiat Res* 149(4):396-400, 1998.

The alkaline comet assay as described by Olive et al. (Exp. Cell Res. 198, 259-267, 1992) was used to detect DNA damage in cells exposed to low doses (0-5 cGy) of gamma radiation. Experiments were performed using lymphocytes isolated from whole blood of rats. The comet parameters, normalized comet moment

and comet length, described by Kent et al. (Int. J. Radiat. Biol. 67, 655-660, 1995), were used as measurements of DNA damage. It was observed that the alkaline comet assay can detect DNA damage at doses as low as 0.6 cGy. The results of the experiments using low-dose gamma radiation are comparable with published results obtained using the alkaline comet assay according to the method of Singh et al. (Int. J. Radiat. Biol. 66, 23-28, 1994). Based on this observation and analysis of results published previously, we conclude that the version of the alkaline comet assay described by Olive et al. is as sensitive as other modifications of the comet assay reported in literature for the detection of DNA damage in cells exposed to low doses of ionizing radiation.

Mann, K, Roschke, J, Effects of pulsed high-frequency electromagnetic fields on human sleep. *Neuropsychobiology* 33(1):41-47, 1996.

In the present study we investigated the influence of pulsed high-frequency electromagnetic fields of digital mobile radio telephones on sleep in healthy humans. Besides a hypnotic effect with shortening of sleep onset latency, a REM suppressive effect with reduction of duration and percentage of REM sleep was found. Moreover, spectral analysis revealed qualitative alterations of the EEG signal during REM sleep with an increased spectral power density. Knowing the relevance of REM sleep for adequate information processing in the brain, especially concerning mnemonic functions and learning processes, the results emphasize the necessity to carry out further investigations on the interaction of this type of electromagnetic fields and the human organism.

Mann, K, Roschke, J, Connemann, B, Beta, H, No effects of pulsed high-frequency electromagnetic fields on heart rate variability during human sleep. *Neuropsychobiology*;38(4):251-256, 1998.

The influence of pulsed high-frequency electromagnetic fields emitted by digital mobile radio telephones on heart rate during sleep in healthy humans was investigated. Beside mean RR interval and total variability of RR intervals based on calculation of the standard deviation, heart rate variability was assessed in the frequency domain by spectral power analysis providing information about the balance between the two branches of the autonomic nervous system. For most parameters, significant differences between different sleep stages were found. In particular, slow-wave sleep was characterized by a low ratio of low- and high-frequency components, indicating a predominance of the parasympathetic over the sympathetic tone. In contrast, during REM sleep the autonomic balance was shifted in favor of the sympathetic activity. For all heart rate parameters, no significant effects were detected under exposure to the field compared to placebo condition. Thus, under the given experimental conditions, autonomic control of heart rate was not affected by weak-pulsed high-frequency electromagnetic fields.

Mann, K, Wagner, P, Brunn, G, Hassan, F, Hiemke, C, Roschke, J, Effects of pulsed high-frequency electromagnetic fields on the neuroendocrine system. *Neuroendocrinology* 67(2):139-144, 1998.

The influence of pulsed high-frequency electromagnetic fields emitted from a circularly polarized antenna on the neuroendocrine system in healthy humans was investigated (900 MHz electromagnetic field, pulsed with 217 Hz, average power density 0.02 mW/cm²). Nocturnal hormone profiles of growth hormone (GH), cortisol, luteinizing hormone (LH) and melatonin were determined under polysomnographic control. An alteration in the hypothalamo-pituitary-adrenal axis activity was found with a slight, transient elevation in the cortisol serum level immediately after onset of field exposure which persisted for 1 h. For GH, LH and melatonin, no significant effects were found under exposure to the field compared to the placebo condition, regarding both total hormone production during the entire night and dynamic characteristics of the secretion pattern. Also the evaluation of the sleep EEG data revealed no significant alterations under field exposure, although there was a trend to an REM suppressive effect. The results indicate that weak high-frequency electromagnetic fields have no effects on nocturnal hormone secretion except for a slight elevation in cortisol production which is transient, pointing to an adaptation of the organism to the stimulus.

Mason PA, Escarciga R, Doyle JM, Romano WF, Berger RE, Donnellan JP, Amino acid concentrations in hypothalamic and caudate nuclei during microwave-induced thermal stress: analysis by microdialysis. *Bioelectromagnetics* 18(3):277-283, 1997.

Exposure to radiofrequency radiation (RFR) may produce thermal responses. Extracellular amino acid concentrations in the hypothalamus (Hyp) and caudate nucleus (CN) were measured by using in vivo microdialysis before and during exposure to RFR. Under urethane anesthetic, each rat was implanted stereotaxically with a nonmetallic microdialysis probe and temperature probe guides and then placed in the exposure chamber. The rat laid on its right side with its head and neck placed directly under the wave guide. Temperature probes were placed in the left brain, right brain, face (subcutaneously), left tympanum, and rectum. Each microdialysis sample was collected over a 20 min period. The microdialysis probe was perfused for 2 h before the rat was exposed to 5.02 GHz radiation (10 microseconds pulse width, 1000 pulses/s). The right and left sides of the brain were maintained at approximately 41.2 and 41.7 degrees C, respectively, throughout a 40 min exposure period. Initially when the brain was being heated to these temperatures, the time-averaged specific absorption rates (SARs) for the right and left sides of the brain were 29 and 40 W/kg, respectively. Concentrations of aspartic acid, glutamic acid, serine, glutamine, and glycine in dialysate were determined by using high-pressure liquid chromatography with electrochemical detection. In the Hyp and CN, the concentrations of aspartic acid, serine, and glycine increased significantly during RFR exposure ($P < .05$). These results indicate that RFR-induced thermal stress produces a general change in the amino acid concentrations that is

not restricted to thermoregulatory centers. Changes in the concentrations of glutamic acid (Hyp, $P = .16$; CN, $P = .34$) and glutamine (Hyp, $P = .13$; CN, $P = .10$) were not statistically significant. Altered amino acid concentrations may reveal which brain regions are susceptible to damage in response to RFR-induced thermal stress.

Mezhevikina LM, Khramov RN, Lepikhov KA , [The simulation of the cooperative effect of development in a culture of early mouse embryos after irradiation with electromagnetic waves in the millimeter range]. *Ontogenez* 31(1):27-31, 2000. [Article in Russian]

We have found that two-cell mouse embryos cultured in vitro can be stimulated by electromagnetic irradiation in the millimeter range. After 30 min of exposure, they acquire the ability to develop in culture on their own and can reach the stage of blastocyst in a relatively large volume of Whitten cultural medium (150 microliters) without serum or growth factors. It is proposed that millimeter range electromagnetic waves activate metabolic processes and specifically the synthesis of factors controlling early embryonic development in culture.

Michelozzi P, Ancona C, Fusco D, Forastiere F, Perucci CA, Risk of leukemia and residence near a radio transmitter in Italy. *Epidemiology* 9 (Suppl) 354p, 1998.

We conducted a small area study to investigate a cluster of leukemia near a high power radio-transmitter in a peripheral area of Rome. The leukemia mortality within 3.5 km (5,863 inhabitants) was higher than expected (SMR=2.5, 95% confident interval 1.07-4.83); the excess was due to a significant higher mortality among men (7 cases observed, SMR=3.5). The results of the Stone's test, after adjusting for socio-economic confounding, showed a significant decline in risk with distance from the transmitter only among men ($p=0.005$), whereas the p -value for both sexes was $p=0.07$.

Miller SA, Bronson ME, Murphy MR, Ultrawideband radiation and pentylenetetrazol-induced convulsions in rats. *Bioelectromagnetics* 20(5):327-329, 1999.

New non-ionizing pulsed systems using ultrawideband (UWB) require safety assessment before they can be used by either military or civilian communities. The development of directed energy weaponry intended for use against electronically vulnerable targets, as well as ground-probing radar systems, have used fast-rise-time high-peak-power electromagnetic pulses characteristic of UWB emitters. It has been postulated that these ultrashort pulses might produce electromagnetic transients resulting in tissue damage. Several challenges to this notion have been posed, however. One report found that rats exposed to UWB after receiving a convulsant drug tended toward longer latency to the onset of convulsions than the no-exposure

group. Although not statistically significant, the presence of this trend prompted the present study. An ED99 dose of the convulsant pentylenetetrazol (PTZ) or saline was given just before UWB or sham exposure and resultant seizure activity was recorded. The data from the current study show no effect of UWB exposure on PTZ-induced seizure activity, thereby not supporting the tissue damage concerns, at least for the exposure parameters used here.

Min ST, Redelmeier DA, Car phones and car crashes: an ecologic analysis. *Can J Public Health* 89(3):157-161, 1998.

OBJECTIVE: Some countries have regulations against using a cellular Telephone while driving. We used ecologic analysis to evaluate cellular telephone use and motor vehicle collisions in a city without such regulations. **METHODS:** We studied locations in Toronto, Ontario (n = 75) that were hazardous (total collisions = 3,234) and tested whether increases in collision rates from 1984 to 1993 correlated with increases in telephone usage over the same time interval. **RESULTS:** Locations with the largest increases in collision rates tended to have the smallest increases in estimated cellular telephone usage. Yet extreme assumptions about potential protective effects from cellular telephones failed to explain the magnitude observed. **CONCLUSIONS:** The effects of cellular telephones on driving ability are small relative to the biases in ecologic analysis. Claims from industry, which argue that cellular telephones are not dangerous based on ecologic analysis, can be misleading in the policy debate about whether to regulate cellular telephone use while driving.

Morrissey JJ, Raney S, Heasley E, Rathinavelu P, Dauphinee M, Fallon JH, IRIDIUM exposure increases c-fos expression in the mouse brain only at levels which likely result in tissue heating. *Neuroscience* 92(4):1539-1546, 1999.

With the rapid development of wireless communication technology over the last 20 years, there has been some public concern over possible health effects of long-term, low-level radiofrequency exposure from cellular telephones. As an initial step in compiling a database for risk analysis by government agencies, the effects of 1-h exposure of mice to a 1.6-GHz radiofrequency signal, given as either a continuous wave or pulse modulated at 11 Hz with a duty cycle of 4:1 and a pulse duration of 9.2 ms (IRIDIUM), on c-fos gene expression in the brain was investigated. The IRIDIUM signal is the operating frequency for a ground-to-satellite-to-ground cellular communications web which has recently become fully operational, and was named as such due to the original designed employment of the same number of low orbiting satellites as there are electrons orbiting the nucleus of an iridium atom. The expression of c-fos was not significantly elevated in the brains of mice until exposure levels exceeded six times the peak dose and 30 times the whole body average dose as maximal cellular telephone exposure limits in humans. Higher level exposure using either continuous wave (analog) or IRIDIUM signals elevated c-fos to a similar extent, suggesting no obvious pulsed modulation-specific effects. The pattern of c-fos elevation in limbic cortex and subcortex areas at higher exposure levels is most consistent with a stress response

due to thermal perception coupled with restraint and/or neuron activity near thermoregulatory regions, and not consistent with any direct interaction of IRIDIUM energy with brain tissue.

Naegeli B, Osswald S, Deola M, Burkart F, Intermittent pacemaker dysfunction caused by digital mobile telephones. *J Am Coll Cardiol* 27(6):1471-1477, 1996.

OBJECTIVES: This study was designed to evaluate possible interactions between digital mobile telephones and implanted pacemakers. **BACKGROUND:** Electromagnetic fields may interfere with normal pacemaker function. Development of bipolar sensing leads and modern noise filtering techniques have lessened this problem. However, it remains unclear whether these features also protect from high frequency noise arising from digital cellular phones. **METHODS:** In 39 patients with an implanted pacemaker (14 dual-chamber [DDD], 8 atrial-synchronized ventricular-inhibited [VDD(R)] and 17 ventricular-inhibited [VVI(R)] pacemakers), four mobile phones with different levels of power output (2 and 8 W) were tested in the standby, dialing and operating mode. During continuous electrocardiographic monitoring, 672 tests were performed in each mode with the phones positioned over the pulse generator, the atrial and the ventricular electrode tip. The tests were carried out at different sensitivity settings and, where possible, in the unipolar and bipolar pacing modes as well. **RESULTS:** In 7 (18%) of 39 patients, a reproducible interference was induced during 26 (3.9%) of 672 tests with the operating phones in close proximity (<10 cm) to the pacemaker. In 22 dual-chamber (14 DDD, 8 VDD) pacemakers, atrial triggering occurred in 7 (2.8%) of 248 and ventricular inhibition in 5 (2.8%) of 176 tests. In 17 VVI(R) systems, pacemaker inhibition was induced in 14 (5.6%) of 248 tests. Interference was more likely to occur at higher power output of the phone and at maximal sensitivity of the pacemakers (maximal vs. nominal sensitivity, 6% vs. 1.8% positive test results, $p = 0.009$). When the bipolar and unipolar pacing modes were compared in the same patients, ventricular inhibition was induced only in the unipolar mode (12.5% positive test results, $p = 0.0003$). **CONCLUSION:** Digital mobile phones in close proximity to implanted pacemakers may cause intermittent pacemaker dysfunction with inappropriate ventricular tracking and potentially dangerous pacemaker inhibition.

Nakamura, H, Seto, T, Nagase, H, Yoshida, M, Dan, S, Ogino, K, Effects of exposure to microwaves on cellular immunity and placental steroids in pregnant rats. *Occup Environ Med* 54(9):676-80, 1997.

OBJECTIVES: Microwaves produce various detrimental changes based on actions of heat or non-specific stress, although the effects of microwaves on pregnant organisms has not been uniform. This study was designed to clarify the effect of exposure to microwaves during pregnancy on endocrine and immune functions. **METHODS:** Natural killer cell activity and natural killer cell subsets in the spleen were measured, as well as some endocrine indicators in blood--corticosterone and adrenocorticotrophic hormone (ACTH) as indices of the hypothalamic-pituitary-

adrenal axis--beta-endorphin, oestradiol, and progesterone in six female virgin rats and six pregnant rats (nine to 11 days gestation) exposed to microwaves at 10 mW/cm² incident power density at 2450 MHz for 90 minutes. The same measurements were performed in control rats (six virgin and six pregnant rats). RESULTS: Skin temperature in virgin and pregnant rats increased immediately after exposure to microwaves. Although splenic activity of natural killer cells and any of the subset populations identified by the monoclonal antibodies CD16 and CD57 did not differ in virgin rats with or without exposure to microwaves, pregnant rats exposed to microwaves showed a significant reduction of splenic activity of natural killer cells and CD16+CD57-. Although corticosterone and ACTH increased, and oestradiol decreased in exposed virgin and pregnant rats, microwaves produced significant increases in beta-endorphin and progesterone only in pregnant rats. CONCLUSIONS: Microwaves at the power of 10 mW/cm² produced activation of the hypothalamic-pituitary-adrenal axis and increased oestradiol in both virgin and pregnant rats, suggesting that microwaves greatly stress pregnant organisms. These findings in pregnant rats suggest that--with exposure to microwaves--pregnancy induces immunosuppression, which could result in successful maintenance of pregnancy. This enhancement of adaptability to heat stress with pregnancy may be mediated by activation of placental progesterone and placental or pituitary beta-endorphin.

Nakamura, H, Seto, T, Hatta, K, Matsuzaki, I, Nagase, H, Yoshida, M, Ogino, K, Natural killer cell activity reduced by microwave exposure during pregnancy is mediated by opioid systems. *Environ Res* 79(2):106-13, 1998.

We have previously demonstrated immunosuppression including reduced splenic natural killer cell activity (NKCA) in pregnant rats exposed to microwaves produced mainly by their thermal action. To examine the involvement of opioid systems in reduced NKCA in pregnant rats exposed to microwaves at a relatively low level (2 mW/cm² incident power density at 2450 MHz for 90 min), we assayed beta-endorphin (betaEP) in blood, pituitary lobes, and placenta as well as splenic NKCA in virgin and/or pregnant rats. Although microwaves elevated colonic temperatures by 0.8 degreesC for virgin and 0.9 degreesC for pregnant rats, and betaEP in blood and anterior pituitary lobes (AP) significantly, it did not change blood corticosterone as an index of hypothalamic-pituitary adrenal axis. There were significant interactions between pregnancy and microwave exposure on splenic NKCA, betaEP in both blood and AP, and blood progesterone. Intra-peritoneal administration of opioid receptor antagonist naloxone prior to microwave exposure increased NKCA, blood, and placental betaEP in pregnant rats. Alterations in splenic NKCA, betaEP and progesterone in pregnant rats exposed to microwaves may be due to both thermal and nonthermal actions. These results suggest that NKCA reduced by microwaves during pregnancy is mediated by the pituitary opioid system.

Nakamura H, Nagase H, Ogino K, Hatta K, Matsuzaki I, Uteroplacental circulatory disturbance mediated by prostaglandin

F(2alpha) in rats exposed to microwaves*. *Reprod Toxicol* 14(3):235-240, 2000.

To clarify the effects of microwaves on pregnancy, uterine or uteroplacental blood flow and endocrine and biochemical mediators, including corticosterone, estradiol, prostaglandin E(2) (PGE(2)), and prostaglandin F(2)alpha (PGF(2)alpha), were measured in rats exposed to continuous-wave (CW) microwave at 2 mW/cm(2) incident power density at 2450 MHz for 90 min. Colonic temperature in virgin and pregnant rats was not significantly altered by microwave treatment. Microwaves decreased uteroplacental blood flow and increased progesterone and PGF(2)alpha in pregnant, but not in virgin rats. Intraperitoneal (i.p.) administration of angiotensin II, a uteroplacental vasodilator, before microwave exposure prevented the reduction in uteroplacental blood flow and the increased progesterone and PGF(2)alpha in pregnant rats. Increased corticosterone and decreased estradiol during microwave exposure were observed independent of pregnancy and pretreatment with angiotensin II. These results suggest that microwaves (CW, 2 mW/cm(2), 2450 MHz) produce uteroplacental circulatory disturbances and ovarian and placental dysfunction during pregnancy, probably through nonthermal actions. The uteroplacental disturbances appear to be due to actions of PGF(2)alpha and may pose some risk for pregnancy.

Nelson BK, Conover DL, Krieg EF Jr, Snyder DL, Edwards RM, Interactions of radiofrequency radiation-induced hyperthermia and 2-methoxyethanol teratogenicity in rats. *Bioelectromagnetics*;18(5):349-359, 1997.

Radiofrequency (RF) radiation is used in a variety of workplaces. In addition to RF radiation, many workers are concurrently exposed to numerous chemicals; exposed workers include those involved with the microelectronics industry, plastic sealers, and electrosurgical units. The developmental toxicity of RF radiation is associated with the degree and duration of hyperthermia induced by the exposure. Previous animal research indicates that hyperthermia induced by an elevation in ambient temperature can potentiate the toxicity and teratogenicity of some chemical agents. We previously demonstrated that combined exposure to RF radiation (10 MHz) and the industrial solvent, 2-methoxyethanol (2ME), produces enhanced teratogenicity in rats. The purpose of the present research is to determine the effects of varying the degree and duration of hyperthermia induced by RF radiation (sufficient to maintain colonic temperatures at control [38.5], 39.0, 40.0, or 41.0 degrees C for up to 6 h) and 2ME (100 mg/kg) administered on gestation day 13 of rats. Focusing on characterizing the dose-response pattern of interactions, this research seeks to determine the lowest interactive effect level. Day 20 fetuses were examined for external and skeletal malformations. The results are consistent with previous observations. Significant interactions were observed between 2ME and RF radiation sufficient to maintain colonic temperatures at 41 degrees C for 1 h, but no consistent interactions were seen at lower temperatures even with longer durations. These data indicate that

combined exposure effects should be considered when developing both RF radiation and chemical exposure guidelines and intervention strategies.

Nelson BK, Conover DL, Shaw PB, Snyder DL, Edwards RM, Interactions of radiofrequency radiation on 2-methoxyethanol teratogenicity in rats. *J Appl Toxicol* 17(1):31-39, 1997.

Concurrent exposures to chemical and physical agents occur in the workplace; exposed workers include those involved with microelectronics industry, plastic sealers and electrosurgical units. Previous animal research indicates that hyperthermia induced by an elevation in ambient temperature can potentiate the toxicity and teratogenicity of some chemical agents. We previously demonstrated that combined exposure to radiofrequency (r.f.; 10 MHz) radiation, which also induces hyperthermia and is teratogenic to exposed animals, and the industrial solvent 2-methoxyethanol (2ME) produces enhanced teratogenicity in rats. A subsequent study replicated and extended that research by investigating the interactive dose-related teratogenicity of r.f. radiation (sham exposure or maintaining colonic temperatures at 42.0 degrees C for 0, 10, 20 or 30 min by r.f. radiation absorption) and 2ME (0, 75, 100, 125 or 150 mg/kg) on gestation days 9 or 13 of rats. The purpose of the present research is to determine the effects of r.f. radiation (sufficient to maintain colonic temperatures at 42.0 degrees C for 10 min) on a range of doses of 2ME (0, 20, 40, 60, 80, 100, 120 and 140 mg kg⁻¹) administered on gestation day 13 of rats. Focusing on characterizing the dose-response pattern of interactions, this research seeks to determine the lowest interactive effect level. Day 20 fetuses were examined for external and skeletal malformations. The results are consistent with previous observations. Dose-related developmental toxicity was observed for 2ME both in the presence and absence of r.f. radiation. However, concurrent RF radiation exposure changed the shape of the dose-effect curve of 2ME. These data indicate that combined exposure effects should be considered when developing exposure guidelines and intervention strategies.

Nelson BK, Conover DL, Krieg EF Jr, Snyder DL, Edwards RM, Effect of environmental temperature on the interactive developmental toxicity of radiofrequency radiation and 2-methoxyethanol in rats. *Int Arch Occup Environ Health* 71(6):413-423, 1998.

OBJECTIVE: This research was conducted to determine if altered environmental temperatures would affect the interactive developmental toxicity of radiofrequency (RF) radiation and the industrial solvent, 2-methoxyethanol (2ME). This is important because RF radiation is used in a variety of workplaces that have poorly controlled environmental temperatures, and many workers are concurrently exposed to various chemicals. Furthermore, we have previously demonstrated that combined exposure to RF radiation (10 MHz) and 2ME produces enhanced teratogenicity in rats.

METHODS: RF radiation sufficient to maintain colonic temperatures at the control value (38degrees), 39.0degrees or 40.0 degrees C for 2 or 4 h combined with either 0 or 100 mg/ kg 2ME at environmental temperatures of 18 degrees , 24 degrees and

30 degrees C (65 degrees , 75 degrees , and 85 degrees F) were given on gestation day 13 to Sprague-Dawley rats. Dams were killed on gestation day 20, and the fetuses were examined for external malformations. RESULTS AND CONCLUSIONS: Environmental temperature does affect the specific absorption rate (SAR) necessary to maintain a specific colonic temperature but does not affect the interactive developmental toxicity of RF radiation and 2ME in rats. These results, consistent with the literature, add to the evidence that the developmental toxicity of RF radiation (combined or alone) is associated with colonic temperature, not with SAR.

Nelson BK, Snyder DL, Shaw PB, Developmental toxicity interactions of salicylic acid and radiofrequency radiation or 2-methoxyethanol in rats. *Reprod Toxicol* 13(2):137-145, 1999.

Radiofrequency (RF) radiation is used in a variety of workplaces where workers are concurrently exposed to chemicals. Combined exposure to RF radiation (10 MHz) and the industrial solvent, 2-methoxyethanol (2ME), produces enhanced teratogenicity in rats. The purpose of the present research was to determine if the synergistic effects noted for RF radiation and 2ME are generalizable to other chemicals. Since salicylic acid (SA) is widely used as an analgesic and is teratogenic in animals, SA was selected to address generalizability. Based on the literature and our pilot studies, 0, 250, or 350 mg/kg SA were administered by gavage on gestation Day 9 or 13 to rats. Concurrently rats given SA on Day 9 were exposed to RF radiation sufficient to maintain colonic temperature at 41 degrees C for 60 min (or sham). Those given SA on Day 13 were also given 0 or 100 mg/kg 2ME (gavage). Dams were sacrificed on gestation Day 20, and the fetuses were examined for external malformations. The data provide no evidence of synergistic interactions between RF radiation and salicylic acid (resorptions and malformations). Limited evidence of antagonism was observed between 2ME and salicylic acid (fetal weights). This investigation highlights the importance of additional research on interactions in developmental toxicology, and emphasizes the need to consider combined exposure effects when developing both physical agent and chemical agent exposure guidelines and intervention strategies.

Neshev NN, Kirilova EI, Environmental-health aspects of pulse-modulated microwaves. *Rev Environ Health* 11(1-2):85-88, 1996.

Our theoretical model describes the potential influence of irradiation with pulse-modulated microwaves on the conformational oscillations of enzymes in living organisms. Certain values of pulse-repetition time, determined by the period of conformational oscillations of the corresponding type of enzyme, can produce the effect at extremely low power levels. Synchronized oscillations in identical enzyme molecules produce in turn large-scale oscillations within living cells. Thus, short periods of exposure to pulse-modulated microwaves could be beneficial to cellular function, whereas maintaining the amplitude of such oscillations at a maximum for long periods may have a stressful effect on

biochemical processes. The model discloses the possible environmental-health risks of long-term exposure in ambient fields that are created by radar, navigation, and communication systems.

Novoselova ET, Fesenko EE, [[Stimulation of production of tumor necrosis factor by murine macrophages when exposed in vivo and in vitro to weak electromagnetic waves in the centimeter range]]. *Biofizika* 43(6):1132-11333, 1998. [Article in Russian]

Whole-body microwave sinusoidal irradiation of male NMRI mice, exposure of macrophages in vitro, and preliminary irradiation of culture medium with 8.15-18 GHz (1 Hz within) at a power density of 1 microW/cm² caused a significant enhancement of tumor necrosis factor production in peritoneal macrophages. The role of microwaves as a factor interfering with the process of cell immunity is discussed.

Novoselova, EG, Fesenko, EE, Makar, VR, Sadovnikov, VB, Microwaves and cellular immunity. II. Immunostimulating effects of microwaves and naturally occurring antioxidant nutrients. *Bioelectrochem Bioenerg*;49(1):37-41, 1999.

The effect of 8.15-18 GHz (1 Hz within) microwave radiation at a power density of 1 microW/cm² on the tumor necrosis factor (TNF) production and immune response was tested. A single 5 h whole-body exposure induced a significant increase in TNF production in peritoneal macrophages and splenic T cells. The mitogenic response in T lymphocytes increased after microwave exposure. The activation of cellular immunity was observed within 3 days after exposure. The diet containing lipid-soluble nutrients (beta-carotene, alpha-tocopherol and ubiquinone Q9) increased the activity of macrophages and T cells from irradiated mice. These results demonstrate that irradiation with low-power density microwaves stimulates the immune potential of macrophages and T cells, and the antioxidant treatment enhances the effect of microwaves, in particular at later terms, when the effect of irradiation is reduced.

Nowak B, Rosocha S, Zellerhoff C, Liebrich A, Himmrich E, Voigtlander T, Meyer J, Is there a risk for interaction between mobile phones and single lead VDD pacemakers? *Pacing Clin Electrophysiol* 19(10):1447-1450, 1996.

Mobile phones may cause pacemaker interference. Patients with a single lead VDD pacemaker might be at special risk, since the atrial sensitivity is often programmed to low (high sensitivity) threshold values and the majority of patients are pacemaker dependent due to the underlying high degree AV block. We evaluated 31 patients with three types of single lead VDD pacemakers: 12 Unity, 292-07 (Intermedics, Inc.); 10 Thera VDD, 8948 or 8968i (Medtronic, Inc.); and 9 Saphir 600 (Vitatron, Inc.) for interference from a cellular mobile phone with a power of 2 W (D-net). For this purpose, atrial and ventricular sensitivity settings were programmed to their most sensitive values (A: 0.1-0.25 mV; V: 1.0 mV) and ventricular sensing was programmed to unipolar.

With the ECG continuously monitored, the phone's extendable antenna was brought in direct contact with the patient's skin at the right sternal border, with the tip of the antenna in skin contact just below the clavicle, within 5 cm of the pacemaker connector. Then multiple phases of phone calls were performed, and the effects on the pacemakers recorded. In our group of patients with three different types of single lead VDD pacemakers, no interference could be detected using a 2-W mobile phone in the digital D-net. The programmed values remained unchanged after the interference test. Therefore, the risk of interference seems to be low for the VDD pacemakers tested, although our study design does not allow to entirely exclude the possibility of interference from a mobile phone.

Obukhan KI, [The effect of ultrahigh-frequency radiation on adaptation thresholds and the damages to blood system cells]. *Lik Sprava* (7):71-73, 1998. [Article in Ukrainian]

Cytologic investigations designed to study bone marrow, peripheral blood, spleen, and thymus of albino rats irradiated by an electromagnetic field, 2375, 2450, and 3000 MEGS, revealed structural and functional changes in populations of megakaryocytes, immunocompetent cells as well as of undifferentiated cells, and of other types of cells that are dependent on the intensity of irradiation and permit establishing the probability-threshold levels of exposure taking account of reactions of perception and physiologic adaptation together with compensatory and regenerative processes and the injury sustained. It is shown that changes in bone marrow cells differentiation and reproduction rather than integral shifts in the peripheral blood that acquire the utmost significance. Subjected to a particular scrutiny in the paper are blast cells, which cells' repopulation was noted to be getting increased in low-intensity exposure as were disturbances in their mitosis pattern.

Occhetta E, Plebani L, Bortnik M, Sacchetti G, Trevi G, Implantable cardioverter defibrillators and cellular telephones: is there any interference? *Pacing Clin Electrophysiol* 22(7):983-989, 1999.

The aim of our study was to consider cellular telephone interference using different cellular telephones and implantable cardioverter defibrillator (ICD) models. Thirty (26 men, 4 women) patients with ICDs were considered during follow-up. The ICD models were: Telectronics (7), CPI (7), Medtronic (7), Ventritex (5), and Ela Medical (4). All patients were monitored with surface ECG; permanent telemetric endo-ECG monitoring was activated. Then, the effect of two different European telephone systems were tested: TACS system (Sony CM-R111, 2W power) and GSM system (Motorola MG1-4A11, 2 W power). For both systems, the effect during call, reception, active conversation (dialogue), and passive conversation (listening) were observed. Cellular telephones were located first in contact with the programming head, then near the leads system, and lastly, in the hands of the patient. At the end of the evaluations, memories were interrogated again to check for false arrhythmia detections. In

five of these patients during arrhythmia induction at device implant (first implant or ICD replacement), we also evaluated possible interference between cellular telephones in the reception phase and the ventricular fibrillation detection phase of the ICD. All evaluated models showed significant noise in the telemetric transmission when the cellular telephone (both TACS and GSM) was located near the ICD and the programming head; noise was particularly significant during call and reception, in most cases leading to loss of telemetry. No false arrhythmia detections have been observed during tests with cellular telephones located on the ICDs. During tests performed with cellular telephones located near the leads or in the hands of patients, no telemetric noises or false arrhythmia detections were observed. During induced ventricular fibrillation and cellular telephones in reception mode near the device, the arrhythmia recognition was always correct and not delayed. In conclusion, present ICD models seem to be well protected from electromagnetic interference caused by European cellular telephones (TACS and GSM), without under-/oversensing of ventricular arrhythmias. However, cellular telephones disturb telemetry when located near the programming head. ICD patients should not be advised against the use of cellular telephones, but it has to be avoided during ICD interrogation and programming.

Ohmoto Y, Fujisawa H, Ishikawa T, Koizumi H, Matsuda T, Ito H, Sequential changes in cerebral blood flow, early neuropathological consequences and blood-brain barrier disruption following radiofrequency-induced localized hyperthermia in the rat. *Int J Hyperthermia* 12(3):321-334, 1996.

We investigated the temperature distribution, early histological changes, blood brain barrier (BBB) disruption and sequential changes in cerebral blood flow (CBF) following hyperthermia ranging from 37 to 45 degrees C in a new rat model of radiofrequency-induced localized cerebral hyperthermia. Significant histological changes and BBB disruption were observed in brain regions heated to 43 degrees C and above. In the cortex heated to 41 degrees C, the CBF doubled 20 min after hyperthermia induction, and then returned gradually to the pre-hyperthermic level. In the cortex heated to 43 degrees C, the CBF increased to 134% of the baseline level 10 min after hyperthermia induction, and then fell gradually to reach its minimum level (31% of the baseline level). In the cortex heated to 45 degrees C, the CBF decreased immediately after hyperthermia induction to reach 10% of the baseline level. The results indicate that hyperthermia-induced cellular injury in the central nervous system is associated with cerebral ischaemia and the threshold temperature for such injury is 43 degrees C. This model is useful for investigating the effects of hyperthermia on various cerebral functions and the CBF changes demonstrated in the present study may provide key information for the analysis of other cerebral functions.

Pashovkina MS, Akoev IG, [Changes in serum alkaline phosphatase activity during in vitro exposure to amplitude-modulated electromagnetic field of ultrahigh frequency (2375 MHz) in guinea pigs]. *Biofizika* 45(1):130-136, 2000.

[Article in Russian]

The activity of alkaline phosphatase by the action of pulse-modulated microwave radiation was studied. The carrier frequency of radiation was 2375 MHz, the range of modulation pulse rate was 10-390 Hz with the on-off time ratio 2, and the specific absorption rate was 8 and 0.8 microW/cm². Time of exposure was 1 and 3 min under conditions of continuous temperature control. It was shown that the activity of alkaline phosphatase depends on both modulation frequency and intensity of superhigh-frequency electromagnetic radiation. At a frequency of 70 Hz, the activity of alkaline phosphatases increased 1.8-2.0 times.

Pashovskina MS, Akoev IG, [Effects of 2375 MHz pulse-modulated microwave radiation on ATPase activity of the rat muscle actomyosin]. [Article in Russian] *Radiats Biol Radioecol* 36(5):700-705, 1996.

Solution of rat muscle actomyosin (AM) was exposed to pulse-modulated microwave. Carried frequency was 2375 MHz. The rectangular pulse modulation was in the range of 50-300 pulses per second. It was shown that AM activity was dependent both on modulation frequency as well as on microwave intensity. It was shown the frequencies of modulation which were changed ATP-ase activity of AM.

Paul Raj, R, Behari, J. Rao, AR, Effects of low level 2.45 GHz microwave radiation on Ca²⁺ efflux and ODC activity in chronically exposed developing rat brain. Presented at the 'National Seminar on Low-level Electromagnetic Field Phenomena in Biological Systems'. New Delhi, India, February, 1999.

Developing rats were exposed to 2.45 GHz microwaves (2 hrs per day for 35 days at 0.334 mW/cm²). A 1.5 fold increase in brain ODC was observed in the exposed group compared to control. An increase in calcium efflux was also observed in forebrain tissue after chronic microwave exposure.

Paulraj R, Behari J, Rao AR, Effect of amplitude modulated RF radiation on calcium ion efflux and ODC activity in chronically exposed rat brain. *Indian J Biochem Biophys* 36(5):337-340, 1999.

The effect of exposing rats to amplitude modulated radiofrequency radiation (112 MHz modulated to 16 Hz) during development and growth has been examined. Wistar rats (35 days old) when exposed at above frequency at the power level 1.0 mW/cm² (SAR, 0.75 W/kg) for 35 days showed enhanced ornithine decarboxylase activity and Ca²⁺ efflux in brain indicating potential health hazards due to exposure.

Pavel A, Ungureanu CE, Bara Il, Gassner P, Creanga DE, [Cytogenetic changes induced by low-intensity microwaves in the species *Triticum aestivum*]. *Rev Med Chir Soc Med Nat Iasi* 102(3-4):89-92, 1998. [Article in Romanian]

Seeds of *Triticum aestivum* having an uniform genophond have been exposed to a microwave flow, with a frequency of 9.75 GHz and a low intensity. The effects of microwaves at various doses on mitotic activity have been followed. Our results show that as compared to the controls different types of chromosomal aberrations appeared: delayed chromosomes, micronuclei, interchromosomal bridges, chromosomal fragments.

Penafiel LM, Litovitz T, Krause D, Desta A, Mullins JM, Role of modulation on the effect of microwaves on ornithine decarboxylase activity in L929 cells. *Bioelectromagnetics* 18(2):132-141, 1997.

The effect of 835 MHz microwaves on the activity of ornithine decarboxylase (ODC) in L929 murine cell was investigated at an SAR of approximately 2.5 W/kg. The results depended upon the type of modulation employed. AM frequencies of 16 Hz and 60 Hz produced a transient increase in ODC activity that reached a peak at 8 h of exposure and returned to control levels after 24 h of exposure. In this case, ODC was increased by a maximum of 90% relative to control levels. A 40% increase in ODC activity was also observed after 8 h of exposure with a typical signal from a TDMA digital cellular telephone operating in the middle of its transmission frequency range (approximately 840 MHz). This signal was burst modulated at 50 Hz, with approximately 30% duty cycle. By contrast, 8 h exposure with 835 MHz microwaves amplitude modulated with speech produced no significant change in ODC activity. Further investigations, with 8 h of exposure to AM microwaves, as a function of modulation frequency, revealed that the response is frequency dependent, decreasing sharply at 6 Hz and 600 Hz. Exposure with 835 MHz microwaves, frequency modulated with a 60 Hz sinusoid, yielded no significant enhancement in ODC activity for exposure times ranging between 2 and 24 h. Similarly, exposure with a typical signal from an AMPS analog cellular telephone, which uses a form of frequency modulation, produced no significant enhancement in ODC activity. Exposure with 835 MHz continuous wave microwaves produced no effects for exposure times between 2 and 24 h, except for a small but statistically significant enhancement in ODC activity after 6 h of exposure. Comparison of these results suggests that effects are much more robust when the modulation causes low-frequency periodic changes in the amplitude of the microwave carrier.

Persson BRR, Salford LG, Brun A, Blood-brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication. *Wireless Network* 3:455-461, 1997.

Biological effects of radio frequency electromagnetic fields (EMF) on the blood-brain barrier (BBB) have been studied in Fischer 344 rats of both sexes. The rats were not anesthetised during the exposure. The brains were perfused with saline for 3-4 minutes, and thereafter perfusion fixed with 4% formaldehyde for 5-6 minutes. Whole coronal sections of the brains were dehydrated and embedded in paraffin and sectioned at 5 micrometers. Albumin and fibinogen were demonstrated

immunochemically and classified as normal versus pathological leakage. In the present investigation we exposed male and female Fischer 344 rats in a Transverse Electromagnetic Transmission line chamber to microwaves of 915 MHz as continuous wave (CW) and pulse-modulated with different pulse power and at various time intervals. The CW-pulse power varied from 0.001 W to 10 W and the exposure time from 2 min to 960 min. In each experiment we exposed 4-6 rats with 2-4 controls randomly placed in excited and non-excited TEM cells, respectively. We have in total investigated 630 exposed rats at various modulation frequencies and 372 controls. The frequency of pathological rats is significantly increased ($P < 0.0001$) from 62/372 (ratio 0.17 ± 0.02) for control rats to 244/630 (ratio: 0.39 ± 0.043) in all exposed rats. Grouping the exposed animals according to the level or specific absorption energy (J/kg) give significant difference in all levels above 1.5 J/kg. The exposure was 915 MHz microwaves either pulse modulated (PW) at 217 Hz with 0.57 ms pulse width, at 50 Hz with 6.6 ms pulse width or continuous wave (CW). The frequency of pathological rats (0.17) among controls in the various groups is not significantly different. The frequency of pathological rats was 170/480 (0.35 ± 0.03) among rats exposed to pulse modulated (PW) and 74/149 (0.50 ± 0.07) among rats exposed to continuous wave exposure (CW). These results are both highly significantly different to their corresponding controls ($p < 0.0001$) and the frequency of pathological rats after exposure to pulsed radiation (PW) is significantly less ($p < 0.002$) than after exposure to continuous wave radiation (CW).

Phillips, J.L., Ivaschuk, O., Ishida-Jones, T., Jones, R.A., Campbell-Beachler, M. and Haggren, W. DNA damage in Molt-4 T- lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro. *Bioelectrochem. Bioenerg.* 45:103-110, 1998

Molt-4 T-lymphoblastoid cells have been exposed to pulsed signals at cellular telephone frequencies of 813.5625 MHz (iDEN signal) and 836.55 MHz (TDMA signal). These studies were performed at low SAR (average = 2.4 and 24 microwatt/g for iDEN and 2.6 and 26 microwatt/g for TDMA) in studies designed to look for athermal RF effects. The alkaline comet, or single cell gel electrophoresis, assay was employed to measure DNA single-strand breaks in cell cultures exposed to the radiofrequency (RF) signal as compared to concurrent sham-exposed cultures. Tail moment and comet extent were calculated as indicators of DNA damage. Statistical differences in the distribution of values for tail moment and comet extent between exposed and control cell cultures were evaluated with the Kolmogorov-Smirnoff distribution test. Data points for all experiments of each exposure condition were pooled and analyzed as single groups. It was found that: 1) exposure of cells to the iDEN signal at an SAR of 2.4 microwatt/g for 2 h or 21 h significantly decreased DNA damage; 2) exposure of cells to the TDMA signal at an SAR of 2.6 microwatt/g for 2 h and 21 h significantly decreased DNA damage; 3) exposure of cells to the iDEN signal at an SAR of 24 microwatt/g for 2 h and 21 h significantly increased DNA damage; 4) exposure of cells to the TDMA signal at an SAR of 26 microwatt/g for 2 h significantly decreased DNA damage. The data

indicate a need to study the effects of exposure to RF signals on direct DNA damage and on the rate at which DNA damage is repaired.

Preece, AW, Iwi, G, Davies-Smith, A, Wesnes, K, Butler, S, Lim, E, Varey, A, Effect of a 915-MHz simulated mobile phone signal on cognitive function in man. *Int J Radiat Biol* 75(4):447-456, 1999.

PURPOSE: To examine whether a simulated mobile telephone transmission at 915 MHz has an effect on cognitive function in man. **MATERIALS AND METHODS:** Thirty-six subjects in two groups were each given two training sessions and then three test sessions in a randomized three-way cross-over design. About 1 W mean power at 915 MHz from a quarter-wave antenna mounted on a physical copy of an analogue phone, as a sine wave, or modulated at 217 Hz with 12.5% duty cycle, or no power, was applied to the left squamous temple region of the subjects while they undertook a series of cognitive function tests lasting approximately 25-30 min. The second group was investigated for sleep, consumption of alcohol and beverages, and any other substances that might affect performance. **RESULTS:** In both groups, the only test affected was the choice reaction time and this showed as an increase in speed (a decrease in reaction time). There were no changes in word, number or picture recall, or in spatial memory. While an effect of visit-order was evident suggesting a learning effect of repeat tests, the design of the study allowed for this. Additionally, there was no systematic error introduced as a result of consumption of substances or sleep time. **CONCLUSIONS:** There was evidence of an increase in responsiveness, strongly in the analogue and less in the digital simulation, in choice reaction time. This could be associated with an effect on the angular gyrus that acts as an interface between the visual and speech centres and which lies directly under and on the same side as the antenna. Such an effect could be consistent with mild localized heating, or possibly a non-thermal response, which is nevertheless power-dependent.

Pu, JS, Chen, J, Yang, YH, Bai, YQ, The effects of 3000 MHz microwave irradiation on electroencephalic energy and energy metabolism in mouse brain. *Electro-and Magnetobiology* 16:243-247, 1997

Mice were exposed to 3000 MHz PW 1h daily for 7 days, with long axes parallel to the magnetic field in an anechoic chamber. The average power density was $5\text{mW}/\text{cm}^2$, and the estimated SAR was about 2 W/kg. There was no significant core temperature rise in the mice after exposure. After the last irradiation, mice were euthanized and the whole brain were frozen. Half of each brain were measured for SDH, and the other half for ATP. Results showed that the ATP in the brains and SDH in the hippocampus and hypothalamus in the irradiation group were significantly decreased as compared to the control. The authors suggested that the decrease in SDH caused the decrease in ATP.

Redelmeier DA, Tibshirani RJ, Association between cellular-telephone calls and motor vehicle collisions. *N Engl J Med* 13;336(7):453-458, 1997.

BACKGROUND: Because of a belief that the use of cellular telephones while driving may cause collisions, several countries have restricted their use in motor vehicles, and others are considering such regulations. We used an epidemiologic method, the case-crossover design, to study whether using a cellular telephone while driving increases the risk of a motor vehicle collision. **METHODS:** We studied 699 drivers who had cellular telephones and who were involved in motor vehicle collisions resulting in substantial property damage but no personal injury. Each person's cellular-telephone calls on the day of the collision and during the previous week were analyzed through the use of detailed billing records. **RESULTS:** A total of 26,798 cellular-telephone calls were made during the 14-month study period. The risk of a collision when using a cellular telephone was four times higher than the risk when a cellular telephone was not being used (relative risk, 4.3; 95 percent confidence interval, 3.0 to 6.5). The relative risk was similar for drivers who differed in personal characteristics such as age and driving experience; calls close to the time of the collision were particularly hazardous (relative risk, 4.8 for calls placed within 5 minutes of the accident, as compared with 1.3 for calls placed more than 15 minutes before the accident; $P < 0.001$); and units that allowed the hands to be free (relative risk, 5.9) offered no safety advantage over hand-held units (relative risk, 3.9; P not significant). Thirty-nine percent of the drivers called emergency services after the collision, suggesting that having a cellular telephone may have had advantages in the aftermath of an event. **CONCLUSIONS:** The use of cellular telephones in motor vehicles is associated with a quadrupling of the risk of a collision during the brief time interval involving a call. Decisions about regulation of such telephones, however, need to take into account the benefits of the technology and the role of individual responsibility.

Reeves GI, Review of extensive workups of 34 patients overexposed to radiofrequency radiation. *Aviat Space Environ Med* 71(3):206-215, 2000.

BACKGROUND: The medical records of 34 patients seen at the Aerospace Medicine Directorate, U.S. Air Force Research Laboratory for confirmed exposure to radiofrequency radiation (RFR) exceeding the permitted exposure limits were reviewed to see if RFR overexposure created any detectable clinical or laboratory alterations that could be correlated with power density or the product of power density and time exposed. The goal of this study was to determine which physiological and laboratory parameters required closest attention on work up of future patients with RFR exposure. **METHODS:** All 34 patients received an extensive history and physical examination, and a large battery of laboratory studies. Clinical findings were also compared with laboratory results. **RESULTS:** A sensation of warmth was positively associated with power density. A negative correlation was observed between an abnormal tissue destruction screen and power density.

Sophisticated neurological tests in 23 patients and extensive psychometric and psychological exams in 30 patients revealed no neurological or ophthalmologic findings attributable to RFR. A few patients reported burning pain that resolved over several weeks; neurological findings were minimal or absent. **CONCLUSIONS:** Patients with suspected RFR overexposures need to be seen promptly at the nearest medical facility. Based on this study, an extensive evaluation of persons overexposed to non-ionizing radiation should not be routinely performed. However, a careful history and physical examination with laboratory studies as indicated should be performed and the patient's concerns about RFR effects addressed fully.

Reiser H, Dimpfel W, Schober F, The influence of electromagnetic fields on human brain activity. *Eur J Med Res* 1(1):27-32, 1995

Possible effects of electromagnetic fields on human brain activity were studied. In a single-blind, cross-over-designed and placebo-controlled study 36 volunteers were exposed firstly to an electromagnetic field originating from a MediLine "MEGA-WAVE 150/1" therapy instrument and secondly to a field originating from a mobile, digital telephone as used for wireless telecommunication. All volunteers also underwent a control experiment with no field exposure. Application of the MEGA-WAVE instrument caused an increase in EEG power in the frequency bands Alpha2, Beta1 and Beta2 during and after field exposure. Operation of the mobile telephone caused an increase in the same frequency bands with a delay of approximately 15 minutes after exposure.

Repacholi, MH, Basten, A, Gebski, V, Noonan, D, Finnie, J, Harris, AW, Lymphomas in E mu-Pim1 transgenic mice exposed to pulsed 900 MHz electromagnetic fields. *Radiat Res* 147(5):631-640, 1997.

Whether radiofrequency (RF) fields are carcinogenic is controversial; epidemiological data have been inconclusive and animal tests limited. The aim of the present study was to determine whether long-term exposure to pulse-modulated RF fields similar to those used in digital mobile telecommunications would increase the incidence of lymphoma in E mu-Pim1 transgenic mice, which are moderately predisposed to develop lymphoma spontaneously. One hundred female E mu-Pim1 mice were sham-exposed and 101 were exposed for two 30-min periods per day for up to 18 months to plane-wave fields of 900 MHz with a pulse repetition frequency of 217 Hz and a pulse width of 0.6 ms. Incident power densities were 2.6-13 W/m² and specific absorption rates were 0.008-4.2 W/kg, averaging 0.13-1.4 W/kg. Lymphoma risk was found to be significantly higher in the exposed mice than in the controls (OR = 2.4. P = 0.006, 95% CI = 1.3-4.5). Follicular lymphomas were the major contributor to the increased tumor incidence. Thus long-term intermittent exposure to RF fields can enhance the probability that mice carrying a lymphomagenic oncogene will develop lymphomas. We suggest that such genetically cancer-prone mice provide an experimental system for more detailed assessment of dose-response relationships for risk of cancer after RF-field exposure.

Rojavin MA, Ziskin MC, Electromagnetic millimeter waves increase the duration of anaesthesia caused by ketamine and chloral hydrate in mice. *Int J Radiat Biol* 72(4):475-480, 1997.

BALB/c mice were injected i.p. with either ketamine 80 mg/kg or chloral hydrate 450 mg/kg. Anaesthetized mice were exposed to unmodulated electromagnetic millimeter waves at the frequency of 61.22 GHz with a peak specific absorption rate of 420 W/kg and corresponding incident power density of 15 mW/cm² for 15 min or sham-exposed. In combination with either of the anaesthetics used, mm waves increased the duration of anaesthesia by approximately 50% ($p < 0.05$) in a dose (power)-dependent manner. Sham exposure to mm waves did not affect the sleeping time of mice. Pretreatment of mice with naloxone, an opioid antagonist, did not change the duration of anaesthesia caused by the corresponding chemical agent, but completely blocked or decreased the additional effect of mm waves. The data in this study indicates that exposure of mice to mm waves in vivo releases endogenous opioids or enhances the activity of opioid signalling pathway.

Romano-Spica V, Mucci N, Ursini CL, Ianni A, Bhat NK, Ets1 oncogene induction by ELF-modulated 50 MHz radiofrequency electromagnetic field. *Bioelectromagnetics* 21(1):8-18, 2000.

We have analyzed gene expression in hemopoietic and testicular cell types after their exposure to 50 MHz radiofrequency (RF) non-ionizing radiation modulated (80%) with a 16 Hz frequency. The exposure system generates a 0.2 microT magnetic field parallel to the ground and a 60 V/m electric field orthogonal to the earth's magnetic field. Exposure conditions were selected so as to interfere with the calcium ion flow. Under these electromagnetic field (EMF) conditions, we observed an overexpression of the ets1 mRNA in Jurkat T-lymphoblastoid and Leydig TM3 cell lines. This effect was observed only in the presence of the 16 Hz modulation, corresponding to the resonance frequency for calcium ion with a DC magnetic field of 45.7 microT. We have also identified a putative candidate gene repressed after EMF exposure. The experimental model described in this paper may contribute to the understanding of the biological mechanisms involved in EMF effects.

Roschke, J, Mann, K, No short-term effects of digital mobile radio telephone on the awake human electroencephalogram. *Bioelectromagnetics* 18(2):172-176, 1997.

A recent study reported the results of an exploratory study of alterations of the quantitative sleep profile due to the effects of a digital mobile radio telephone. Rapid eye movement (REM) was suppressed, and the spectral power density in the 8-13 Hz frequency range during REM sleep was altered. The aim of the present study was to illuminate the influence of digital mobile radio telephone on the awake electroencephalogram (EEG) of healthy subjects. For this purpose, we investigated

34 male subjects in a single-blind cross-over design experiment by measuring spontaneous EEGs under closed-eyes condition from scalp positions C3 and C4 and comparing the effects of an active (0.05 mW/cm²) and an inactive digital mobile radio telephone (GSM) system. During exposure of nearly 3.5 min to the 900 MHz electromagnetic field pulsed at a frequency of 217 Hz and with a pulse width of 580 microseconds, we could not detect any difference in the awake EEGs in terms of spectral power density measures.

Rothman KJ, Loughlin JE, Funch DP, Dreyer NA, Overall mortality of cellular telephone customers. *Epidemiology* 7(3):303-305, 1996.

Unlike mobile cellular telephones, in which the antenna is not part of the handset, a portable cellular telephone exposes the user's head to radio frequency energy transmitted from the antenna. This exposure has prompted concerns about potential biological effects, including brain cancer. As a first step in a record-based mortality surveillance of cellular telephone customers, we report on overall mortality of a cohort of more than 250,000 portable and mobile telephone customers during 1994. We found age-specific rates to be similar for users of the two types of telephones. For customers with accounts at least 3 years old, the ratio of mortality rates in 1994 for portable telephone users, compared with mobile telephone users, was 0.86 (90% Confidence interval = 0.47-1.53).

Ryan KL, Walters TJ, Tehrany MR, Lovelace JD, Jauchem JR, Age does not affect thermal and cardiorespiratory responses to microwave heating in calorically restricted rats. *Shock* 8(1):55-60, 1997.

This study sought to determine whether age influences the thermal distribution and cardiorespiratory responses to 35 GHz microwave (MW) heating. Male Sprague-Dawley rats (n = 8/group) 3 to 4 mo old (young), 15 to 16 mo old (middle-aged), and 24 to 25 mo old (old) were used. All animals were restricted to 63% of ad libitum feed. Rats were anesthetized (ketamine) and a catheter was placed into a carotid artery for measurement of mean arterial blood pressure (MAP). Anesthetized rats were then exposed to MWs until death, while measuring MAP, heart rate and temperatures at five sites (colonic, left and right tympanic, subcutaneous, and tail). Before MW exposure, there were no significant ($p < .05$) differences among age groups in measured parameters. MW produced increases in temperature at each of the measured sites; temperatures at death did not differ between groups. Heart rate increased throughout MW exposure, in a statistically identical manner in all age groups. MAP was initially well maintained and then, in the latter phases of heating, precipitously declined until death, with no discernible age-related difference. Respiration rate was not altered by MW exposure in any group. Finally, there were no group differences in the MW exposure time required to induce death. Thus, age does not alter thermal and cardiorespiratory responses to 35 GHz MW heating in food-restricted rats.

Safronova VG, Gapeev AB, Alovskaja AA, Gabdulhakova AG, Chemeris NK,

Fesenko EE [Millimetre waves inhibit the synergistic effect of calcium ionophore A23187 and phorbol ester in neutrophil respiratory burst]. *Biofizika* 42(6):1267-1273, 1997.

[Article in Russian]

The effect of extremely high frequency electromagnetic field (mm-waves) on respiratory burst of neutrophils was studied. The peritoneal evoked neutrophils of the mice (NMRI line) were used. The production of reactive oxygen species was estimated by luminol-dependent chemiluminescence technique. Cells were irradiated by the mm-waves of 41.95 GHz in the far field zone of the channel radiator during 20 min. Absorbed energy flux density was 150 microW/cm². The irradiation was carried out at different concentrations of calcium ionophore A23187 and then neutrophils were stimulated by phorbol 12-myristate 13-acetate (PMA) 1 microM, activator of PKC. At irradiation of neutrophils the synergistic action of A23187 and PMA was not changed at low concentration of ionophore 10 nM-0.5 microM and was suppressed at high concentrations 0.5-10 microM. The largest inhibition of about 60% was obtained at the concentration of A23187 20 microM. The effect of mm-waves was not found under exposure in Ca²⁺-free medium for all used A23187 concentrations. We suggest that the mm-wave effect on the production of reactive oxygen species by neutrophils is determined by the influx of extracellular Ca²⁺ and PKC.

Sakakibara Y, Mitsui T, Concerns about sources of electromagnetic interference in patients with pacemakers. *Jpn Heart J* 40(6):737-743, 1999.

Electromagnetic noise is rapidly increasing in our environment so electromagnetic interference (EMI) with pacemakers (PM) may become a more important problem despite technological improvements in PM. The aim of this study was to evaluate the kinds of EMI which affect the quality of life of PM patients. The participants (1,942 Japanese Association for Pacemaker Patients: Pacemaker-Tomonokai) were asked to respond to a questionnaire about their major EMI troubles, and 1,567 patients (80.7%) responded by mail. The main concerns were from mobile telephones (MT) (39%), magnetic resonance imaging (MRI) (17%), electronic kitchen appliances, automobile engines and high voltage power lines. If possible, PM implantation sites should be carefully selected not only according to the physician's convenience but also considering information on each patient's habits and physical limitations.

Salford LG, Brun A, Persson BRR, Brain tumour development in rats exposed to electromagnetic fields used in wireless cellular communication. *Wireless network* 3: 463-469, 1997.

It has been suggested that electromagnetic fields (EMF) act as promoters late in the carcinogenesis process. To date, however, there is no convincing laboratory evidence that EMFs cause tumour promotion at non-thermal exposure levels. Therefore the effects of exposure to electromagnetic fields were investigated in a rat brain glioma model. Some of the exposures correspond to electromagnetic fields used in wireless communication. Microwaves at 915 MHz were used both as

continuous waves (1 W), and pulse-modulated at 4, 8, 16 and 217 Hz in 0.57 ms pulses and 50 Hz in 6.67 ms pulses (2 W per pulse). Fischer 344 rats of both sexes were used in the experiments. By stereotaxic technique rat glioma cells (RG2 and N32) were injected into the head of the right caudate nucleus in 154 pairs of rats, exposed and matched controls. Starting on day 5 after inoculation, the animals were exposed for 7 hours a day, 5 days a week during 2-3 weeks. Exposed animals were kept unanaesthetized in well-ventilated TEM cells producing 915 MHz continuous or modulated microwaves. Their matched controls were kept in identical TEM cells without EMF exposure. All brains were examined histopathologically and the tumour size was estimated as the volume of an ellipsoid. Our study of 154 matched pairs of rats does not show any significant difference in tumour size between animals exposed to 915 MHz, and those not exposed. Thus our results do not support that even an extensive daily exposure to EMF promotes tumour growth when given from the fifth day after the start of tumour growth in the rat brain until the sacrifice of the animal after about 16 days.

Sanmartin M, Fernandez Lozano I, Marquez J, Antorrena I, Bautista A, Silva L, Ortigosa J, de Artaza M, [The absence of interference between GSM mobile telephones and implantable defibrillators: an in-vivo study. Groupe Systemes Mobiles]. *Rev Esp Cardiol* 50(10):715-719, 1997. [Article in Spanish]

INTRODUCTION AND OBJECTIVES: The electromagnetic field created by mobile telephones can cause pacemaker dysfunction. Although implantable cardioverter defibrillators are also susceptible to electromagnetic interference, few studies have addressed this issue and compatibility with the GSM mode has not been tested. This study was developed to detect possible "in vivo" interference between GSM mobile telephones and implantable cardioverter defibrillators.

MATERIAL AND METHODS: The study group is composed of 30 patients with 8 different models of defibrillators. Twenty six had endocardial leads and 4 epicardial. Three GSM mobile phones were used: Siemens S3 COM and Motorola 6200 in all cases and Ericsson GA 318 in one. The tests were performed under continuous electrocardiographic monitoring. All therapies were deactivated and sensitivities were set to maximal parameters. The telephones were positioned in close contact to the defibrillator can and precordium, in two different angles. Three situations were evaluated: calling, established contact for 15 seconds and ringing. The protocol was repeated during pacing to assess the possibility of pacemaker mode inhibition. **RESULTS:** No cases of electromagnetic interference were observed. One patient presented non-sustained ventricular tachycardia episodes during the tests that were detected by the defibrillator. **CONCLUSIONS:** These results suggest that electromagnetic interference by GSM mobile phones are not a probable cause of implantable defibrillators dysfunction.

Sarkar, S, Tandem repeat sequences as markers to study microwave-DNA interaction. Presented at the 'National Seminar on Low-level Electromagnetic Field Phenomena in Biological Systems'. New Delhi, India, February, 1999.

DNA sequence was measured in cells of the testis and brain of mice exposed to 2450-MHz microwaves (2 hrs daily for 10, 150, and 200 days at an SAR of 1.18 W/kg). DNA rearrangement was consistently observed in the DNA of exposed animals. The rearrangement can be attributed to some sort of non-specific stress created by low intensity microwave field.

Schilling, CJ, Effects of acute exposure to ultrahigh radiofrequency radiation on three antenna engineers. *Occup Environ Med* 54(4):281-284, 1997.

Three men were accidentally exposed to high levels of ultrahigh frequency radiofrequency radiation (785 MHz mean frequency) while working on a television mast. They experienced an immediate sensation of intense heating of the parts of the body in the electromagnetic field followed by a variety of symptoms and signs which included pain, headache, numbness, and parasthesiae, malaise, diarrhoea, and skin erythema. The most notable problem was that of acute then chronic headache involving the part of the head which was most exposed.

Schilling CJ, Effects of exposure to very high frequency radiofrequency radiation on six antenna engineers in two separate incidents. *Occup Med* 60:49-56, 2000.

Six men are likely to have been accidentally exposed to high levels of very high frequency (VHF) radiofrequency radiation (100 MHz) while working on transmission masts; four men in one incident and two in another. They experienced symptoms and signs which included headache, parasthesiae, diarrhoea, malaise and lassitude. The condition of four men, two men from each incident likely to have had the highest exposure, has shown no significant improvement. The first incident occurred in 1995 and the second in 1996.

Schirmacher, A, Bahr, A, Kullnick, U, Stoegbauer, F, Electromagnetic fields (1.75 GHz) influence the permeability of the blood-brain barrier in cell culture model. Presented at the Twentieth Annual Meeting of the Bioelectromagnetics Society, St. Pete Beach, FL, June 1998.

An in vitro model of blood-brain barrier was used to study the effect of exposure to RFR (1.75 GHz, 217 Hz pulsed, 0.3 W/kg averaged over 1 g of tissue). Results indicate an increase of the radiation on permeability of the BBB-model. Highly significant differences between exposed and control cultures were obtained. Thermal effects could be excluded.

Schirmacher A, Winters S, Fischer S, Goeke J, Galla H, Kullnick U, Ringelstein EB, Stogbauer F, Electromagnetic fields (1.8 GHz) increase the permeability to sucrose of The blood-brain barrier in vitro. *Bioelectromagnetics* 21(5):338-345, 2000.

We report an investigation on the influence of high frequency electromagnetic fields (EMF) on the permeability of an in vitro model of the blood-brain barrier (BBB). Our model was a co-culture consisting of rat astrocytes and porcine brain capillary endothelial cells (BCEC). Samples were characterized morphologically by scanning electron microscopy and immunocytochemistry. The BBB phenotype of the BCEC was shown by the presence of zona occludens protein (ZO-1) as a marker for tight junctions and the close contact of the cells together with the absence of intercellular clefts. Permeability measurements using (14)C-sucrose indicated a physiological tightness which correlated with the morphological findings and verified the usefulness of our in vitro model. Samples were exposed to EMF conforming to the GSM1800-standard used in mobile telephones (1.8 GHz). The permeability of the samples was monitored over four days and compared with results of samples that were cultured identically but not exposed to EMF. Exposure to EMF increased permeability for (14)C-sucrose significantly compared to unexposed samples. The underlying pathophysiological mechanism remains to be investigated.

Schlegel RE, Grant FH, Raman S, Reynolds D Electromagnetic compatibility study of the in-vitro interaction of wireless phones with cardiac pacemakers. *Biomed Instrum Technol* 32(6):645-55, 1998.

This large-scale in-vitro investigation of the interaction between hand-held wireless phones and cardiac pacemakers tested 29 pacemaker models with five different phone standards. The phones were operational and suspended on a grid above a torso simulator filled with a saline bath with the pacemaker submerged at 0.5 cm. Testing consisted of 8,296 runs, during which any interactions detected were classified by type and regularity. Only a few pacemakers were responsible for a disproportionately large number of interactions. Likewise, interactions occurred during 21% of the tests using one particular phone technology, with little or no interaction resulting from use of the other standards. Other significant factors included the relative orientation of the phone and the pacemaker case, as well as the presence or absence of an injected ECG signal. The ECG signal facilitated observation of certain forms of interaction to the extent that this study indicates the importance of including an injected ECG signal in all testing. The study also supports the recommendation to maintain a separation distance of at least 6 inches between pacemakers and wireless phones. Each pacemaker reverted to its normal operation when the phone creating an interaction was turned off. This study may be useful in ongoing efforts to define test protocols, evaluate pacemaker designs, and mitigate interactions, perhaps providing the basis for future certification and screening efforts.

Schrader, SM, Langford, RE, Turner, TW, Breitenstein, MJ, Clark, JC, Jenkins, BL, Lundy DO, Simonl SD, Weyandtl TBI, Reproductive function in relation to duty assignments among military personnel. *Reprod Toxicol* 12(4):465-468, 1998.

As a follow-up to the pilot study of semen quality of soldiers with various

military assignments a larger, more complete study was conducted. Soldiers were recruited at Fort Hood, Texas. Thirty-three men were exposed to radar as part of their duty assignment in the Signal Corps, 57 men were involved with firing the 155 mm howitzer (potential lead exposure), and 103 soldiers had neither lead nor radar exposure and served as the comparison control group. Both serum and urinary follicle-stimulating hormone and luteinizing hormone and serum, salivary, and urine testosterone levels were determined in all men. A complete semen analysis was conducted on each soldier. For statistical analysis, the primary study variables were: sperm concentration, sperm/ejaculate, semen volume, percent normal morphology, percent motile, percent viable (both vital stain and hypoosmotic swelling), curvilinear velocity, straight-line velocity, linearity, sperm head length, width, area, and perimeter. Variables were adjusted for significant confounders (e.g., abstinence, sample age, race). No statistical differences ($P < 0.05$) were observed in any measurement. While these results are in agreement with two previous studies assessing soldiers firing the 155-mm howitzer, they contradict our previous report indicating that radar exposure caused a significant decrease in sperm numbers. A possible explanation is that the radar exposure in this study was that used in Signal Corps operations while the men in the previous study were using different radar as part of military intelligence operations. The data presented here in men firing the 155-mm howitzer combined with the results from the previous studies confirms that there are no deficits in semen quality in these men. The contradiction between the results of the radar exposure studies indicates that more data are needed to evaluate the relationship of military radar and male reproductive health.

Scott, IR, Tattersall, JEH The effects of radiofrequency radiation on long term potentiation in rat hippocampal slices. Presented at the Twenty-first Annual Meeting of the Bioelectromagnetics Society, Long Beach, CA, June 1999.

Long term potentiation in rat hippocampal slice can be modified in vitro by exposure to both CW and GSM RF fields and are consistent with in vivo studies which suggest that exposure to microwave fields can affect the performance of rats in a radial arm maze task.

Seaman RL, Belt ML, Doyle JM, Mathur SP, Ultra-wideband electromagnetic pulses and morphine-induced changes in nociception and activity in mice. *Physiol Behav* 65(2):263-270, 1998.

Mice were exposed to ultra-wideband (UWB) electromagnetic pulses averaging 99-105 kV/m peak amplitude, 0.97-1.03 ns duration, and 155-174 ps rise time, after intraperitoneal administration of saline or morphine sulfate. They were then tested for thermal nociception on a 50 degrees C surface and for spontaneous locomotor activity and its time profile over 5 min. Analysis of results showed no effect of UWB exposure on nociception and activity measures in CF-1 mice after 15-, 30-, or 45-min exposure to pulses at 600/s or after 30-min exposure to UWB pulses at 60/s. Similarly, no effect was seen in C57BL/6 mice after 30-min exposure to pulses at 60/s or 600/s. Although trends in morphine-modified measures seen with UWB pulse

repetition frequency could be expected because of increased levels of low-frequency energy, no significant change was seen in normal or morphine-modified nociception or activity after UWB exposure. This indicated lack of effect of the UWB pulses used in these experiments on nervous system components, including endogenous opioids, involved in these behaviors.

Seaman RL, Belt ML, Doyle JM, Mathur SP, Hyperactivity caused by a nitric oxide synthase inhibitor is countered by ultra-wideband pulses. *Bioelectromagnetics* 20(7):431-439, 1999.

Potential action of ultra-wideband (UWB) electromagnetic field pulses on effects of N(G)-nitro-L-arginine methyl ester (L-NAME), an inhibitor of nitric oxide synthase (NOS), on nociception and locomotor activity was investigated in CF-1 mice. Animals were injected IP with saline or 50 mg/kg L-NAME and exposed for 30 min to no pulses (sham exposure) or UWB pulses with electric field parameters of 102 ± 1 kV/m peak amplitude, 0.90 ± 0.05 ns duration, and 160 ± 5 ps rise time (mean \pm S.D.) at 600/s. Animals were tested for thermal nociceptive responses on a 50 degrees C surface and for spontaneous locomotor activity for 5 min. L-NAME by itself increased mean first-response (paw lift, shake, or lick; jump) and back-paw-lick response latencies and mean locomotor activity. Exposure to UWB pulses reduced the L-NAME-induced increase in back-paw-lick latency by 22%, but this change was not statistically significant. The L-NAME-induced hyperactivity was not present after UWB exposure. Reduction and cancellation of effects of L-NAME suggest activation of opposing mechanism(s) by the UWB pulses, possibly including increase of nitric oxide production by NOS. The action, or actions, of UWB pulses appears to be more effective on locomotor activity than on thermal nociception in CF-1 mice.

Sienkiewicz ZJ, Blackwell RP, Haylock RG, Saunders RD, Cobb BL, Low-level exposure to pulsed 900 MHz microwave radiation does not cause deficits in the performance of a spatial learning task in mice. *Bioelectromagnetics* 21(3):151-158, 2000.

There is some concern that short-term memory loss or other cognitive effects may be associated with the use of mobile cellular telephones. In this experiment, the effect of repeated, acute exposure to a low intensity 900 MHz radiofrequency (RF) field pulsed at 217 Hz was explored using an appetitively-motivated spatial learning and working memory task. Adult male C57BL/6J mice were exposed under far field conditions in a GTEM cell for 45 min each day for 10 days at an average whole-body specific energy absorption rate (SAR) of 0.05 W/kg. Their performance in an 8-arm radial maze was compared to that of sham-exposed control animals. All behavioral assessments were performed without handlers having knowledge of the exposure status of the animals. Animals were tested in the maze immediately following exposure or after a delay of 15 or 30 min. No significant field-dependent effects on performance were observed in choice accuracy or in total times to complete the task across the experiment. These results suggest that exposure to RF radiation simulating a

digital wireless telephone (GSM) signal under the conditions of this experiment does not affect the acquisition of the learned response. Further studies are planned to explore the effects of other SARs on learned behavior.

Sparks PB, Mond HG, Joyner KH, Wood MP, The safety of digital mobile cellular telephones with minute ventilation rate adaptive pacemakers. *Pacing Clin Electrophysiol* 19(10):1451-1455, 1996.

In vitro tests suggest that rate adaptive pacemakers using changes in transthoracic impedance to vary pacing rate may be affected by digital mobile telephones. Electromagnetic fields generated by digital mobile telephones (Global System for Mobile [GSM]) represent a potential source of electromagnetic interference (EMI) for the Telectronics META rate adaptive pacemakers, which use transthoracic impedance as a sensor to determine changes in minute ventilation. Sixteen implanted Telectronics META pulse generators were exposed to 25-W simulated GSM transmissions (900-MHz carrier pulsed at 2, 8, and 217 Hz with a pulse width of 0.6 ms) and the antenna of a 2-W digital mobile telephone (900-MHz, 217-Hz pulse, 0.6-ms pulse width). The 12 dual and four single chamber devices were programmed to maximum sensitivity and assessed in unipolar and bipolar settings and rate adaptive and nonrate adaptive modes. In all cases of EMI, testing was repeated at lower, more routinely set bipolar sensitivity levels. At maximum sensitivity, 11 of 16 devices displayed no evidence of EMI. Brief ventricular triggering occurred in 2, a brief pause in 1, a combination of both in 1, and a brief episode of pacemaker-mediated tachycardia in 1. With pulse generators programmed to more routine sensitivities, only one device displayed rare single beat ventricular triggering. No changes in minute ventilation rate adaptive pacing were observed. At maximum unipolar sensitivities, the META series of rate adaptive pacemakers are resistant to clinically important EMI from digital mobile telephones. Set at routine sensitivities, these devices perform reliably in the presence of digital mobile telephones.

Stagg RB, Thomas WJ, Jones RA, Adey WR, DNA synthesis and cell proliferation in C6 glioma and primary glial cells exposed to a 836.55 MHz modulated radiofrequency field. *Bioelectromagnetics* 18(3):230-236, 1997.

We have tested the hypothesis that modulated radiofrequency (RF) fields may act as a tumor-promoting agent by altering DNA synthesis, leading to increased cell proliferation. In vitro tissue cultures of transformed and normal rat glial cells were exposed to an 836.55 MHz, packet-modulated RF field at three power densities: 0.09, 0.9, and 9 mW/cm², resulting in specific absorption rates (SARs) ranging from 0.15 to 59 μ W/g. TEM-mode transmission-line cells were powered by a prototype time-domain multiple-access (TDMA) transmitter that conforms to the North American digital cellular telephone standard. One sham and one energized TEM cell were placed in standard incubators maintained at 37 degrees C and 5% CO₂. DNA synthesis experiments at 0.59-59 μ W/g SAR were performed on log-phase and

serum-starved semiquiescent cultures after 24 h exposure. Cell growth at 0.15-15 $\mu\text{W/g}$ SAR was determined by cell counts of log-phase cultures on days 0, 1, 5, 7, 9, 12, and 14 of a 2 week protocol. Results from the DNA synthesis assays differed for the two cell types. Sham-exposed and RF-exposed cultures of primary rat glial cells showed no significant differences for either log-phase or serum-starved condition. C6 glioma cells exposed to RF at 5.9 $\mu\text{W/g}$ SAR (0.9 mW/cm^2) exhibited small (20-40%) significant increases in 38% of [^3H]thymidine incorporation experiments. Growth curves of sham and RF-exposed cultures showed no differences in either normal or transformed glial cells at any of the power densities tested. Cell doubling times of C6 glioma cells [sham (21.9 \pm 1.4 h) vs. field (22.7 \pm 3.2 h)] also demonstrated no significant differences that could be attributed to altered DNA synthesis rates. Under these conditions, this modulated RF field did not increase cell proliferation of normal or transformed cultures of glial origin.

Stark KD, Krebs T, Altpeter E, Manz B, Griot C, Abelin T, Absence of chronic effect of exposure to short-wave radio broadcast signal on salivary melatonin concentrations in dairy cattle. *J Pineal Res* 22(4):171-176, 1997

A pilot study was conducted to investigate the influence of electromagnetic fields in the short-wave range (3-30 MHz) radio transmitter signals on salivary melatonin concentration in dairy cattle. The hypothesis to be tested was whether EMF exposure would lower salivary melatonin concentrations, and whether removal of the EMF source would be followed by higher concentration levels. For this pilot study, a controlled intervention trial was designed. Two commercial dairy herds at two farms were compared, one located at a distance of 500 m (exposed), the other at a distance of 4,000 m (unexposed) from the transmitter. At each farm, five cows were monitored with respect to their salivary melatonin concentrations over a period of ten consecutive days. Saliva samples were collected at two-hour intervals during the dark phase of the night. As an additional intervention, the short-wave transmitter was switched off during three of the ten days (off phase). The samples were analyzed using a radioimmunoassay. The average nightly field strength readings were 21-fold greater on the exposed farm (1.59 mA/m) than on the control farm (0.076 mA/m). The mean values of the two initial nights did not show a statistically significant difference between exposed and unexposed cows. Therefore, a chronic melatonin reduction effect seemed unlikely. However, on the first night of re-exposure after the transmitter had been off for three days, the difference in salivary melatonin concentration between the two farms (3.89 pg/ml , CI: 2.04, 7.41) was statistically significant, indicating a two- to seven-fold increase of melatonin concentration. Thus, a delayed acute effect of EMF on melatonin concentration cannot completely be excluded. However, results should be interpreted with caution and further trials are required in order to confirm the results.

Szmigielski, S, Cancer morbidity in subjects occupationally exposed to high frequency (radiofrequency and microwave) electromagnetic radiation. *Sci Total Environ* 180(1):9-17, 1996.

Cancer morbidity was registered in the whole population of military career personnel in Poland during a period of 15 years (1971-1985). Subjects exposed occupationally to radiofrequencies (RF) and microwaves (MW) were selected from the population on the basis of their service records and documented exposures at service posts. The population size varied slightly from year to year with a mean count of about 128,000 persons each year; each year about 3700 of them (2.98%) were considered as occupationally exposed to RF/MW. All subjects (exposed and non-exposed to RF/MW) were divided into age groups (20-29, 30-39, 40-49 and 50-59). All newly registered cases of cancer were divided into 12 types based on localisation of the malignancy; for neoplasms of the haemopoietic system and lymphatic organs an additional analysis based on diagnosis was performed. Morbidity rates (per 100,000 subjects annually) were calculated for all of the above localisations and types of malignancies both for the whole population and for the age groups. The mean value of 15 annual rates during 1971-1985 represented the respective morbidity rate for the whole period. Morbidity rates in the non-exposed groups of personnel were used as 'expected' (E) rates for the exposed subjects, while the real morbidity rates counted in the RF/MW-exposed personnel served as 'observed' (O) rates. This allowed the calculation of the observed/expected ratio (OER) representing the odds ratio for the exposed groups. The cancer morbidity rate for RF/MW-exposed personnel for all age groups (20-59 years) reached 119.1 per 100,000 annually (57.6 in non-exposed) with an OER of 2.07, significant at $P < 0.05$. The difference between observed and expected values results from higher morbidity rates due to neoplasms of the alimentary tract (OER = 3.19-3.24), brain tumours (OER = 1.91) and malignancies of the haemopoietic system and lymphatic organs (OER = 6.31). Among malignancies of the haemopoietic/lymphatic systems, the largest differences in morbidity rates between exposed and non-exposed personnel were found for chronic myelocytic leukaemia (OER = 13.9), acute myeloblastic leukaemia (OER = 8.62) and non-Hodgkin lymphomas (OER = 5.82).

Szmigielski, S, Bortkiewicz, A, Gadzicka, E, Zmyslony, M, Kubacki, R, Alteration of diurnal rhythms of blood pressure and heart rate to workers exposed to radiofrequency electromagnetic fields. *Blood Press Monit* 3(6):323-330, 1998.

BACKGROUND: In previous studies we found measurable effects on variability of heart rate and on blood-pressure parameters of workers exposed to radiofrequency electromagnetic fields (EMF) compared with a control population, but none of the effects could be assigned clinical significance. In general, the obtained results strongly suggested that dysregulation of the autonomic control of the circulatory system was occurring. Therefore, it seemed logical that analysis of diurnal rhythms of blood pressure and heart rate, on the basis of data from 24 h recordings, might

further support the above hypothesis. **OBJECTIVE:** The aim of this study was to determine the course of diurnal rhythms of blood pressure and heart rate in a group of workers exposed to various intensities of radiofrequency electromagnetic fields. **METHODS:** In the study we used 61 healthy workers (aged 30-50 years) who had been exposed to radiofrequency EMF of 0.738-1.503 Mhz and 42 healthy workers at radio-line stations (aged 28-49 years), who had not been exposed to EMF occupationally. The work patterns of these two groups were identical (12 h day working shift, 24 h interval, 12 h night shift and then 48 h rest). During the second day of the rest period 24 h ambulatory blood pressure (ABP) was recorded. For analysis of diurnal rhythms the group of exposed workers was divided into two subgroups: group A of 38 subjects exposed to low intensities of radiofrequency EMF (20-180 V/m) and group B of 23 subjects exposed to high intensities of radiofrequency EMF (200-550 V/m). Parameters of diurnal rhythms of blood pressure and heart rate (acrophase, amplitude and mean) were calculated by performing a least-square fit of a 24 h cosinor (single cosinor analysis) at $P < 0.05$. **RESULTS:** Healthy men aged 28-49 years, working on a pattern of 12-24-12-48 h, exhibited typical, well-preserved diurnal rhythms of blood pressure and heart rate with two maxima (at about 1400 and 1700-1800 h) and one minimum (at about 0200-0400 h). For workers exposed to radiofrequency EMF we noted a significant lowering of the amplitudes of rhythms of blood pressure and heart rate ($P < 0.01$) and a shift of the acrophase to an earlier time (1100-1200 h; $P < 0.05$). These changes were more pronounced among workers exposed to high intensities of radiofrequency EMF. **CONCLUSIONS:** Occupational exposure to radiofrequency EMF can result in changes of the diurnal rhythms of blood pressure and heart rate with lowering of their amplitudes and a shift of the acrophase. The clinical relevance of the present finding needs to be investigated in further studies.

Tattersell, JEH, Nettell, JJ, Wood, SJ, Suppression of evoked and spontaneous field potentials by radiofrequency radiation in rat hippocampal slices. Presented at the Twentieth Annual Meeting of the Bioelectromagnetics Society, St. Pete Beach, FL, June 1998.

700 MHz RFR at field intensities below current safety guidelines can influence evoked and spontaneous activity in the rat hippocampus without causing measurable changes in temperature.

Trigano AJ, Azoulay A, Rochdi M, Campillo, A Electromagnetic interference of external pacemakers by walkie-talkies and digital cellular phones: experimental study. *Pacing Clin Electrophysiol* 22(4 Pt 1):588-593, 1999.

A number of experimental and clinical studies have documented the risk potential of interference with implanted pacemakers by various types of cellular phones. Radiofrequency susceptibility of external medical equipment has also been reported in experimental studies. The purpose of this experimental study was to evaluate electromagnetic interference of external pacemakers by walkie-talkies and digital cellular telephones. External bipolar

pacing was monitored using a digital oscilloscope to record pacemaker pulses and electromagnetic interference separately. Tests with the walkie-talkie, Private Mobile Radio (PMR) (160 MHz, 2.5 W) were conducted during the calling phase. Tests with the cellular phones, global system for mobile communications (GSM) (900 MHz, 2 W) and Digital Cellular System (DCS) (1,800 MHz, 1 W) were conducted in the test mode. Nine widely used external pacemakers from four manufacturers were tested. Various disturbances including pacing inhibition and asynchronous pacing were observed in eight pacemakers by the PMR, in four by the GSM phone, and in two by the DCS phone. The maximum distance that interference persisted ranged from 10-200 cm. This experimental study shows a potential risk of interference of external pacemakers by walkie-talkies and cellular digital phones. Appropriate warnings should be issued against the potentially serious risks of using communication devices in the vicinity of acutely ill patients treated with temporary transvenous cardiac pacemakers.

Trosic I, Matausicpisl M, Radalj Z, Prlic I, Animal study on electromagnetic field biological potency. *Arh Hig Rada Toksikol* 50(1):5-11, 1999.

This recent basic research study used an animal model protocol to assess specific biomarkers of the effect of non-ionising, non-thermal radiation (2450 MHz microwave radiation at 5-15 mW/cm²) on bone marrow, peripheral blood, and bronchoalveolar free cell populations. Of 40 male Wistar rats taken in the study, 20 animals of the experimental group were irradiated for 2 hours a day, 5 days a week, and subsequently killed on days 1, 8, 16, and 30 of the experiment. The remaining 20 rats served as control. All animals were previously intratracheally instilled with biologically inert microspheres to see the influence of irradiation on lung retention kinetics. The cell response to chosen electromagnetic irradiation was followed quantitatively and qualitatively using the standard laboratory methods. The results of peripheral blood cell response suggested a decreasing tendency in total leukocyte count and in relative lymphocyte count in the treated group. A slight increase was also observed in granulocyte count and in the absolute count of peripheral blood erythrocytes over control animals.

Tsurita G, Nagawa H, Ueno S, Watanabe S, Taki M, Biological and morphological effects on the brain after exposure of rats to a 1439 MHz TDMA field. *Bioelectromagnetics* 21(5):364-371, 2000.

We investigated the effects of exposure to a 1439 MHz TDMA (Time Division Multiple Access) field, as used in cellular phones, on the permeability of the blood-brain barrier (BBB), on the morphological changes of the brain, and on body-mass fluctuations. Male Sprague-Dawley (SD) rats were divided into Three groups of eight rats each. The rats in the EM(+) group, which had their heads arrayed in a circle near the central antenna of an exposure system, were exposed to a 1439 MHz field for one hour a day. The rats in EM(-) group were also in the exposure system, however, without high-frequency electromagnetic wave (HF-EMW) exposure. The animals in the control group were neither placed in the system nor exposed to HF-EMWs. The exposure period was two or four weeks. The energy dose rate peaked at 2 W/kg in

the brain; the average over the whole body was 0.25 W/kg. The changes in the permeability of BBB were investigated by Evans blue injection method and by immunostaining of serum albumin. HF-EMWs had no effect on the permeability of BBB. The morphological changes in the cerebellum were investigated by assessing the degeneration of Purkinje cells and the cell concentration in the granular layer. No significant changes were observed in the groups of rats exposed to HF-EMWs for two or four weeks. Averaged body masses were not affected by HF-EMWs exposure. In conclusion, a 1439 MHz TDMA field did not induce observable changes in the permeability of the BBB, morphological changes in the cerebellums, or body mass changes in rats, as evaluated by the conventional methods.

Tuschl, H, Neubauer, G, Garn, H, Duftschmid, K, Winker, N, Brusl, H, Occupational exposure to high frequency electromagnetic fields and its effect on human immune parameters. *Int J Occup Med Environ Health*;12(3):239-251, 1999.

The present study recorded a considerable excess of recommended exposure limits in the vicinity of shortwave diathermy devices used for medical treatment of patients. Different kinds of field probes were used to measure electric and magnetic field strength and the whole body exposure of medical personnel operating shortwave, decimeter wave and microwave units was calculated. To investigate the influence of chronic exposure on the immune system of operators, blood was sampled from physiotherapists working at the above mentioned devices. Eighteen exposed and thirteen control persons, matched by sex and age, were examined. Total leucocyte and lymphocyte counts were performed and leucocytic subpopulations determined by flow cytometry and monoclonal antibodies against surface antigens. In addition, to quantify subpopulations of immunocompetent cells, the activity of lymphocytes was measured. Lymphocytes were stimulated by mitogen phytohemagglutinin and their proliferation measured by a flow cytometric method. No statistically significant differences between the control and exposed persons were found. In both study groups all immune parameters were within normal ranges.

Tynes T, Hannevik M, Andersen A, Vistnes AI, Haldorsen T, Incidence of breast cancer in Norwegian female radio and telegraph operators. *Cancer Causes Control* 7(2):197-204, 1996.

Exposure to electromagnetic fields may cause breast cancer in women if it increases susceptibility to sex-hormone-related cancer by diminishing the pineal gland's production of melatonin. We have studied breast cancer incidence in female radio and telegraph operators with potential exposure to light at night, radio frequency (405 kHz-25 MHz), and, to some extent, extremely low frequency fields (50 Hz). We linked the Norwegian Telecom cohort of female radio and telegraph operators working at sea to the Cancer Registry of Norway to study incident cases of breast cancer. The cohort consisted of 2,619 women who were certified to work as radio and telegraph operators between 1920 and 1980. Cancer incidence was analyzed on the basis of the standardized incidence

ratio (SIR), with the Norwegian female population as the comparison group. The incidence of all cancers was close to unity (SIR = 1.2). An excess risk was seen for breast cancer (SIR = 1.5). Analysis of a nested case-control study within the cohort showed an association between breast cancer in women aged 50+ years and shift work. In a model with adjustment for age, calendar year, and year of first birth, the rate ratio for breast cancer associated with being a radio and telegraph operator--in comparison with all Norwegian women born 1935 or later--analyzed with Poisson regression, was 1.5 after adjustment for fertility factors. These results support a possible association between work as a radio and telegraph operator and breast cancer. Future epidemiologic studies on breast cancer in women aged 50 and over, should address possible disturbances of chronobiological parameters by environmental factors.

Urban, P, Lukas, E, Roth, Z, Does acute exposure to the electromagnetic field emitted by a mobile phone influence visual evoked potentials? A pilot study. *Cent Eur J Public Health* 6(4):288-290, 1998.

To search for a potential negative influence on the central nervous system (CNS) of the electromagnetic field emitted by a mobile phone, the authors performed a pilot experimental study of the influence of a single short acute exposure to the GSM mobile phone Motorola 8700, using visual evoked potentials (VEP) examination as an electrophysiological marker of CNS dysfunction. The study group consisted of 20 healthy volunteers. The duration of exposure was 5 minutes. The output power of the device was 1.5 W when the antenna was pulled up. Five parameters of VEP were evaluated by means of multifactorial ANOVA. Confounding effects of age, sex, and of the call in itself were taken into consideration. No statistically significant influence of the above-described exposure to the electromagnetic field emitted by the mobile phone on latencies or amplitudes of VEP was observed.

Urech, M, Eicher, B, Siegenthaler, J, Effects of microwave and radio frequency electromagnetic fields on lichens. *Bioelectromagnetics* 17(4):327-334, 1996.

The effects of electromagnetic fields on lichens were investigated. Field experiments of long duration (1-3 years) were combined with laboratory experiments and theoretical considerations. Samples of the lichen species *Parmelia tiliacea* and *Hypogymnia physodes* were exposed to microwaves (2.45 GHz; 0.2, 5, and 50 mW/cm²; and control). Both species showed a substantially reduced growth rate at 50 mW/cm². A differentiation between thermal and nonthermal effects was not possible. Temperature measurements on lichens exposed to microwaves (2.45 GHz, 50 mW/cm²) showed a substantial increase in the surface temperature and an accelerated drying process. The thermal effect of microwave on lichens was verified. The exposure of lichens of both species was repeated near a short-wave broadcast transmitter (9.5 MHz, amplitude modulated; maximum field strength 235 V/m, 332 mA/m). No visible effects on the exposed lichens were detected. At this frequency, no thermal effects were expected, and the experimental results support this hypothesis. Theoretical estimates based on climatic data and literature showed that

the growth reductions in the initial experiments could very likely have been caused by drying of the lichens from the heating with microwaves. The results of the other experiments support the hypothesis that the response of the lichens exposed to microwaves was mainly due to thermal effects and that there is a low probability of nonthermal effects.

Van Leeuwen GM, Lagendijk JJ, Van Leersum BJ, Zwamborn AP, Hornsleth SN, Kotte AN, Calculation of change in brain temperatures due to exposure to a mobile phone. *Phys Med Biol* 44(10):2367-2379, 1999.

In this study we evaluated for a realistic head model the 3D temperature rise induced by a mobile phone. This was done numerically with the consecutive use of an FDTD model to predict the absorbed electromagnetic power distribution, and a thermal model describing bioheat transfer both by conduction and by blood flow. We calculated a maximum rise in brain temperature of 0.11 degrees C for an antenna with an average emitted power of 0.25 W, the maximum value in common mobile phones, and indefinite exposure. Maximum temperature rise is at the skin. The power distributions were characterized by a maximum averaged SAR over an arbitrarily shaped 10 g volume of approximately 1.6 W kg(-1). Although these power distributions are not in compliance with all proposed safety standards, temperature rises are far too small to have lasting effects. We verified our simulations by measuring the skin temperature rise experimentally. Our simulation method can be instrumental in further development of safety standards.

Velizarov, S, Raskmark, P, Kwee, S, The effects of radiofrequency fields on cell proliferation are non-thermal. *Bioelectrochem Bioenerg* 48(1):177-180, 1999.

The number of reports on the effects induced by radiofrequency (RF) electromagnetic fields and microwave (MW) radiation in various cellular systems is still increasing. Until now no satisfactory mechanism has been proposed to explain the biological effects of these fields. One of the current theories is that heat generation by RF/MW is the cause, in spite of the fact that a great number of studies under isothermal conditions have reported significant cellular changes after exposure to RF/MW. Therefore, this study was undertaken to investigate which effect MW radiation from these fields in combination with a significant change of temperature could have on cell proliferation. The experiments were performed on the same cell line, and with the same exposure system as in a previous work [S. Kwee, P. Raskmark, Changes in cell proliferation due to environmental non-ionizing radiation: 2. Microwave radiation, *Bioelectrochem. Bioenerg.*, 44 (1998), pp. 251-255]. The field was generated by signal simulation of the Global System for Mobile communications (GSM) of 960 MHz. Cell cultures, growing in microtiter plates, were exposed in a specially constructed chamber, a Transverse Electromagnetic (TEM) cell. The Specific Absorption Rate (SAR) value for each cell well was calculated for this exposure system. However, in this study the cells were exposed to the field at a higher or lower temperature than the temperature in the field-free incubator i.e., the temperature in the TEM cell was either 39 or 35 +/- 0.1 degrees C. The

corresponding sham experiments were performed under exactly the same experimental conditions. The results showed that there was a significant change in cell proliferation in the exposed cells in comparison to the non-exposed (control) cells at both temperatures. On the other hand, no significant change in proliferation rate was found in the sham-exposed cells at both temperatures. This shows that biological effects due to RF/MW cannot be attributed only to a change of temperature. Since the RF/MW induced changes were of the same order of magnitude at both temperatures and also comparable to our previous results under isothermal conditions at 37 degrees C, cellular stress caused by electromagnetic fields could initiate the changes in cell cycle reaction rates. It is widely accepted that certain classes of heat-shock proteins are involved in these stress reactions.

Von Klitzing, L, Low-frequency pulsed electromagnetic fields influence EEG of man. *Phys. Medica* 11:77-80, 1995.

New techniques using low-frequency pulsed electromagnetic fields (e.g., digital telecommunication) have raised the question for interference with the biological system of man. EEG data of man sampled under the influence of these electromagnetic fields are altered extremely in the range of alpha-activity as well as during after exposure for some hours. The biological effect is induced by field intensities lower than the given international limiting values.

Vijayalaxmi, Mohan, N, Meltz, ML, Wittler, MA, Proliferation and cytogenetic studies in human blood lymphocytes exposed in vitro to 2450 MHz radiofrequency radiation. *Int J Radiat Biol* 72(6):751-757, 1997.

Aliquots of human peripheral blood collected from two healthy human volunteers were exposed in vitro to continuous wave 2450 MHz radiofrequency radiation (RFR), either continuously for a period of 90 min or intermittently for a total exposure period of 90 min (30 min on and 30 min off, repeated three times). Blood aliquots which were sham-exposed or exposed in vitro to 150 cGy gamma radiation served as controls. The continuous wave 2450 MHz RFR was generated with a net forward power of 34.5 W and transmitted from a standard gain rectangular antenna horn in a vertically downward direction. The mean power density at the position of the cells was 5.0 mW/cm². The mean specific absorption rate calculated by Finite Difference Time Domain analysis was 12.46 W/kg. Immediately after exposure, lymphocytes were cultured for 48 and 72 h to determine the incidence of chromosomal aberrations and micronuclei, respectively. Proliferation indices were also recorded. There were no significant differences between RFR-exposed and sham-exposed lymphocytes with respect to; (a) mitotic indices; (b) incidence of cells showing chromosome damage; (c) exchange aberrations; (d) acentric fragments; (e) binucleate lymphocytes, and (f) micronuclei, for either the continuous or intermittent RFR exposures. In contrast, the response of positive control cells exposed to 150 cGy gamma radiation was significantly different from RFR-exposed and sham-exposed lymphocytes. Thus, there is no evidence for an effect on mitogen-stimulated proliferation kinetics or for excess genotoxicity within 72 h in human blood lymphocytes exposed in vitro to 2450 MHz RFR.

Vijayalaxmi, Frei, MR, Dusch, SJ, Guel, V, Meltz, ML, Jauchem, JR, Frequency of micronuclei in the peripheral blood and bone marrow of cancer-prone mice chronically exposed to 2450 MHz radiofrequency radiation. *Radiat Res* 147(4):495-500, 1997.

C3H/HeJ mice, which are prone to mammary tumors, were exposed for 20 h/day, 7 days/week, over 18 months to continuous-wave 2450 MHz radiofrequency (RF) radiation in circularly polarized wave guides at a whole-body average specific absorption rate of 1.0 W/kg. Sham-exposed mice were used as controls. The positive controls were the sentinel mice treated with mitomycin C during the last 24 h before necropsy. At the end of the 18 months, all mice were necropsied. Peripheral blood and bone marrow smears were examined for the extent of genotoxicity as indicated by the presence of micronuclei in polychromatic erythrocytes (PCEs). The results indicate that the incidence of micronuclei/1,000 PCEs was not significantly different between groups exposed to RF radiation (62 mice) and sham-exposed groups (58 mice), and the mean frequencies were 4.5 +/- 1.23 and 4.0 +/- 1.12 in peripheral blood and 6.1 +/- 1.78 and 5.7 +/- 1.60 in bone marrow, respectively. In contrast, the positive controls (7 mice) showed a significantly elevated incidence of micronuclei/1,000 PCEs in peripheral blood and bone marrow, and the mean frequencies were 50.9 +/- 6.18 and 55.2 +/- 4.65, respectively. When the animals with mammary tumors were considered separately, there were no significant differences in the incidence of micronuclei/1,000 PCEs between the group exposed to RF radiation (12 mice) and the sham-exposed group (8 mice), and the mean frequencies were 4.6 +/- 1.03 and 4.1 +/- 0.89 in peripheral blood and 6.1 +/- 1.76 and 5.5 +/- 1.51 in bone marrow, respectively. Thus there was no evidence for genotoxicity in mice prone to mammary tumors that were exposed chronically to 2450 MHz RF radiation compared with sham-exposed controls. ***A correction was published in a subsequent issue of the journal, stating that there was actually a significant increase in micronucleus formation in peripheral blood and bone marrow cells after chronic exposure to the radiofrequency radiation.***

“Vijayalaxmi, Frei, MR, Dusch, SJ, Guel, V, Meltz, ML, Jauchem, JR, Correction of an error in calculation in the article "Frequency of micronuclei in the peripheral blood and bone marrow of cancer-prone mice chronically exposed to 2450 MHz radiofrequency radiation" (*Radiat. Res.* 147, 495-500, 1997). *Radiat Res* 149(3):308, 1998 “

Vijayalaxmi, Leal BZ, Szilagyi M, Prihoda TJ, Meltz ML, Primary DNA Damage in Human Blood Lymphocytes Exposed In Vitro to 2450 MHz Radiofrequency Radiation. *Radiat Res* 153(4):479-486, 2000.

Human peripheral blood samples collected from three healthy human volunteers were exposed in vitro to pulsed-wave 2450 MHz radiofrequency (RF) radiation for 2 h. The RF radiation was generated with a net forward power of 21 W and transmitted from a standard gain rectangular antenna horn in a vertically downward direction. The average power density at the position of the cells in the flask was 5 mW/cm².

The mean specific absorption rate, calculated by finite difference time domain analysis, was 2.135 (+/-0.005 SE) W/kg. Aliquots of whole blood that were sham-exposed or exposed in vitro to 50 cGy of ionizing radiation from a (137)Cs gamma-ray source were used as controls. The lymphocytes were examined to determine the extent of primary DNA damage (single-strand breaks and alkali-labile lesions) using the alkaline comet assay with three different slide-processing schedules. The assay was performed on the cells immediately after the exposures and at 4 h after incubation of the exposed blood at 37 +/- 1 degrees C to allow time for rejoining of any strand breaks present immediately after exposure, i.e. to assess the capacity of the lymphocytes to repair this type of DNA damage. At either time, the data indicated no significant differences between RF-radiation- and sham-exposed lymphocytes with respect to the comet tail length, fluorescence intensity of the migrated DNA in the tail, and tail moment. The conclusions were similar for each of the three different comet assay slide-processing schedules examined. In contrast, the response of lymphocytes exposed to ionizing radiation was significantly different from RF-radiation- and sham-exposed cells. Thus, under the experimental conditions tested, there is no evidence for induction of DNA single-strand breaks and alkali-labile lesions in human blood lymphocytes exposed in vitro to pulsed-wave 2450 MHz radiofrequency radiation, either immediately or at 4 h after exposure.

Vijayalaxmi, Seaman RL, Belt ML, Doyle JM, Mathur SP, Prihoda TJ, Frequency of micronuclei in the blood and bone marrow cells of mice exposed to ultra-wideband electromagnetic radiation. *Int J Radiat Biol* 75(1):115-120, 1999.

PURPOSE: To investigate the extent of genetic damage in the peripheral blood and bone marrow cells of mice exposed to ultra-wideband electromagnetic radiation (UWBR). **MATERIALS AND METHODS:** CF-1 male mice were exposed to UWBR for 15 min at an estimated whole-body average specific absorption rate of 37 mW x kg(-1). Groups of untreated control and positive control mice injected with mitomycin C were also included in the study. After various treatments, half of the mice were killed at 18 h, and the other half at 24 h. Peripheral blood and bone marrow smears were examined to determine the extent of genotoxicity, as assessed by the presence of micronuclei (MN) in polychromatic erythrocytes (PCE). **RESULTS:** The percentages of PCE and the incidence of MN per 2000 PCE in both tissues in mice killed at 18 h were similar to the frequencies observed in mice terminated at 24 h. There were no significant differences in the percentage of PCE between control and the mice with or without UWBR exposure; the group mean values (+/- standard deviation) were in the range of 3.1 +/- 0.14 to 3.2 +/- 0.23 in peripheral blood, and 49.0 +/- 3.56 to 52.3 +/- 4.02 in bone marrow. The mean incidence of MN per 2000 PCE in control and in mice with or without UWBR exposure ranged from 7.7 +/- 2.00 to 9.7 +/- 2.54 in peripheral blood and 7.4 +/- 2.32 to 10.0 +/- 3.27 in bone marrow. Pairwise comparison of the data did not reveal statistically significant differences between the control and mice with or without UWBR exposure groups (excluding positive controls). **CONCLUSION:** Under the experimental conditions tested, there was no evidence for excess genotoxicity in peripheral blood or bone marrow cells of mice exposed to UWBR.

Violanti JM, Cellular phones and traffic accidents. *Public Health* 111(6):423-428, 1997.

Cellular phone use in motor vehicles is becoming an increasing world-wide phenomenon. Using data obtained from traffic accidents reported between 1992 and 1995 in the state of Oklahoma, USA, this study examined statistical rate-ratios of accident characteristics between drivers with or without cellular phones. Rates were calculated between cellular phone involvement and reported accident causes, types of collision, driver actions immediately prior to the accident, location of the accident, the extent of fatalities, and age and gender of drivers. Results indicated a significant increased rate among drivers with cellular phones for inattention, unsafe speed, driving on wrong side of road, striking a fixed object, overturning their vehicle, swerving prior to the accident, and running off the roadway. People with phones stood an increased risk of being killed in an accident over persons without phones. Males with phones had a significantly higher rate than females for many of accident characteristics mentioned above. Rate-ratios of some accident characteristics and fatalities increased as age increased, with the exception of drivers under age 20 yrs, who had the highest fatality rate. Limitations of the study and possible prevention alternatives are discussed.

Violanti JM, Cellular phones and fatal traffic collisions. *Accid Anal Prev* 30(4):519-524, 1998

A case-control study was conducted to determine statistical associations between traffic fatalities and the use or presence of a cellular phone, given involvement in a collision. The hypothesis of this study does not imply that cellular phones directly affect fatalities, but that phones increase the risk of certain accident characteristics in fatal collisions more than those same characteristics in non-fatal collisions. Analysis employed data from 223,137 traffic accidents occurring between 1992 and 1995. Information on collision characteristics and cellular phone involvement for each fatality was compared with the same information for each non-fatality (controls). Statistically adjusting for other collision variables (age, gender, alcohol use, speed, inattention and driving left of center), an approximate nine-fold increased risk was found for a fatality given the use of a cellular phone. An approximate two-fold increased risk for a fatality was found given the presence of a cellular phone in the vehicle. Combined effects of reported phone use, driving to the left of center and inattention increased the risk of a fatal collision more than phone use did by itself. This analysis implies a statistical, but not necessarily a causal, relationship. A multitude of factors are involved in any traffic collision, and the exact cause of an accident and its severity level is difficult to disentangle.

Violanti JM, Marshall JR, Cellular phones and traffic accidents: an epidemiological approach. *Accid Anal Prev* 28(2):265-270, 1996.

Using epidemiological case-control design and logistic regression techniques, this study examined the association of cellular phone use in motor vehicles and traffic accident risk. The amount of time per month spent talking on a cellular phone and 18 other driver inattention factors were examined. Data were obtained from: (1) a case group of 100 randomly selected drivers involved in accidents within the past 2 years, and (2) a control group of 100 randomly selected licensed drivers not involved in accidents within the past 10 years. Groups were matched on geographic residence. Approximately 13% (N = 7) of the accident and 9% (N = 7) of the non-accident group reported use of cellular phones while driving. Data was obtained from Department of Motor Vehicles accident reports and survey information from study subjects. We hypothesized that increased use of cellular phones while driving was associated with increased odds of a traffic accident. Results indicated that talking more than 50 minutes per month on cellular phones in a vehicle was associated with a 5.59-fold increased risk in a traffic accident. The combined use of cellular phones and motor and cognitive activities while driving were also associated with increased traffic accident risk. Readers should be cautioned that this study: (1) consists of a small sample, (2) reveals statistical associations and not causal relationships, and (3) does not conclude that talking on cellular phones while driving is inherently dangerous.

Vollrath L, Spessert R, Kratzsch T, Keiner M, Hollmann H, No short-term effects of high-frequency electromagnetic fields on the mammalian pineal gland. *Bioelectromagnetics* 18(5):376-387, 1997.

There is ample experimental evidence that changes of earth-strength static magnetic fields, pulsed magnetic fields, or alternating electric fields (60 Hz) depress the nocturnally enhanced melatonin synthesis of the pineal gland of certain mammals. No data on the effects of high-frequency electromagnetic fields on melatonin synthesis is available. In the present study, exposure to 900 MHz electromagnetic fields [0.1 to 0.6 mW/cm², approximately 0.06 to 0.36 W/kg specific absorption rate (SAR) in rats and 0.04 W/kg in Djungarian hamsters; both continuous and/or pulsed at 217 Hz, for 15 min to 6 h] at day or night had no notable short-term effect on pineal melatonin synthesis in male and female Sprague-Dawley rats and Djungarian hamsters. Pineal synaptic ribbon profile numbers (studied in rats only) were likewise not affected. The 900 MHz electromagnetic fields, unpulsed or pulsed at 217 Hz, as applied in the present study, have no short-term effect on the mammalian pineal gland.

Vorobyov VV, Galchenko AA, Kukushkin NI, Akoev IG, Effects of weak microwave fields amplitude modulated at ELF on EEG of symmetric brain areas in rats. *Bioelectromagnetics* 18(4):293-298, 1997.

Averaged electroencephalogram (EEG) frequency spectra were studied in eight unanesthetized and unmyorelaxed adult male rats with chronically implanted carbon electrodes in symmetrical somesthetic areas when a weak (0.1-0.2 mW/cm²) microwave (MW, 945 MHz) field, amplitude-modulated at extremely low frequency (ELF) (4 Hz), was applied. Intermittent (1 min "On," 1 min "Off") field exposure (10-min duration) was used. Hemispheric asymmetry in frequency spectra (averaged data for 10 or 1 min) of an ongoing EEG was characterized by a power decrease in the 1.5-3 Hz range on the left hemisphere and by a power decrease in the 10-14 and 20-30 Hz ranges on the right hemisphere. No differences between control and exposure experiments were shown under these routines of data averaging. Significant elevations of EEG asymmetry in 10-14 Hz range were observed during the first 20 s after four from five onsets of the MW field, when averaged spectra were obtained for every 10 s. Under neither control nor pre- and postexposure conditions was this effect observed. These results are discussed with respect to interaction of MW fields with the EEG generators.

Wagner, P, Roschke, J, Mann, K, Hiller, W, Frank, C, Human sleep under the influence of pulsed radiofrequency electromagnetic fields: a polysomnographic study using standardized conditions. *Bioelectromagnetics* 19(3):199-202, 1998.

To investigate the influence of radiofrequency electromagnetic fields (EMFs) of cellular phone GSM signals on human sleep electroencephalographic (EEG) pattern, all-night polysomnographies of 24 healthy male subjects were recorded, both with and without exposure to a circular polarized EMF (900 MHz, pulsed with a frequency of 217 Hz, pulse width 577 micros, power flux density 0.2 W/m²). Suppression of rapid eye movement (REM) sleep as well as a sleep-inducing effect under field exposure did not reach statistical significance, so that previous results indicating alterations of these sleep parameters could not be replicated. Spectral power analysis also did not reveal any alterations of the EEG rhythms during EMF exposure. The failure to confirm our previous results might be due to dose-dependent effects of the EMF on the human sleep profile.

Walters TJ, Blick DW, Johnson LR, Adair ER, Foster KR, Heating and pain sensation produced in human skin by millimeter waves: comparison to a simple thermal model. *Health Phys* 78(3):259-267, 2000.

Cutaneous thresholds for thermal pain were measured in 10 human subjects during 3-s exposures at 94 GHz continuous wave microwave energy at intensities up to approximately 1.8 W cm⁻². During each exposure, the temperature increase at the skin's surface was measured by infrared thermography. The mean (+/- s.e.m.) baseline temperature of the skin was 34.0 +/- 0.2 degrees C. The threshold for pricking pain was 43.9 +/- 0.7 degrees C, which corresponded to an increase in surface temperature of approximately 9.9 degrees C (from 34.0 degrees C to 43.9 degrees C). The measured increases in surface temperature were in good agreement with a simple thermal model that accounted for heat conduction and

for the penetration depth of the microwave energy into tissue. Taken together, these results support the use of the model for predicting thresholds of thermal pain at other millimeter wave (length) frequencies.

Walters TJ, Ryan KL, Belcher JC, Doyle JM, Tehrany MR, Mason PA, Regional brain heating during microwave exposure (2.06 GHz), warm-water immersion, environmental heating and exercise. *Bioelectromagnetics* 19(6):341-53,1998.

Nonuniform heating may result from microwave (MW) irradiation of tissues and is therefore important to investigate in terms of health and safety issues. Hypothalamic (Thyp), cortical (Tctx), tympanic (Tty), and rectal (Tre) temperatures were measured in rats exposed in the far field, k-polarization (i.e., head pointed toward the transmitter horn and E-field in vertical direction) to two power densities of 2.06 GHz irradiation. The high-power density (HPM) was 1700 mW/cm² [specific absorption rate (SAR): hypothalamus 1224 W/kg; cortex 493 W/kg]; the low-power density (LPM) was 170 mW/cm² (SAR: hypothalamus 122.4 W/kg; cortex 49.3 W/kg). The increase (rate-of-rise, in degrees C/s) in Thyp was significantly greater than those in Tctx or Tre when rats were exposed to HPM. LPM produced more homogeneous heating. Quantitatively similar results were observed whether rats were implanted with probes in two brain sites or a single probe in one or the other of the two sites. The qualitative difference between regional brain heating was maintained during unrestrained exposure to HPM in the h-polarization (i.e., body parallel to magnetic field). To compare the temperature changes during MW irradiation with those produced by other modalities of heating, rats were immersed in warm water (44 degrees C, WWI); exposed to a warm ambient environment (50 degrees C, WSED); or exercised on a treadmill (17 m/min 8% grade) in a warm ambient environment (35 degrees C, WEX). WWI produced uniform heating in the regions measured. Similar rates-of-rise occurred among regions following WSED or WEX, thus maintaining the pre-existing gradient between Thyp and Tctx. These data indicate that HPM produced a 2-2.5-fold difference in the rate-of-heating within brain regions that were separated by only a few millimeters. In contrast, more homogeneous heating was recorded during LPM or nonmicrowave modalities of heating.

Wang, BM, Lai, H, Acute exposure to pulsed 2450-MHz microwaves affects water maze learning in the rat. *Bioelectromagnetics* 21:52-56, 2000.

Rats were trained in six sessions to locate a submerged platform in a circular water maze. They were exposed to pulsed 2450-MHz microwaves (pulse width 2 μ s, 500 pulses/s, power density 2 mW/cm², average whole body specific absorption rate 1.2 W/kg) for 1 hr in a circular waveguide system immediately before each training session. One hour after the last training session, they were tested in a probe trial during which the platform was removed and the time spent in the quadrant of the maze in which the platform had been located during the 1-min trial was scored.

Three groups of animals: microwave-exposed, sham-exposed, and cage control were studied. Data show that microwave-exposed rats were slower than sham-exposed and cage control rats in learning to locate the platform. However, there was no significant difference in swim speed among the three groups of animals, indicating that the difference in learning was not due to a change in motor functions or motivation. During the probe trial, microwave-exposed animals spent significantly less time in the quadrant that had contained the platform, and their swim patterns were different from those of the sham-exposed and cage control animals. The latter observation indicates that microwave-exposed rats used a different strategy in learning the location of the platform. These results show that acute exposure to pulsed microwaves caused a deficit in spatial "reference" memory in the rat.

Weyandt, TB, Schrader, SM, Turner, TW, Simon, SD, Semen analysis of military personnel associated with military duty assignments. *Reprod Toxicol* 10(6):521-528, 1996.

A collaborative study between the U.S. Army Biomedical Research and Development Laboratory (USABRD) and the National Institute for Occupational Safety and Health (NIOSH) was designed to assess fecundity of male artillery soldiers with potential exposures to airborne lead aerosols. Potential exposure assessment was based upon information provided in an interactive questionnaire. It became apparent from extensive questionnaire data that many soldiers in the initial control population had potentially experienced microwave exposure as radar equipment operators. As a result, a third group of soldiers without potential for lead or microwave exposures, but with similar environmental conditions, was selected as a comparison population. Blood hormone levels and semen analyses were conducted on artillerymen (n = 30), radar equipment operators (n = 20), and the comparison group (n = 31). Analysis of the questionnaire information revealed that concern about fertility problems motivated participation of some soldiers with potential artillery or microwave exposures. Although small study population size and the confounding variable of perceived infertility limit the reliability of the study, several statistically significant findings were identified. Artillerymen who perceived a possible fertility concern demonstrated lower sperm counts/ejaculate (P = 0.067) and lower sperm/mL (P = 0.014) than the comparison group. The group of men with potential microwave exposures demonstrated lower sperm counts/mL (P = 0.009) and sperm/ejaculate (P = 0.027) than the comparison group. Variables used to assess endocrine, accessory sex gland, and sperm cell function were not different than the comparison group. Additional studies, incorporating larger numbers of individuals, should be performed in order to more optimally characterize potential lead and microwave exposure effects on male fecundity.

Wilke A, Grimm W, Funck R, Maisch B, Influence of D-net (European GSM -Standard) cellular phones on pacemaker function in 50 patients with permanent pacemakers. *Pacing Clin Electrophysiol* 19(10):1456-1458, 1996.

The widespread use of cellular phones in the last years has prompted some

recent studies to suggest an interference of pacemaker function by cellular phone usage. To determine the risk of pacemaker patients using D-net cellular phones, we tested 50 patients with permanent pacemakers after routine pacemaker check by short phone calls using a cellular phone (Ericsson, D-net, frequency 890-915 MHz, digital information coding, equivalent to the European Groupe Systemes Mobiles standard). A six-channel surface ECG was continuously recorded from each patient to detect any interactions between pacemakers and cellular phones. Phone calls were repeated during the following pacemaker settings: (1) preexisting setting; (2) minimum ventricular rate of 90 beats/min and preexisting sensitivity; and (3) minimum ventricular rate of 90 beats/min and maximum sensitivity without T wave oversensing. Only 2 (4%) of 50 patients repeatedly showed intermittent pacemaker inhibition during calls with the cellular phone. Both pacemakers had unipolar sensing. Therefore, although interactions between cellular phone use and pacemaker function appear to be rare in our study, pacemaker dependent patients in particular should avoid the use of cellular phones.

Wolke S, Neibig U, Elsner R, Gollnick F, Meyer R, Calcium homeostasis of isolated heart muscle cells exposed to pulsed high-frequency electromagnetic fields. *Bioelectromagnetics* 17(2):144-153, 1996.

The intracellular calcium concentration ($[Ca^{2+}]_i$) of isolated ventricular cardiac myocytes of the guinea pig was measured during the application of pulsed high-frequency electromagnetic fields. The high-frequency fields were applied in a transverse electromagnetic cell designed to allow microscopic observation of the myocytes during the presence of the high-frequency fields. The $[Ca^{2+}]_i$ was measured as fura-2 fluorescence by means of digital image analysis. Both the carrier frequency and the square-wave pulse-modulation pattern were varied during the experiments (carrier frequencies: 900, 1,300, and 1,800 MHz pulse modulated at 217Hz with 14 percent duty cycle; pulsation pattern at 900 MHz: continuous wave, 16 Hz, and 50 Hz modulation with 50 percent duty cycle and 30 kHz modulation with 80 percent duty cycle). The mean specific absorption rate (SAR) values in the solution were within one order of magnitude of 1 mW/kg. They varied depending on the applied carrier frequency and pulse pattern. The experiments were designed in three phases: 500 s of sham exposure, followed by 500 s of field exposure, then chemical stimulation without field. The chemical stimulation (K^+ -depolarization) indicated the viability of the cells. The K^+ depolarization yielded a significant increase in $[Ca^{2+}]_i$. Significant differences between sham exposure and high-frequency field exposure were not found except when a very small but statistically significant difference was detected in the case of 900 MHz/50 Hz. However, this small difference was not regarded as a relevant effect of the exposure.

Wu Y, Jia Y, Guo Y, Zheng Z, Influence of EMP on the nervous system of rats. *ACTA Biophysica Sinica* 15:152-157, 1999.

To explore the effects of electromagnetic pulse (EMP) exposure on the nervous system of rats, Wistar rats were divided into four groups: three exposure groups and one normal control group. The measurement of ability of learning of rats was carried out with a y-maze, followed by the detection of the content of neurotransmitters in different areas of cerebrum. Compared with control group, in the following three days of EMP exposure, the ability of learning of exposed groups was decreased ($P < 0.05$). For one day group, in hippocampus, the content of 5-HT and DOPAC increased ($P < 0.05$), and in hypothalamus, the content of dopamine increased ($P < 0.05$), while the content of Adr decreased ($p < 0.05$). the content of Adr and 5-HT in hippocampus of the second day group was reduced ($P < 0.05$). the content of Adr in hippocampus of the third day group was still lower than that of control group ($P < 0.05$). According to the results above, we can conclude that EMP exposure results in changes of the content of neurotransmitters in different cerebral areas of rats, lowering their ability of learning.

Youbicier-Simo, BJ, Lebecq, JC, Bastide, M, Mortality of chicken embryos exposed to EMFs from mobile phones. Presented at the Twentieth Annual Meeting of the Bioelectromagnetics Society, St. Pete Beach, FL, June 1998.

Exposure to mobile phone-radiated EMFs during development worsens embryonic mortality in chicken.

Zotti Martelli* L, Peccatori M, Migliore* L, Human lymphocyte micronucleus assay as biological indicator of cytogenetic damage by microwave radiation**

Microwave radiation is known as a physical agent which can cause changes at the level of DNA synthesis and its structure. The micronucleus assay is widely used as a method for the evaluation of cytogenetic damage in both in vivo and in vitro environmental mutagenesis. Therefore our aim was to investigate the genotoxic effects of microwave radiation by micronucleus test in human lymphocytes experimentally exposed to particular intensities of microwave radiation.

Human whole-blood samples were exposed to continuous microwave radiation with frequencies 2.45 GHz and 7.7 GHz. In both cases, the power density was 10, 20 and 30 mW/cm² for 15, 30 and 60 min. of exposition. The results, analyzed by using Fisher's exact test, showed for both frequencies of radiation an induction of micronuclei in the exposed samples higher than in the control at power density of 30 mW/cm² and after 30 and 60 min. of exposition. Our study indicates that induced cytogenetic damage in human lymphocytes may be either power density- and/or time exposition-related.