57. Electromagnetic radiation and health: Human indicators

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and

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Abstract

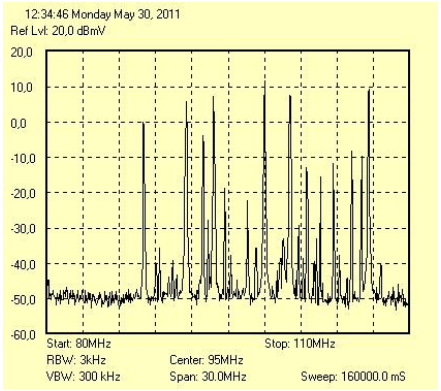
Manmade electromagnetic radiation increases in the environment as new applications are frequently adopted. Humans serve as receiving antennas for electromagnetic waves. Thus various new responses can be expected. In addition to radio and television programs, mobile telephony, distant reading of electricity and water consumption and many other technologies load us electrically and magnetically both out- and indoors. Most exposures are active all the time, day and night, continuously or in regular pulses. Personal devices are also important sources, since they touch the skin and are held near the brain and heart. Humans are good bioindicators, as their physiological parameters, such as heart function and blood biochemistry, are frequently recorded. Data storage and analysis are getting better. Humans

also report symptoms that cannot be directly measured, and carry valuable information on bioeffects. Studies from recent decades have shown that exposure to electromagnetic waves can break DNA chains, damage proteins, even increase the blood brain barrier permeability, disturb sleep, and cause fatigue, memory and concentration problems. Neural, hormonal and psychosocial development is affected. An increase in human brain tumours has been described in correlation with mobile phone use on the exposed side of the head. The symptoms of electrohypersensitivity cause morbidity, but the interaction between multiple radiation frequencies and the mechanisms leading to frequency sensitivity are still poorly understood. Producers of mobile communication devices continuously warn users not to keep personal devices in skin contact. The Precautionary Principle that has been signed by many nations applies to all environmental risk factors, including exposure to electromagnetic waves.

Keywords: city planning, electromagnetic fields, human antennas, radiation; sensing, animals; humans; symptoms; oxidative stress; tumours

57.1 Introduction – human exposure to electromagnetic waves

Humans and all living organisms are *receiving antennas* for electromagnetic radiation. Atoms, molecules and ions in human tissues interact with the electromagnetic waves, for example iron, present in many catalysts, haemoglobin and other carriers of oxygen, and magnetite crystals. The antenna function of the human body can be directly registered in the same way data from physical antennas are recorded. Fig. 57.1 presents radiation signals recorded with a spectrum analyzer from the skin of a sitting subject.



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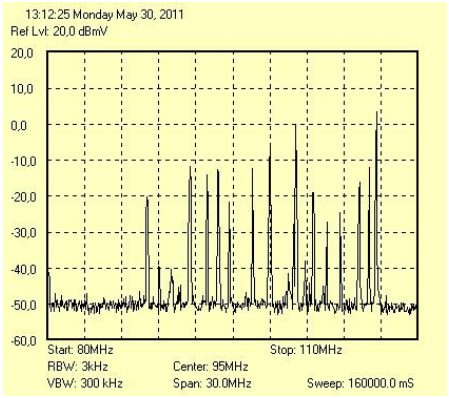

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Fig. 57.1 Radiation spectra around the 100 MHz commonly used in frequency modulated (FM) radio transmissions, recorded with a spectrum analyzer (GW Instek GSP-827).

(A) The horizontally polarized signals were captured with the aid of a 150 cm long dipole antenna.
(B) Directly recorded from the same site level from the elbow skin of a sitting subject (one of the authors served as the receiving antenna).
Without antenna, only minor noise was recorded (not shown). (Hänninen et al., 2013 reproduced with the permission of the J. African Association of Physiological Sciences).

Living organisms have been adapting to exposure to electromagnetic radiation from natural sources, and its effects, over millions of years. Outdoors, humans are exposed to the natural environment. We must start to consider that in the 21st century we have become too remote from the natural conditions to which humans and all other living organisms have adapted. The growing use of electromagnetic radiation by industry, the military, and the general public has raised the environmental baseline exposure to electromagnetic waves by several orders of magnitude. All species must now readapt to this new man-made artificial environment. Adaptation and evolution is not necessarily a fast process. Members of a species may show variation in their adaptation capacity. Therefore, precautionary measures must be taken rapidly to protect susceptible sub-populations in the general public.

Research results are still accumulating regarding the relatively new abundance of electromagnetic applications used by the general public since the last decades of the 20th century. Synergistic or additive effects of interactions between different factors, and the long-term effects of low level exposure on humans, are even less known. Nevertheless new applications are adopted all the time, based on the assumption of safety. These are mostly controlled by regulations, but since much is still unknown, current exposure limits may not be protective. Indeed, there are many studies that show biological effects (bioeffects) at levels below current exposure limits. The planning of research is slow and the execution of studies is even slower than the rapidly advancing technology. Due to the scarcity of clear results and knowledge, lay findings and individual case reports are an additional important source of information, as they have always been, especially since modern information technology facilitates collection of these data.

A large part of our lives is spent indoors, protected from harsh climate conditions; but the indoor ambience exposes humans to multiple agents, such as cigarette smoke, chemicals and electromagnetic waves emitted from devices. It is notable that skin tumours are often seen in covered parts of the body and not only in the areas exposed to sunshine, as would intuitively be expected.

When people commute they are not in a natural environment either. Transportation vehicles like busses, trains, cars and ships have metal frames and their exterior is covered in metal. The lighting inside the vehicle is an artificial light. Many cars, trains, and busses operate wireless telecommunication or Internet connection inside the vehicle, e.g., cellphone antennas, Bluetooth or WiFi connections. Electromagnetic means are also used for tracking the transport of goods and of people, via satellites.

In many countries, regulations are not up to date with the most recent scientific knowledge on the possible human effects of electromagnetic radiation. Electromagnetic bioeffects were assumed in the past to be insignificant, and therefore regulations paid little attention to them. Recent studies and re-emerging data from the 1970-80's Eastern Europe and the United States indicate the significant existence of bioeffects of human exposure to electromagnetic radiation (see Bioinitiative Report 2012). Susceptible members of the general population, such as children, pregnant women, the sick and elderly, and those with a weaker immune system, are more at risk. The effect of long-term exposure, even at lower intensities, is not known.

57.2 City and house planning

Increasingly more adults, children and teenagers spend their time indoors, at work and leisure. Populations live and act in buildings, in cities, and along their streets. The planning of areas is regulated.

Urban blocks of flats are usually made of steel-reinforced concrete. The roofs, and even the walls, are covered by materials that contain steel or other metals, which do not enable electromagnetic radiation to penetrate, but are reflective. Many small houses made of wood have roofs that contain iron or other metals.

Steel roofs of buildings help to protect the indoor inhabitants from exposure to an outdoor source of electromagnetic radiation. But electromagnetic waves can be reflected on the outer surface of the roof and redirected farther away, exposing others. Radiation from an external

source can enter a building through the side walls. Radiation that enters a building is then reflected inside the building. Direct radiation and its reflections can interact, to form standing waves and hot spots. These can hamper the indoor electric processes. Fig. 57.2 illustrates reflections of radiofrequency waves outside and inside a house.

Many common building materials enable electromagnetic radiation to penetrate the walls. There are, however, materials that can be used to damp the electromagnetic waves and their reflections. Insulation materials containing aluminium foil are effective. If the building contains sensitive systems, it is possible to protect them by steel walls. Therefore, some factories install coverings made from metallic and other specialized materials to block the propagation of electromagnetic waves indoors. There are also metal-containing paints and curtains that limit radiation somewhat, but their efficacy is limited because the protective layer is very thin.

Electromagnetic radiation is emitted from radio and television systems, as well as, in higher frequencies, from radar transmission towers. In many urban as well as rural environments these and other sources, such as electric power lines, are activated all the time. Towers allow the radiation to reach a wide diameter. However, radiation beams are directional. If the beams are directed to the horizon, the immediate proximity of a tower may have lower exposure to the radiation. Negative health effects in the proximity of radiation emitting towers, if found, could be due to coexisting significant environmental exposures, e.g., chemical exposures. (Atzmon et al., 2012).

Transmission towers and base stations are often located in densely populated areas. Small base stations, used for cellphone communication, can be found on roofs, on street poles, and inside shopping centers. In some countries, legislation still allows cellphone companies to rent space for use by base stations in vacant apartments or even on people's balconies, sometimes even without notifying the public about this exposure.

Recently, electric energy, water and gas companies have begun installing electronic wireless "Smart meters" instead of analog meters. These emit pulses of radiofrequency waves all day and all night, or internal wall pulses of radiofrequency waves all day and all night, emit several seconds in every hour, or more. Chronic all-day every-day exposure is more likely than short and intermittent exposure, such as cell phone use, to produce harmful health effects. Although the exposure levels may be lower, the accumulated exposure over time has the potential to be greater, and to cause greater harm.

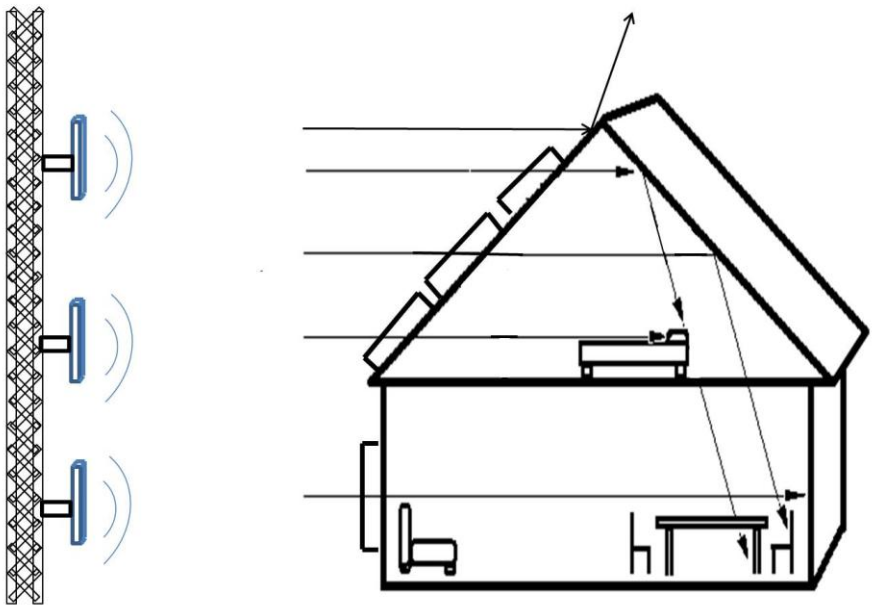

Fig. 57.2 Electromagnetic radiation and common house materials A European-type single family house with steel roof that prevents the penetration of radiation and reflects the radiofrequency radiation to air. However, when the steel structures create odd reflections *inside* the house, radiofrequency radiation gets in through windows (in high power densities).

The discussion above has been about radiofrequency radiation and alternating current (AC) magnetic and electric fields. However, in many locations the static magnetic field can be generated or altered by ferrous structures and by direct current (DC) electrical currents. A typical example of this anomaly is a bed with metal springs occasionally causing a substantial

DC magnetic anomaly. Man-made pollution created by extensive static magnetic field-generating structures has recently been reviewed and illustrated (Armadillo *et al*., 2012). Biological cell proliferation and differentiation can be heavily affected by both AC and DC magnetic fields (Portelli *et al*., 2013). When inspecting health effects, both AC and DC fields need to be measured and understood.

57.3 Testing for short term and long term exposures

Exposure to electromagnetic radiation and fields continues, day and night, since radio and television broadcasts are continuous. Electric power lines and switchboxes emit low frequency electromagnetic waves all the time. Surveillance of traffic, energy and water consumption is constantly transmitted from central locations or via remot near every home. Electromagnetic waves from such devices, located on the external walls of homes, penetrate the normal building materials, exposing families and pets constantly. Cellphone towers, antennas and base stations emit electromagnetic waves all the time. Many people also expose themselves and their families voluntarily to WiFi wireless Internet network routers in their homes, or they may be exposed by their neighbours' routers. Wireless technology is installed in coffee shops, at hospitals, in government buildings and large workplaces.In many large cities people are involuntarily exposed even in the streets.

We do not know the cumulative effects of these chronic, long term exposures. Commercial bodies continue to claim that there is no evidence of harm, but much evidence has accumulated, raising questions on the validity of current regulations that take only thermal effects into account and ignore all non-thermal reported health effects and bioeffects.

In required safety tests for cellphone communication, the electromagnetic waves emitted by cellular phones are tested only for short-term effects of heating. In 1975, research determined the heat levels caused by microwave heating that leads to damage to animals. The measurement currently performed is the specific absorption rate (SAR), i.e., the amount of power or heat energy absorbed per unit mass of tissue (Watt per kilogram). In the experiment, trained rats stopped working for food after their whole body exposure reached average SAR of 4 W/kg (D'Andrea et al., 1975

Specific Anthropomorphic Mannequin (SAM) is the standard model used for radiation testing of mobile devices by their manufacturers. This is a large plastic head mannequin (Beard and Kainz, 2004), with an opening at the top of its head, containing a liquid whose electrical permittivity and conductivity parameters are equivalent to the average electrical parameters of the 40 tissue types in the human head (Gandhi et al., 2001). The size of the model head was initially based on the 90th percentile of 1989 United States military recruits (Gordon et al., 1989). The model is exposed to electromagnetic waves in the radio frequency microwave range, from the device being tested, and the currents induced within the salt solution inside the plastic head are measured for six minutes. Then the values are averaged. There are no official limit values for long term exposures, and therefore they are not measured.

One drawback of this system is that in reality, the human brain is a complicated network made of millions of neurons and other cells. No pathophysiological conclusion can be drawn by the Specific Absorption (SAR) tests recorded in this technique on long-term functions of neural networks. Another problem is that the test does not reflect the physiology of smaller individuals, including women and young children.

A different method for measuring and modelling tissue absorption using computational electrodynamics is the Finite-Difference Time-Domain (FDTD) method. According to several authors, the finite-difference time-domain (FDTD) algorithm is the most widely accepted computation method for SAR modelling, because this method simulates more anatomic tissue models derived from MRI or CT scans (Chan et al., 1997, Gandhi 2002, Gandhi et al., 2011). In the FDTD method, every cell is modelled according to specifically defined tissue characteristics. The area around the head is also modelled. This way, the interaction between different tissues and the emitting source are seen in the model, and we can identify "hot spots" in the tissues, which are areas that absorb more energy. The FDTD computer simulation cell phone certification process is immediately available and provides three orders of magnitude higher resolution than the SAM-based system for the head.

A serious health risk not taken into account by modern wireless technology is that functional neural networks take about two decades to develop in humans, beginning prenatally and continuing throughout childhood. In modern life, cell phones, radiation

emitting tablet devices, computers, WiFi and other sources radiate all the time near the child, teenager and constantly developing tissues. Brain neuronal networks must make an unnatural effort to meet the electric challenge in response to the abundant electrical signals of the environment, i.e., electromagnetic noise.

The best protection against exposure to radiation and electromagnetic noise is distance from the body. Radiation decreases in the distance squared. Terrain affects and especially rocks can provide measures of safety.

57.4 Mobile technology

People use mobile technology to run their daily personal and business matters. Cellular phone and tablet devices are often kept in skin contact. Mobile computers, emitting electromagnetic waves, are held in people's

Wireless communication devices interact with transmission and receiver stations. Traditional high radiofrequency transmission towers are often complemented by smaller base stations. Both types are active day and night. Exposure from base stations depends on distance, direction, and use. If more personal mobile devices are sending and receiving data via the base station, it emits more radiation. The density of base stations is high in the cities, allowing the supply of fast mobile communication speed to more people. In rural areas the distance to the base station is greater. Therefore, the transmitted connecting signals from the personal devices must be stronger to reach the base stations and the receivers. The greater the distance, the more energy is needed in contacts.

As industry offers more and more services via wireless, people forsake the option of landline and wired communication and embrace the convenience of wireless technology, disregarding the warnings of potential hazards. Medical associations have expressed concerns about the levels of electromagnetic load to which people are exposed. For instance, the Austrian Medical Association recommends that microwave radiation exposure levels should

be less than 10 uW/m2, one millionth of the limit value currently allowed in Finland (e.g. Johansson 2009).

Children are constantly exposed to electromagnetic radiation from cellphones carried by other children and by wireless Internet at school. Schools are areas where radiation limitations are important, as are homes, especially bedrooms. Constant exposure to electromagnetic fields from the proximity of mobile devices and their chargers, networks induced by routers, and exposure from Smart meters or external base stations can affect the learning process, disturb night sleep, and hamper the normal development of the brain.

57.6 Symptom based bioindication in humans

Humans absorb electromagnetic signals and act as receiving antennas as shown in Fig. 57.1.

Humans are actually one of the most useful sensitive bioindicator species, as they are constantly exposed. In addition to measured reactions and health statistics, people can also express their sensations (Huttunen et al., 2009). Human data banks provide possibilities to follow health developments in different areas. In Sweden, it has been reported that the general public health markers have deteriorated with the increase in electromagnetic exposure (Hallberg and Johansson, 2009).

Feldman et al. (2008, 2009) and Safrai et al. (2012) have suggested a unique environmental indicator for remote sensing of physiological effects in humans and primates. Eccrine sweat ducts in human skin are helically shaped tubes, filled with a conductive aqueous solution. The skin spectral response in the sub-Terahertz region is governed by the level of activity of the perspiration system and shows the minimum of reflectivity at some frequencies in the frequency band of 75–110 GHz. It is also correlated to physiological stress

as manifested by the pulse rate and the systolic blood pressure. The technology for remote sensing of this physiological signal is under development.

It is important to note that human exposure to emissions in the sub-Terahertz frequency band may interact with this physiological mechanism, causing perception of pain or other yet unrecognized health-related or psychological consequence.

57.6.1 Oxidative stress, increased brain metabolism, and cognitive effects

Radiofrequency and microwave fields from mobile phones held close to the body have been shown to increase free radicals, especially in neural cells. These free radicals appear to enhance mainly lipid peroxidation, and change the antioxidase activities of human blood, thus leading to oxidative stress (Moustafa et al., 2001; Aitken et al. 2006; Friedman et al., 2007; Campisi et al., 2010.)

Volkov et al. (2013) demonstrated direct effects of RF radiation on the brain with cell phone use. In healthy participants, 50-minute cell phone exposure was associated with increased brain glucose metabolism in the region closest to the antenna – as compared with no exposure.

Effects on sleep and cognitive performance in humans have been described by Regel et al. (2006-7) and Hutter et al. (2006), as well as symptoms, such as Alzheimer's di and vertigo (Huss et al., 2009 and others).

Highly electromagnetically exposed people complain of one or more of the symptoms described in Table 57.1, mostly due to neural-related problems. Many people connect their symptoms with their exposure to different sources, such as mobile phones, cordless phones, mobile phone stations, other electric appliances, television, computers, TV and radio broadcasting, and microwave ovens (Hagström et al., 2013). Cardiac arrhythmia has been

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reported by some to be increased when becoming sensitive, but this may also be due to increased age. The prevalence of implanted pacemakers increases steadily, e.g., in Finland, but again this may be due to population aging.

Table 57.1 Reported main symptoms of electromagnetically hypersensitive persons during their acute phase (194 returned valid responses,80.9% women and 19.1% men (Hagström et al. 2013).

Symptom	%
Stress (nervous)	60.3
Sleeping disorders	59.3
Fatigue	57.2
Concentration problems	56.7
Memory problems	54.6
Anxiety	52.6

57.6.2 Cardiovascular system

Easiest to quantify are the cardiovascular and respiratory cycles. Cardiovascular responses are easy to register. Ancient Chinese traditional medicine has done so for 3000 years or more. In ancient Chinese medicine the examiner compares the findings with his own pulse i.e. heart rate and arterial tonus, with respiratory cycles (Veith, 1997). Electrocardiograms are easily recorded by skin contact electrodes, or the signal can be recorded by mobile networks from a

distance, even through a telephone connection. The blood pressure and respiratory cycles can be recorded remotely, although this is seldom done. With computer programs readily available, more data can be obtained and analysed. Fig. 57. 3 illustrates some cardiovascular responses to activation of a mobile phone in a person carrying a pacemaker.

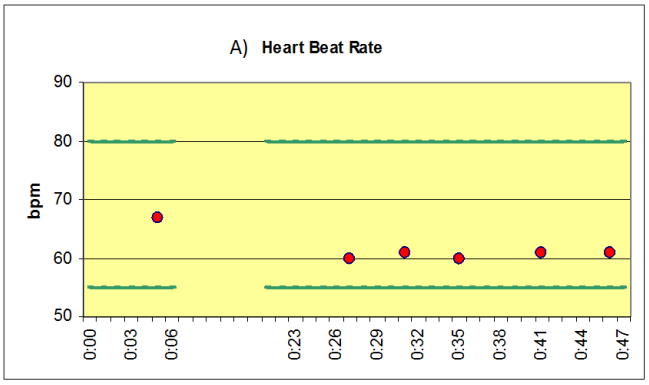


Fig. 57.3 A

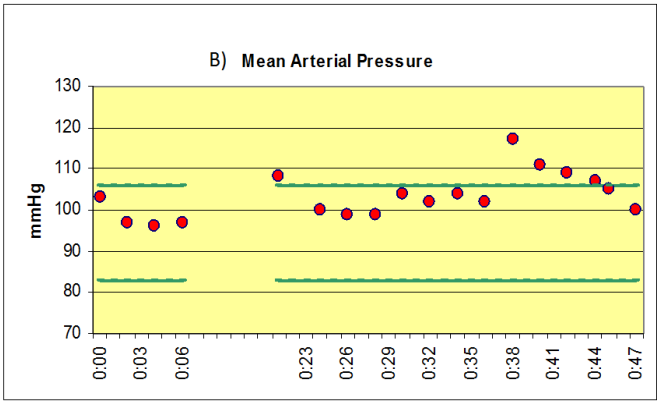


Fig. 57.3 B

Fig. 57.3 The cardiovascular responses (heart rate (A) and mean arterial pressure (B)) in a person carrying a pacemaker, when a silent mobile phone was turned on and off to enable the phone to make contact with its base station. This experiment was performed in a laboratory Faraday cage. The phone was placed behind the occiput of the blinded person (Hänninen et al., 2013, reproduced with the permission of the Journal)

57.6.3 Reproductive effects

Animal studies indicate that electromagnetic radiation may have a wide range of damaging effects on the testicular function and male germ line (Dasdag et al., 1999; Davoudi et al., 2002; Mailankot et al., 2009). Men who used their cell phones the most had significant poorer sperm quality than those who used them the least. The lowest average sperm count was found in men who used their cell phone more than four hours a day (Agarwal et al., 2008).

Purified human spermatozoa exposed to raised levels of RF/microwave radiation exhibited significantly reduced sperm motility and vitality (De Iuliis et al., 2009). Use of mobile phones

may have a harmful effect on male and female fertility (Erogul et al., 2006; Wdowiak et al., 2007; Gul et al., 2009).

57.7 Electrohypersensitivity and Multiple Chemical sensitivity

The interaction of electromagnetic fields with biological systems is known at different levels, but understanding and unravelling the cumulative effects are a big challenge (Blank, 2009; Bioinitiative report, 2012).

Manmade radiation is constantly turned on, for example radio and TV transmissions, military, police and rescue personnel communication systems and naval systems. It has been shown that pulsed fields have an effect on the EEG and the central nervous system (Bawin et al., 1975).

One can expect to see responses in different species and in humans due to the electromagnetic changes in the environment that have taken place in recent decades. As we know, there is biological variation regarding human sensitivity and hypersensitivity to allergens. The brain has a central role in the allergy response. After hypersensitivity is initially triggered, the allergic or hypersensitive response to different allergens can broaden to include new agents, varying from chemical to physical agents and vice versa.

After a person has developed hypersensitivity to a chemical or to a certain frequency of electromagnetic waves, the patient's patt
trigger is chemical, biological, particulate, nutritional, or electrical – it is characteristic of the patient. Typical subjective symptoms that have been described are drowsiness, malaise and headache, mood swings, tearfulness and eye pain, poor concentration, vertigo and tinnitus, numbness and tingling, nausea, convulsions, noise sensitivity, alteration in appetite, visual disturbances, restlessness, blushing, and muscle pain.

Wireless networks, such as WLAN, Wi-Fi etc., in offices and in many homes, and wireless radiating Smart Meters, increase the environmental irradiation load. Indoor sources of radiofrequency waves, such as those emitted from portable computers connected to a network, or sources of electromagnetic waves in other frequencies, such as high frequency voltage transients from electricity lines, add to this load (Milham 2010).

A multitude of electronic devices is used every day in the homes for various tasks. Many of these devices also emit stray electromagnetic waves that have no useful function. The electric lines carry long distances transients, which are harmful. High frequency voltage transients affect individuals with Multiple Sclerosis, may elevate blood sugar levels among people with diabetes and prediabetes conditions, and contribute to triggering Electromagnetic hypersensitivity (Havas, 2006)

Fig.57.2a gives the electromagnetic spectrum of a commonly used computer and Fig. 57.2b shows the huge increase in electromagnetic radiation of the attached WLAN in another computer (note the logarithmic scale).

57.8 Electrohypersensitivity – Recovery is possible

When a person has become sensitive, the first step towards recovery is to minimize the electromagnetic exposure. Many people who have become electromagnetically sensitive have previously suffered allergies to other agents, and know that they should avoid these exposures. Most important is to keep sources of electromagnetic waves such as mobile phones, TV sets, and computers turned off when not in use. Unfortunately, base stations and wireless networks cannot be turned off by individuals who wish to avoid this exposure, and therefore regulations must limit the installation of electromagnetic radiation emitting sources near people's homes, or near schools, where exposures, will be exposed. Fig. 57.4 illustrates cardiovascular hyperactivity in an electrohypersensitive individual, and reduction of this response after avoidance of electromagnetic exposure for several weeks.

The major mobile phone producers have regularly issued warnings to their users, urging them not to keep their active mobile phones in skin contact. This may indicate a new turn in

their attitude, possibly as an outcome of their failure to get health-related insurances for their products. However, these warnings are written in small and therefore are not read by most users (Davis, 2010).

Some devices emit more electromagnetic waves than others. Fig. 57.5 compares the radiation spectra of two Hand Held Tablet Personal Computers. One device has extremely high emissions that cannot be tolerated by an electrohypersensitive person. The other device emits lower, more acceptable levels.

In the countryside one can find niches, e.g., rock surrounded valleys, where the electromagnetic load is weaker. The radiati her/himself as the antenna (see also Fig. 57.1). Food rich in essential components, such as amino acids, unsaturated fatty acids, vitamins and other elements, increases the endogenous defence against the attacks of oxygen free radicals.

One can also reduce the penetrating radiofrequency radiation by paint on walls and curtains with conducting threads in accordance with electric safety regulations in different countries. If the person avoids electromagnetic exposure and uses nutritional supplements, positive results of reduction in hypersensitivity symptoms may be expected within about three months (Hagström, 2010/2013, personal communication).

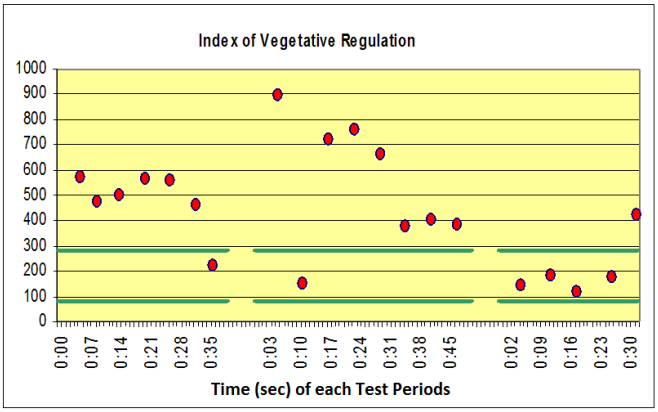
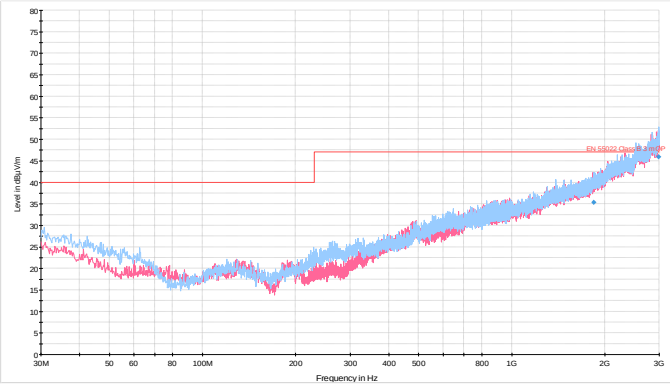


Fig. 57.4 Avoidance of electromagnetic exposure in a rural cottage outside a city. The cardiovascular abnormality of a sensitive person normalized in several weeks at least partially. The recordings of the heart rate and blood pressure were made in a Faraday cage, calculating the Index of Vegetative Regulation. (Hänninen et al., 2013, reprinted with permission of the Journal).



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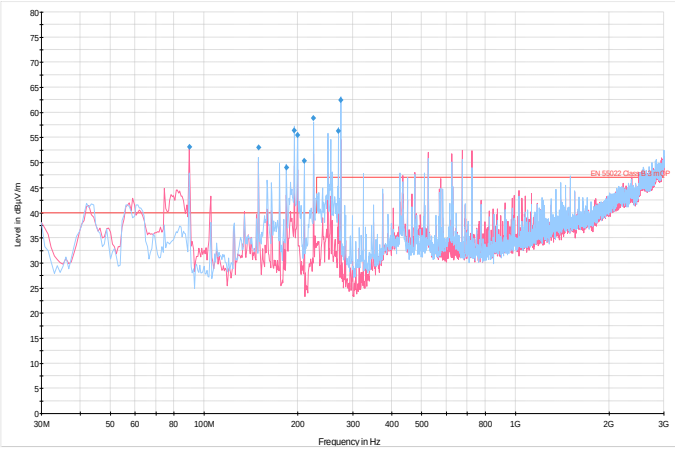

B

Fig. 57.5 Radiation spectra of two Hand Held Tablet Personal Computers measured in a Faraday room of a Radio laboratory. European Union EMC directive emission standard EN 55022 is indicated by the thin horizontal red line. According to the directive, one cannot sell dators exceeding this line, but these emissions were much exceeded in the lower tracing (B) of one tablet sold in Finland and sensitized persons cannot use it. The upper curve (A) shows that some devices emit more acceptable levels and can be used more safely.

57.9 Discussion – human effects as environmental indicators

There are various ways to document the human abnormalities and effects caused by electromagnetic exposure. As the direct recording of the antenna function of the human body is possible, this would be recommendable, in order to demonstrate the exposure and to correlate body effects or responses with the absorbed radiation (Fig. 57.5).

As the skin is directly exposed to electromagnetic load, one can expect the greatest changes there, as one would expect skin cancers in skin exposed to the sun. Skin cancers are common, including melanoma, which has increased,possibly due to sunbathing. The electromagnetic exposure of a person can be detected by recording the signals directly, to identify the irradiation sources currently activated. For example, signals from the fingers during typing on a keyboard, as seen in Fig. 57.6.

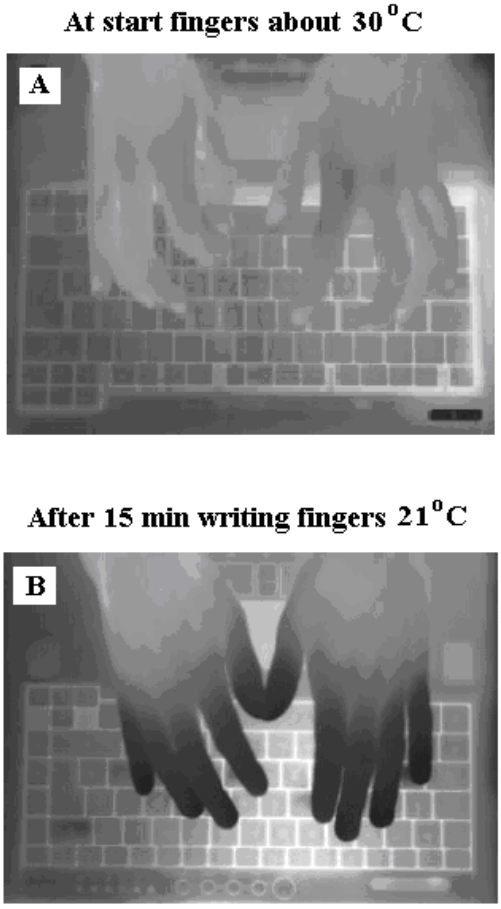

Fig. 57.6 The finger temperature of a sensitized person recorded by infrared camera during typing a heavily radiating laptop computer. While the increasing temperature can be seen from the keyboard the temperature of fingers was cooling. At the same time the person sensed pain and the hands got clumsy. (Hänninen et al.,2011, J. Environmental Sciences, with permission of the journal)

In the skin or near it are various types of glands and glandular tissue. The breasts are a type of glandular tissue. The incidence of breast cancer has been rising and rising in the Western world. The causes of breast cancer are multifactorial. While the specific triggers for eruption of the disease in each person is difficult to specify, electromagnetic waves that have the ability to affect cells and chromosomes may act as an added factor or a catalyst in this morbidity.

The salivary glands are relatively superficial, near the skin. The parotid gland is particularly exposed to electromagnetic waves in the RF/MW range, due to the use of mobile phones near to, or in skin contact with, the ear and the head. A study from China has shown that parotid cancers have recently increased some 30-fold (Duan et al., 2011). A recent study from Israel (Czerninski et al., 2011) demonstrated that the total number of parotid gland cancers in Israel increased 4-fold from 1970 to 2006 (from 16 to 64 cases per year), whereas other major salivary gland cancers remained stable.

Glandular cells are more exposed than cells of the central nervous system, i.e., the brain and the spinal cord. The brain is protected by the skull. Nevertheless, the incidence of brain tumours has doubled during the last decades, since the introduction of mobile telephony. A recent study demonstrated that use of a mobile phone for a total of 1600 hours seems to double the incidence of acoustic neuroma. Gliomas and astrocytomas are more common on the side of the head where the electromagnetic wave load has been greater than on the other side, i.e., the side that the person uses the phone. (Hardell et al., 2010, 2013). A large epidemiological study found greater odds ratios for acoustic neuroma in those who used cellphones for 1640 and more cumulative hours. In some cases, use of over 5 hours a day was reported (Interphone Study Group, 2011). The tumour morbidity is expected to grow in the future, as young children actively use mobile phones extensively.

The permeability of the blood brain barrier against the entrance of harmful molecules has been shown to increase after mobile phone radiation exposure (Nittby et al., 2009). Children are especially susceptible to this effect, since the protective skull grows until the bone sutures have closed, and skull bone thickness continues to increase until adulthood.

A unique mechanism in which electromagnetic waves of a specific frequency (Sub-terahertz) can enter the body through the skin is directly via the eccrine sweat glands that are found over most areas of the skin, in humans and primates (Feldman et al., 2009). The exact physiology and mechanism of function of this recently discovered frequency-specific biological sensor is currently being researched.

Biochemical responses in humans and other creatures can by analysed as indicators, e.g., hormones, such as cortisol, and melatonin (Burch, 1999). The release of iron has also been used as an indicator for effects and responses to exposure to both radio frequency and low frequency electromagnetic waves (Allen et al., 2000; Cespedes and Ueno, 2009). The first step in this process is probably activation of plasma membrane NADH oxidase and generation of oxygen free radicals, followed by activation of protein kinases (Friedman et al. 2007). Fragmentation of DNA has been shown to occur (Phillips et al., 2009; Campisi et al., 2010) and genotoxic effects are expressed (Ruediger, 2009). The exposure to electromagnetic waves also activates the synthesis of heat shock proteins which act as chaperons and transmute the three dimensional structures of proteins (Blank and Goodman, 2009). These cause changes in cellular metabolism and can be seen also in the proteome findings. There may be differences between the responses to exposure to different wave lengths (Nylund et al., 2010).

Measurements help to quantify the sensations reported. For instance, a decrease in skin temperature is a sensation that a number of people have reported, and it can be followed with the aid of infrared thermography of the fingers. The person who is being monitored can report when feeling pain in the fingers and also the sensation that their hands are becoming clumsy, qualities that are more difficult to measure. Fig. 57.4 a & b shows how exposure to electromagnetic waves constricts the circulation in the fingers and cools them within a few minutes to room temperature, although the computer induces heat that is expected to warm the fingers. Other people have reported a sudden feeling of heat in the head or neck or a sharp sensation of pain after exposure to electromagnetic waves. A testing mechanism should be developed to examine these phenomena.

Phone conversations while driving and esp
attention. This affects the driver mentally and can cause car crashes (Drews and Stayer, 2004; McEvoy et al., 2006).

Humans can sense the standing waves of some radio transmissions. People feel these waves in the form of a spontaneous muscle contraction. Some more sensitive individuals seem to be able to sense the differences of standing waves in different wavelengths, with a unique sensitivity, almost as most of us can differentiate between colours (Huttunen et al., 2009). Such people are specifically frequency sensitive.

57.9.1 Occupational data on human exposure to electromagnetic fields (mostly in military settings)

In 1972, Glaser published a 106 page report for the US Naval Medical Research Institute, reviewing over 2,300 articles that assess biological responses and effects of non-ionizing radiation on humans. Many of these effects had been called microwave sickness. He classified the biological effects into 17 categories, listing both thermal and non-thermal effects. These include: changes in physiologic function such as blood and vascular disorders, biochemical changes (enzymes and others), metabolic, gastro-intestinal, and hormonal disorders, alterations in the nervous system, histological changes, genetic and chromosomal effects, psychological disorders, behavioural changes in animal studies, and others.

Steneck et al. and Cook et al. reported in 1980 on research published during the years 1940-1960 in Russia and East Europe on the biological effects of microwave radiation.

In 1996 and 2001, Szmigielski published data on cancer morbidity of military personnel occupationally exposed to electromagnetic radiation from radar for a follow up period of 20 years. Grayson (1996b) found a slight excess risk for brain tumour after exposure to electromagnetic radiation (ELF and RF/MW) in the US air force. Robinette et al. (1980) looked at 20,000 US Korean War Naval Veterans 1954-58 with occupational exposure to

radar. The subgroup defined as the most intensely exposed, Aviation Technicians, had the highest level of crude death rates per 1000. Groves et al. (2002), in a follow-up study of Robinette's cohort 40 years-exposure occupation group reported out of three, in which rates of non-lymphocytic leukemia were significantly elevated.

Degrave et al. (2005, 2009) found an excess incidence of hematolymphatic cancers in two retrospective cohort studies in Belgian male military personnel exposed to anti-aircraft radars in Western Europe between the 1960s and1990s.

Occupational exposures to EMF have also been described by Goldsmith. In his report of 1997, Goldsmith presents evidence of chromosomal changes in lymphocytes cultured *in vitro* from employees who had worked in the U.S embassy and had been unknowingly exposed to low levels of radiofrequency/microwave radiation.

Richter et al. reported exposures and cancers in several sentinel patients in a cluster of such workers and in patients. Some of the patients presented with brain cancer with short latent periods of less than 10 years.

Stein et al. (2011) reported a sentinel case series of 47 cancer patients, who had been occupationally exposed to RF/MW or ELF, in various mostly in military settings. Data analysis suggested a coherent and biologically plausible pattern of cancer latency in relation to the onset of exposure to EMF and accompanying agents, since latent periods for testicular tumours were very short, the latency was longer for Hemato-Lymphatic cancers and still longer in solid tumours

57.10 The Precautionary Principle

The Precautionary Principle is a notion which supports taking protective action before there is complete scientific proof of a risk; that is, action should not be delayed simply because full scientific information is lacking. The precautionary principle or precautionary approach has been incorporated into several international environmental agreements, and some claim that it is now recognized as a general principle of international environmental law.

Currently, safety thresholds for electromagnetic exposure of the general public are being set mostly by engineers, not by public health experts, and are based on thermal effects only, totally ignoring reported bioeffects.

In view of the Precautionary Principle, the prudent conclusion is to reduce exposure of susceptible members of society, such as children, pregnant women, the sick and elderly and electrohypersensitive individuals, as a protective measure until the safety of the exposures is proven.

57.11 Conclusions

Ever-growing manmade electromagnetic radiation and fields cover the globe. This load has increased rapidly, by orders of magnitude, due to increasing mobile telephony, distant recording of services such as electricity and water services using wireless "Smart meters", and Internet Wi-Fi networks applied in public spaces, including mandatory exposure of children in schools. All organisms are exposed to different degrees. Humans and other creatures serve as antennas. All people are passively exposed at least to some degree, but many are exposed much more, due to the active use of mobile telephones of other citizens including their neighbours at their homes.

Examples of animals, plants and humans indicate that they are harmfully affected. Human questionnaire surveys and epidemiological studies provide increasing evidence of risks of increased morbidity. Electrohypersensitivity is becoming more common. The worst signs are studies showing DNA damage and increased carcinomas.

Birds are able to leave high exposure areas. Humans seem to be able to recover, if they diminish use and avoid the presence of active radiating devices, or flee to radiation-free zones. Children need increased concern. The Precautionary Principle signed by many nations should be used and observed.

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