

Electromagnetic irradiation exposure and its bioindication – An overview

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Abstract

Man made electromagnetic irradiation and fields cover now the globe due to the recent extensive propagation of mobile telephony. The increased load affects animals and also plants. Especially birds have been studied. Humans are also sensitive. They are good bioindicators as epidemiological methods are available. Humans can also report symptoms which cannot be directly measured with presently available technologies. The nonionizing irradiation can as the ionizing one break the DNA, damage proteins, even increase the blood brain barrier permeability, disturb the night rest, cause fatigue and hormonal disturbances. An increase of the tumours of human head has been described in correlation with the long term mobile phone use and on that side more exposed. The regulations covering mobile telephony are already about two decades old and need re-evaluation. The multitude of irradiation and the interaction of the different wavelength exposures, i.e., frequency sensitivity is poorly known at present. We should not forget the comparative studies of different species especially those which rely in their lives on electromagnetic orientation physiology. Some countries have issued warnings on the exposures of children. The producers of mobile technology have recently warned the users not to keep those devices in active stage in skin contact.

Key words: nonionizing radiation; electromagnetic fields; their sensing, animals; humans; symptoms; oxidative stress; DNA breaks, tumours

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Introduction

All organisms have been exposed to natural electromagnetic irradiation and fields and have had time to adapt. They have also several mechanisms to safeguard their vital reactions. Plants which synthesize organic material also produce multitude of antioxidants and have thus extensive mechanisms to cope with the oxygen and other free radicals generated for different reasons. The animals benefit in their metabolism also these chemicals as they absorb at least some of them from the plants they eat. Animals can also search of protection. Many animals travel to distant areas especially during their annual migration cycles. Some animals including migrating butterflies, beluga whales, sea turtles, homing pigeons and honeybees have magnetoreceptors and use the natural magnetic fields to guide them over vast distances. Magnetite is found in the bones or teeth of many vertebrates including humans and also in insects – the abdomen of honeybees and the heads and abdomens of some ants (Kirschvink et al., 1992; Russel et al., 2008). Therefore, one can expect to see

responses in several species due to the electromagnetic changes in environment – humans included.

The high increase of man made radiofrequency irradiation is rather recent phenomenon. It has, however, exploded with the wireless communication. There are already more mobile phones than people in a number of countries. Also the traffic based electromagnetic control has increased in the route sensing over the seas, land, skies and even in space. All these are served by radars (e.g. Davis, 2010). One cellular phone can also have several radio transmitters for different usages. Mobile phones need base stations. Their density is high in cities, and only a few are in rural areas. The man made signals must be strong enough to reach the receivers. The longer is the distance, the more energy is needed. The traditional high radio transmission towers are complemented by often lower base stations, which are also attached in buildings. Both types are active day and night (Davis, 2010).

The interaction of electromagnetic fields with the biological systems is known at different levels, but the cumulative effects are a big challenge (Bioinitiative report, 2007; Blank, 2009). Practically all species are exposed

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to man made irradiation. Some birds are good indicators, e.g. white storks. Their nests as their lowered reproduction success can there easily be registered (Balmori, 2005). Another species is sparrow whose density has declined with the electric field strength (Balmori and Hallberg, 2007). The birds like sea gulls have seen to leave their traditional resting sites, when the irradiation is increased by the introduction of a new phone base station(s) (Väkeväinen, 2010, personal communication). There are several studies also on other species like insects and even plants, e.g., trees near the phone masts (Balmori, 2009).

Many people are active mobile phone users, but all are passively affected – even those who do not have a mobile phone. The same is true to the animals and plants as seen from the recording of a city parking lot (Fig. 1a). The irradiation is practically always on due to frequent

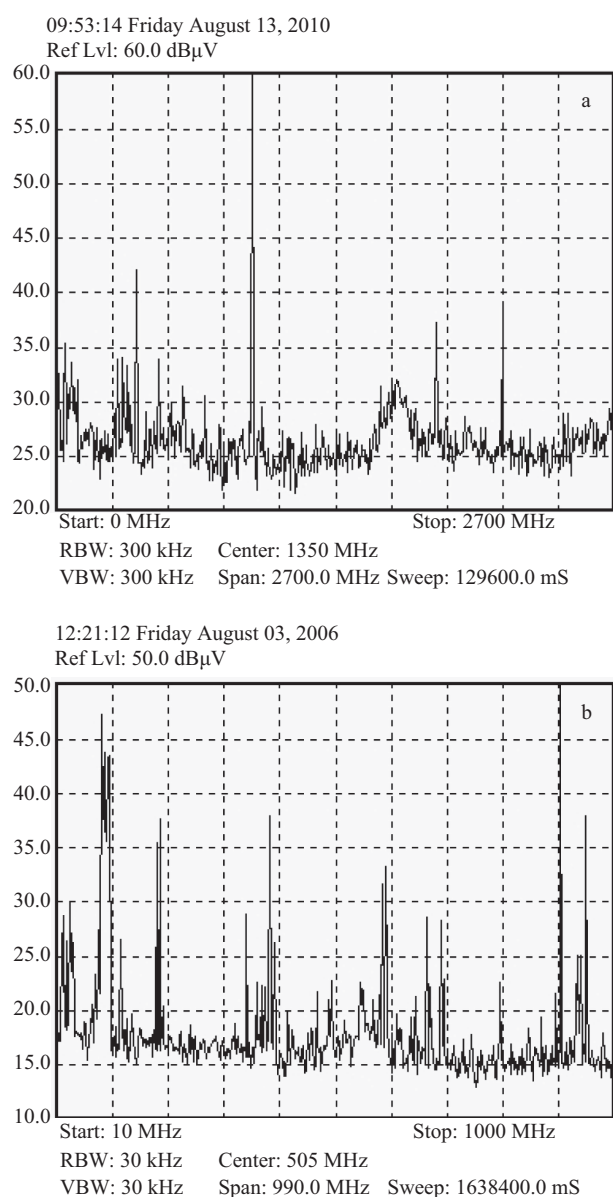


Fig. 1 Electromagnetic spectrum in a city parking lot of shopping center close to a park (a). The electromagnetic spectrum in one author's office where main instruments were table computer and printer indicating many sources sending their signals in the room and neighborhood (b). The radio transmissions penetrate the walls. The office has no windows out from the building. Scales are logarithmic.

mobile phone use in the neighborhood. Constantly active are the traditional radio and TV transmissions and the new mobile phone base stations. There are also another source of electromagnetic irradiations and fields due to the communication systems of military, police and rescue personnel. The wireless networks like WLAN, Wi-Fi etc. in offices and even in many homes increase the irradiation load as seen in Fig. 1b. Within an office, and also at homes one has many other sources of the radio waves, like the portable computers or their components, which are not widely known. Figure 2a gives the electromagnetic spectrum of a commonly used computer and Fig. 2b shows the huge increase electromagnetic irradiation of the attached WLAN in another computer (note the logarithmic scale).

We use a multitude of electronic devices for various other tasks. They are, however, sending radio waves even though there is no purpose or need of these signals. People are not aware that most electric devices release nonsense electric radio waves. The electric lines carry long distances transients, which are also harmful.

1 Symptom based bioindication in humans

Humans absorb electromagnetic signals and act as antennas. Actually humans are one of the most useful

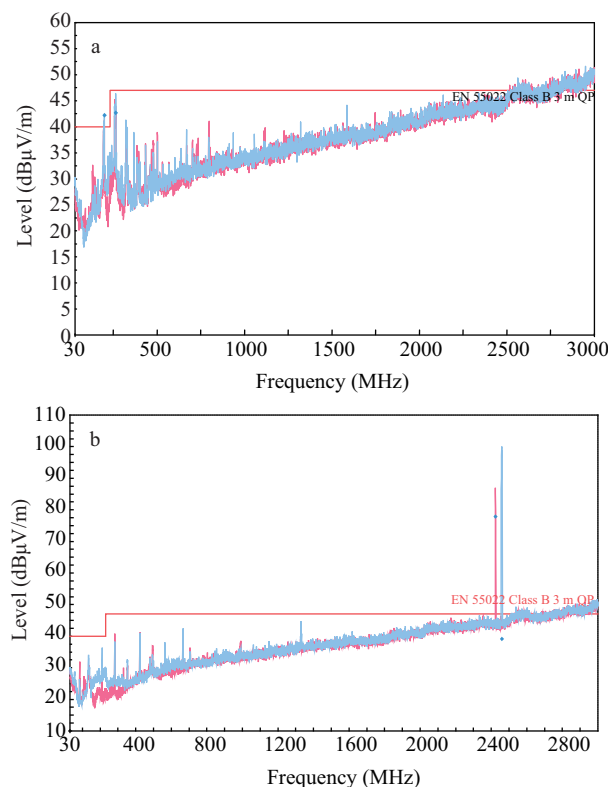


Fig. 2 Electromagnetic spectrum of a commonly used laptop computer having a mouse and a large screen as usually and connected to power line (a) and one now connected with WLAN (b). The scales are exponential and that the WLAN increases thousand fold the irradiation at around the 2.4 GHz. The spectra have been registered at two positions of the registering antennas indicating that the spatial orientation of signals released are different (colours red and blue). The horizontal broken red line indicates the maximum irradiation permitted at the moment by the directives of the European Union.

and sensitive bioindicator species. In addition to measured reactions and health statistics persons can express their sensations (Huttunen et al., 2009). Human statistics are collected continuously into global epidemiologic data bases. Our species populates every corner of the globe. Thus these data banks provide a possibility to follow the developments in different areas. In Sweden, it has been reported that the general public health markers have deteriorated with the increase of electromagnetic exposure (Hallberg and Johansson, 2009).

Highly electromagnetically exposed people complain one or more symptoms like headache, nervousness, sleep disorders, fatigue, concentration difficulties, anxiety, tinnitus, vertigo, cardiac arrhythmia, pain, skin stinging and burns, and hormonal disturbances. Many have connected their symptoms to their exposure to different sources like mobile phones, cordless phones, mobile phone stations, other electric appliances, television, computers, TV and radio broadcasting and microwave ovens (Hänninen et al., 2007; Davis, 2010). Some of the effects are probably related to the calcium efflux in cells (Blackman et al., 1979, 1989) and some on the release of iron (Allen et al., 2000; Cespedes and Ueno, 2009). The first step can be the activation of the plasma membrane NADH oxidase and generation of oxygen free radicals followed by the activation of the protein kinases (Friedman et al., 2007). Also the fragmentation of DNA occurs (Phillips et al., 2009; Campisi et al., 2010) and genotoxic effects are expressed (Ruediger, 2009). The irradiation also activates the synthesis of heat shock proteins which act as chaperons and correct the three dimensional structures of proteins (Blank and Goodman, 2009). These cause changes in the cellular metabolism and can be seen also in the proteome findings. There may be differences between the differences in wavelengths used in exposure (Nylund et al., 2010).

The brains are protected by the blood brain barrier against the entrance of harmful molecules. Its permeability increases by mobile phone irradiation exposure (Nittby et al., 2009). The electromagnetic exposure can induce tumour generation in the brains in long run. This can be expected as these signals interfere, even break DNA as mentioned above. The brain gliomas and astrocytomas are more common on the side of the head where the mobile phones have been used (Hardell et al., 2010). The tumour morbidity is expected to grow in future as already young children actively use extensively mobile phones. Several countries have issued concerns and signed precautionary principle document to protect children. The human development means not only the increase of brain mass, but also the proper networking of its neurons. This lasts two first decades with learning process, but it continues even after that. This means that developmental disturbances are possible. The protective skull grows until the bone sutures have closed, but the bone thickness increases still thereafter in adulthood. The electromagnetic exposure of a persons can be detected by recording directly the signals, e.g. from fingers in his/her workstation and at home to identify the irradiation sources currently on as seen in Fig. 3.

The measurements help to quantify the sensations

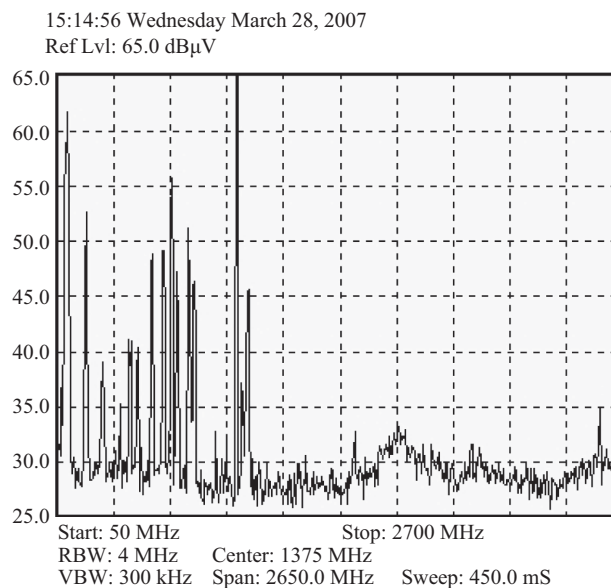


Fig. 3 Absorbed electromagnetic spectrum directly registered from a finger of one of the authors at his home. The scale is exponential.

reported. For instance the decrease of the skin temperature is sensed by a number of persons, and it can be followed with the aid of infrared thermography of fingers. The person can also tell feeling pain in fingers and their hands becoming clumsy, which are more difficult to measure. Figure 4a, b shows how the electromagnetic irradiation of constricts the circulation of the fingers and cools them in some minutes to room temperature, although the computers irradiates heat that is expected to warm the fingers.

Phone conversation while driving distracts driver's attention, effects mentally the driver and can cause crash (Drews and Stayer, 2004; McEvoy et al., 2006). Humans can also sense the standing waves of the radio transmissions and feel it like spontaneous muscle contraction. Some of them seem to be able to sense also the differences of the standing waves of different wavelengths (Huttunen et al., 2009), they are rather specifically frequency sensitive, if not so sensitive as we are sensing the colours. The differences in wavelength exposure can also seen in proteomic responses of cells (Nylund et al., 2010).

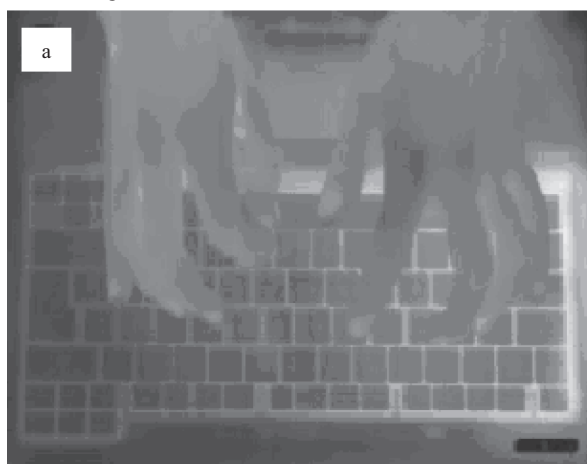
2 Recovery seems to be possible

When a human has become sensitive, the first step for the recovery is to minimize the further electromagnetic exposure. This means that at home the devices, especially during nights, should be disconnected. Most important is to keep the mobile phones and TV sets and computers closed always when not used. Similar action should also take place in the nearest environment. Unfortunately there may be base stations and wireless networks nearby and you need specific measurements to become aware of them.

Recently several major mobile phone producers have issued warnings to users not to keep the active mobile phones in skin contact. This may indicate a new turn in their attitude, and be an outcome of the failure of getting health related insurances for their products (Davis, 2010).

In countryside, one can find niches, e.g. rock surrounded

At start fingers about 30 C



After 15 min writing fingers 21 C



Fig. 4 Decrease of finger temperature of a person who is sensitive to electromagnetic radiation during typing with a portable computer. The temperature of fingers was in the start about 30°C and after 15 min typing about 21°C (room temperature) while the computer seems to irradiate more warm (getting in infrared picture wore light as an indication of the high electromagnetic irradiation its releases).

valleys, where the electromagnetic loading is small due to absence of close by radio transmission towers and base stations. The irradiation silence can be recorded as the electromagnetic spectrum either with physical antenna or using the person her/himself as the indicator antenna. With such measurements one can find less intensity places, e.g. within a house or outdoors in countryside. Figure 5a reveals that practically only the instrumentation noise was recorded in rural area with very few masts. See the map of one rural municipality (Fig. 5b).

As the electromagnetic irradiation increases the level of oxygen free radicals in tissues, also in neural cells (Campisi et al., 2010) the food should be rich in components which are essential like amino acids, unsaturated fatty acids, vitamins and elements which all increase the endogenous defence against the attacks of oxygen free radicals. The vitamins C and E as well as selenium could be expected to help.

One can also reduce the penetrating radiofrequency radiation by proper electrically conducting paints on the walls and curtains with conducting threads on the windows, in accordance with electric safety regulations in different countries. If the person avoids the extra electromagnetic exposure, positive results can be expected in about three months and nutritional supplements may be helpful (Hagström, 2010, personal communication).

3 Discussion

Although the electromagnetic mobile technology has made possible a significant economic progress, it has also caused drawbacks as indicated above. The man made irradiation has in the present scale existed only a reasonably short period of time, but already now even human tumour morbidity has increased among the long term users and on the side of the mobile phone use (Hardell et al., 2010). This means that serious concerns are motivated. Several international medical conferences have issued warnings, especially for the protection of children and underlined the implementation of precautionary principle (Johansson,

2009). We should include also the pregnant mothers and brain disease patients to especially protected groups and recommend them to avoid of electromagnetic exposure. Along these lines have also the mobile phone producers like Black Berry (model 8300), iPhone, Motorola (V195), Nokia (1100) and Verizon (HTC Droid Eris) recently warned in their users' manuals the customers not to keep their mobile phones on in skin contact (Davis, 2010)

The standards of the electromagnetic exposure have been estimated by using physical tests by measuring the temperature effects with salt solution filled model heads. The measures of an American soldier have been used for this purpose (Davis, 2010). This model was probably acceptable two decades ago, but not any more, when the users are also young children and women whose heads are very different. We also have so much biological information which tells that this model is too simplified (Bioinitiative report, 2007; Blank, 2009). Therefore, new models should be searched. Luckily, the proteomic studies already start to be available and these technologies provide much data in a short time (Nylund et al., 2010). The electromagnetic phenomena should be studied as carefully as the new drugs. This process often requires one decade and still the outcome can be rejection. Any drug is always administered only those who are expected to get benefit from it. The wildlife may be exposed to these drugs only indirectly, if the wastewater cleaning is not efficient. Present increase of electromagnetic irradiations and fields cover, however, practically whole globe and exposed are practically all species of animals and plants as well as people, even those who do not want even to be passively exposed.

The sensitive subjects should lessen their exposure at their work. The worker's protection legislation should be consulted as in principle it is relevant. At homes people should keep the unnecessary electronic devices closed to permit proper night rest. Luckily the recovery of sensitive people seems to be possible, if they move to areas with little man made electromagnetic irradiation. Wildlife is facing another situation as they may have difficulties to find safe zones when moving along their traditional migration

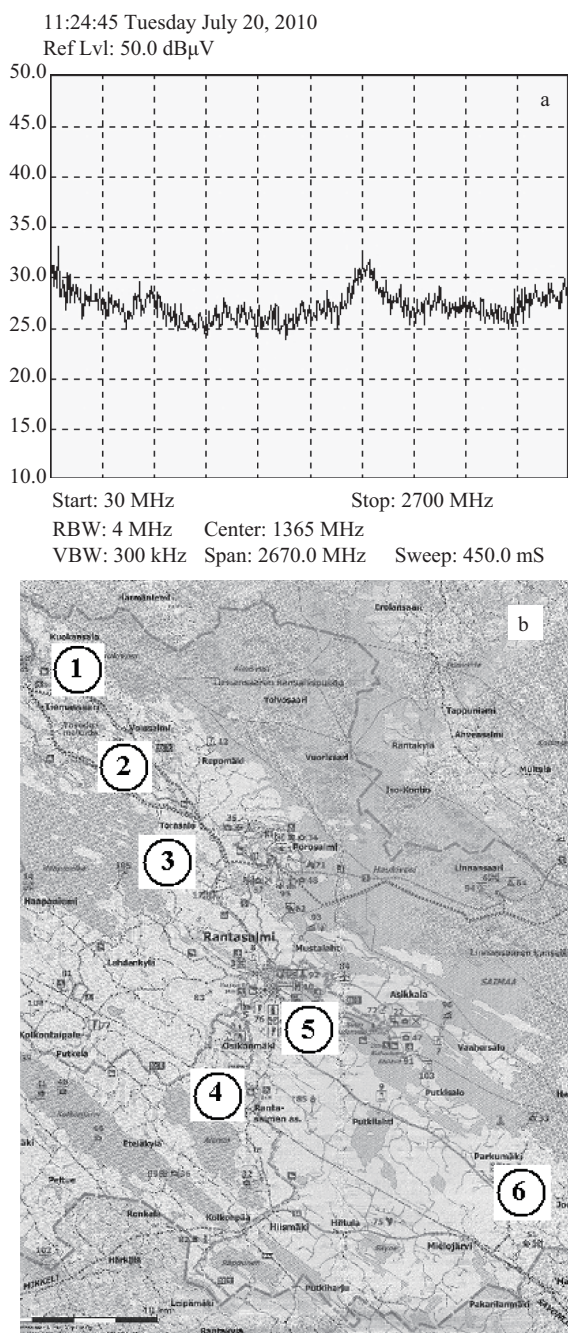


Fig. 5 Electromagnetic spectrum registered in countryside far from radio towers and base stations (a) (site 1 of the map). The background is noise from the instrumentation used to record the electromagnetic spectrum. The scale is logarithmic. The map of the village area and the sites of measurements indicated by dots and numbers (site 1 one of most electromagnetically silent) (b).

routes (Russel et al., 2008). Optical communication links using fiber cables make it possible to transfer information safely and photonic signal capacity is practically limit less. These signals can directly be connected to phones and computers. That will help humans to avoid electromagnetic radiation from wireless communication equipment. Shielding homes with conductive material like painting the walls of rooms and having curtains containing metal is also possible decreasing the intensity of radiation indoors.

Albert Einstein understood that the chemistry and physics ($E = mc^2$) are only different points of view to

describe the same phenomena. This is also true in normal metabolic reactions, biochemistry is at the same time biophysics. The metabolic reactions and the functions of the organs and also the organisms are controlled both by signal molecules and electric signals. The bioelectronic signaling systems can be disturbed by electronic devices.

People are different. Some can be exposed to high levels of electromagnetic loading while some others cannot. As also the nonionizing irradiation causes the generation of oxygen derived free and other radicals, the foods and supplements may be helpful.

4 Conclusions

Man made electromagnetic irradiation and fields cover the globe, and the load has increased rapidly due to increasing mobile telephony especially. All organisms are exposed to different degrees. All people are also passively exposed to some degree, but many are more due to the active use of mobile telephones. There examples of animals, even plants and also of humans which indicate that they are harmfully affected. Especially some birds are sensitive biomonitors. Human epidemiology provides increasing evidence on risks of increased morbidity. The worst signs are the DNA damage and increased carcinomas. Birds are able to leave high exposure areas. Humans seem also be able recover, if they avoid the active use irradiating devices and find irradiation shadow areas. The exposure of young children receive increased concerns. Precautionary principle is observed already in several countries.

References

- Allen P D, St Pierre T G, Chua-Anursorn W, Strom V, Rao K V, 2000. Low-frequency low-field magnetic susceptibility of ferritin and hemosiderin. *Biochim Biophys Acta*, 1500: 186–196.
- Balmori A, 2005. Possible effects of electromagnetic fields from phone masts on a population of white stock (*Ciconia ciconia*). *Electromagnetic Biollogy and Medicine*, 24: 109–119.
- Balmori A, 2009. Electromagnetic pollution from phone masts. Effects on wildlife. *Pathophysiology*, 16(2-3): 191–199.
- Balmori A, Hallberg Ö, 2007. The urban decline of the house sparrow (*Passer domesticus*): A possible link with electromagnetic irradiation. *Electromagnetic Biollogy and Medicine*, 26: 141–151.
- Biointiative report, 2007. A rational for a biologically-based public exposure standard for electromagnetic fields (ELF and RF). <http://www.biointiative.org>.
- Blackman C F, Elder J A, Weil C M, Benane S G, Eichinger D C, House D E, 1979. Induction of calcium-ion efflux from brain tissue by radio-frequency radiation: Effects of modulation frequency and field strength. *Radio Science*, 14: 93–98.
- Blackman C, Kinney L S, House D E, Joines W T, 1989. Multiple power-density windows and their possible origin. *Bioelectromagnetics*, 10(2): 115–128.
- Blank M (Guest Editor), 2009. Special issue electromagnetic fields (EMF). *Pathophysiology*, 16(2-3): 67–249.
- Blank M, Goodman R, 2009. Electromagnetic fields stress living

- cells. *Pathophysiology*, 16(2-3): 71–78.
- Campisi A, Gulino M, Acquaviva R, Bellia P, Raciti G, Grasso R et al., 2010. Reactive oxygen species levels and DNA fragmentation on astrocytes in primary culture after acute exposure to low intensity microwave electromagnetic field. *Neuroscience Letters*, 473(1): 52–55.
- Cespedes O, Ueno S, 2009. Effects of radio frequency magnetic fields on iron release from cage proteins. *Bioelectromagnetics*, 30: 336–342.
- Davis D, 2010. Disconnect, Dutton, Penguin Group, USA. 274.
- Drews F A, Stray D L, 2004. Profiles in driver distraction: Effects of cell phone conversation on young and older drivers. *Human Factors*, 46: 640–649.
- Friedman J, Kraus S, Hauptman Y, Schiff Y, Seger R, 2007. Mechanism of short-term ERK activation by electromagnetic fields at mobile phone frequencies. *Biochemical Journal*, 405(3): 559–568.
- Hallberg Ö, Johansson O, 2009. Apparent decreases in Swedish public health indicators after 1997—Are they due to improved diagnostics or to environmental factors? *Pathophysiology*, 16(2-3): 23–26.
- Hardell H, Carlberg M, Hansson M K, 2010. Mobile phone use and the risk for malignant brain tumors: A case-control study on deceased case and controls. *Neuroepidemiology*, 35: 109–114.
- Huttunen P, Hänninen O, Myllylä R, 2009. FM-radio and TV tower signals can cause spontaneous hand movements near moving RF reflector. *Pathophysiology*, 16(2-3): 201–204.
- Hänninen O, Kinnunen S, Nilsson M, Tuormaa E, Kassinen A, 2007. Matkapuhelinteknologia – Mitkä ovat terveystriskit? In: Mobile Technology—What are the Health Risks? (Tamminen E, ed.). House Protector/EMF Books, Järvenpää, Finland. 255.
- Johansson O, 2009. The London resolution. *Pathophysiology*, 16(2-3): 247–248.
- Kirschvink J L, Kobayashi-Kirschvink A, Diaz-Ricci J C, Kirschvink S J, 1992. Magnetite in human tissues: a mechanism for the biological effects of weak ELF magnetic fields. *Bioelectromagnetics*, (Suppl. 1): 101–113.
- McEvoy S P, Stevenson M R, Woodward M, 2006. Phone use and crashes while driving: A representative survey of drivers in two Australian states. *The Medical Journal of Australia*, 185(11-12): 628–629.
- Nittby H, Brun A, Eberhardt J, Malmgren L, Persson B R R, Salford L G, 2009. Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. *Pathophysiology*, 16(2-3): 103–112.
- Nylund R, Kuster N, Leszysinski D, 2010. Analysis of proteome response to the mobile phone radiation in types of human primary endothelial cells. *Proteome Science*, 18: 52. DOI: 10.1186/1477-5956-8-52.
- Phillips J L, Singh N P, Lai H, 2009. Electromagnetic fields and DNA damage. *Pathophysiology*, 16(2-3): 79–88.
- Ruediger H W, 2009. Genotoxic effects of radio frequency electromagnetic fields. *Pathophysiology*, 16(2-3): 89–102.
- Russel P J, Wolfe S L, Herz P E, Starr C, McMillan B, 2008. Biology, the Dynamic Science. Thompson, Brooks/Cole USA. 904–906.