Bioelectromagnetics

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|---|---|
| Journal: | *Bioelectromagnetics* |
| Manuscript ID: | Draft |
| Wiley - Manuscript type: | Regular Article |
| Date Submitted by the Author: | n/a |
| Complete List of Authors: | Tuengler, Andreas; RWTH Aachen University, Institute of History, Theory and Ethics in Medicine, and Human Technology Centre (HumTec)<br>von Klitzing, Lebrecht; Institute of Environmental Physics<br>Gross, Dominik; RWTH Aachen University, Institute of History, Theory and Ethics in Medicine, and Human Technology Centre (HumTec) |
| Keywords: | hypersensitivity to electromagnetic fields, radiofrequency, athermal effects, heart rate variability, time-series analysis |
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# Mobile Phones, Electromagnetic Hypersensitivity, and the Precautionary Principle

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**Abstract**

This paper describes some effects of electromagnetic field exposure on a cellular level, and, in the form of electromagnetic hypersensitivity, on humans. It is based (1) on a systematic re-analysis of the existing literature and smaller single studies in this field and (2) on a discussion of limit values and the Specific Absorption Rate (SAR) in relation to athermal (non-thermal) effects of electromagnetic radiation in the mobile phone frequency range (800 – 2.000 MHz).

A proposal on how to measure electromagnetic hypersensitivity is presented using simultaneous recordings of heart rate variability (HRV), microcirculation and electric skin potentials. Thus it is possible to distinguish 'true' electromagnetic hypersensitive individuals from those who suffer from other conditions. It is explained why the precautionary principle should be applied to protect the vulnerable group of electromagnetic hypersensitive individuals.

**Key words:** hypersensitivity to electromagnetic fields, radiofrequency, athermal effects, heart rate variability, time-series analysis

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This study was supported by the excellence initiative of the German federal and state government.

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## INTRODUCTION

Electromagnetic Hypersensitivity (EHS) is a term used to describe individuals who consider themselves suffering from the effects of electromagnetic radiation. Their estimated percentage varies according to country and year of inquiry and is dependent on the classification used. No objective criteria for EHS exist. In Sweden their number rose from 0.06% in 1985 to 9% in 2003, while in 2003 in Switzerland their number was 5%, and in 2004 they numbered 9% in Germany and 11% in England.[Hallberg and Oberfeld 2006] The prevalence for Austria increased from 2% in 1994 to 3,5% in 2008.[Schroettner and Leitgeb 2008]

The symptoms described by people suffering from EHS are non-specific and range from headache, skin symptoms to sleeping problems, heart problems and nervous symptoms. [Irvine 2005]

Bergqvist and Vogel describe three stages in the development of EHS: temporary symptoms in the first stage, persisting symptoms with increasing intensity, duration or number of symptoms in the second stage, and frequent neurovegetative symptoms triggered by electromagnetic fields (EMF) in the third stage. [Bergqvist and Vogel 1997] Accordingly, the impacts of the complaints range from mild impairment to withdrawal from work and society.

Scientists and sufferers disagree about aetiology and significance of this illness.[Moore and Stilgoe 2009]

Not every individual responds to electromagnetic radiation. The probability of adverse effects in relation to electromagnetic field exposure depends on the individual constitution, pre-existing disease, duration of exposure, type of electromagnetic radiation (continuous-wave or modulated), and intensity, among others. There is no specific set of symptoms that would clearly distinguish an electromagnetic hypersensitive individual from someone with other hypersensitivity syndromes. Until now, no model of effect could be established. Because of that it is not possible to define the influencing factor of an athermal effect, which is a prerequisite for any statistical testing. EHS seems to be a multicausal event.

In double blind provocation studies with regard to electromagnetic hypersensitivity, people are classified as sensitive or not according to their own assessment (e.g. self-reported electromagnetic hypersensitivity).[Eltiti et al. 2007; Hillert et al. 2008; Kim et al. 2008; Landgrebe et al. 2008; Wilén et al. 2006] Huss et al., in an innovative environmental medicine counselling project, came to the conclusion that in 32% of cases there was a plausible relationship between EMF exposure and reported symptoms.[Huss et al. 2005] This means that 68% of those who claim to be electromagnetic hypersensitive could in fact suffer from other conditions or even have a psychological condition causing their symptoms. With this in mind it is no surprise that provocation studies with self-reported electromagnetic hypersensitive individuals could not find any association between symptoms and exposure. What is needed is a method to measure genuine electromagnetic hypersensitivity in order to differentiate this kind of hypersensitivity from other kinds of conditions.

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## MATERIALS AND METHODS

The paper is based (1) on a systematic re-analysis of the existing literature and single studies in this field and (2) on a discussion of limit values and the Specific Absorption Rate (SAR) in relation to athermal (non-thermal) effects of electromagnetic radiation in the mobile phone frequency range (800 – 2.000 MHz). The proposed method to measure electromagnetic hypersensitivity using simultaneous recordings of heart rate variability (HRV), microcirculation and electric skin potentials is the result of extensive measurements by one of the authors (von Klitzing) in this area.

## RESULTS

### Thermal and non-thermal effects of electromagnetic fields

Effects of electromagnetic fields are divided into thermal effects and athermal (non-thermal) effects. Thermal effects are caused by absorption of energy from the electromagnetic field which results in heating of the tissue. Thermal effects are assessed through the specific absorption rate (SAR) and are described as the rate at which energy is absorbed by a particular mass of tissue.[Cox 2003] The unit of measurement is watts per kilogram. Athermal effects do not result in detectable temperature increases. There are numerous reports of athermal effects of EMF in the mobile phone frequency range (800 – 2.000 MHz).

French et al. showed that exposure of an astrocytoma cell line to an 835 MHz electromagnetic field could alter cell morphology and inhibit cell proliferation at power densities in the mobile phone range. Since no significant heating was detectable it must be called an athermal

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effect.[French et al. 1997] The electromagnetic field was a continuous (sinusoidal) one without modulation. Such fields are used as carrier waves in analogue mobile phone communication systems. The authors conclude: “The decrease in astrocytoma proliferation is intriguing, and the fact that effects on cell proliferation can be induced by exposure to 835 MHz indicates that this frequency may be capable of affecting fundamental biological processes in the apparent absence of significant heating.”

Mancinelli et al. could provide evidence for effects of electromagnetic fields on refolding of acidic myoglobin and suggest that microwaves could affect protein folding.[Mancinelli et al. 2004]

Exposure to pulsed electromagnetic fields is more likely to cause a biological reaction than exposure to continuous fields.[Juutilainen et al. 2011; Laurence et al. 2000]

Athermal effects of electromagnetic fields are involved in the activation of so called “heat shock proteins”. Heat shock proteins act as chaperonins e.g. they affect the folding and assist in the proper conformation of proteins and prevent protein-aggregation. Thus they represent a part of the cellular repair capacity. A heat shock response may be elicited by different stressors, be it heat, osmotic pressure changes, pH, UV radiation or oxidants and heavy metals.[Gutzeit 2001]

Gutzeit asked if the interaction of two or more stressors can produce critical stress levels, given the fact that a single analysis of each of the stressors alone would not show any effect. He could show that stressors act in concert affecting homeostatic regulation of an organism and concludes that this illustrates potential environmental hazards which have not been addressed so far.[Gutzeit 2001]

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In a 2011 report the European Council came to the following conclusion: “After analysing the scientific studies available to date, and also following the hearings for expert opinions organised in the context of the Committee on the Environment, Agriculture and Local and Regional Affairs, there is sufficient evidence of potentially harmful effects of electromagnetic fields on fauna, flora and human health to react and to guard against potentially serious environmental and health hazards.”[Huss 2011]

Many years of research into athermal effects not only brought about more knowledge, but also more sources of uncertainty and ignorance. This may be due to the complexity of interaction of electromagnetic fields with biological systems and the variety of methodology used. Nevertheless it cannot be denied that those athermal effects exist. In fact they seem to profoundly affect living systems. We are only at the beginning of understanding those complex interactions. And that should pave the way to more research but at the same time not hinder us from being more cautious in respect to exposure to electromagnetic fields. We should not follow the principle of “paralysis by analysis” but instead heed the early warnings.

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## Limit values

The limit values for non-ionizing radiation are based on the physical law of thermodynamics and suggest that energy is absorbed by the body according to physical laws. The underlying assumption is that only thermal effects could harm the organism. That is despite the fact that athermal effects are documented nowadays. (see above)

In 2009 the International Commission on Non-Ionizing Radiation Protection (ICNIRP) stated in respect to athermal effects: "With regard to non-thermal interactions, it is in principle impossible to disprove their possible existence but the plausibility of the various non-thermal mechanisms that have been proposed is very low." Our way of adding knowledge to the scientific edifice may contribute its part. In science it is conventional practice to keep the chance of getting false positive results relatively low in order not to add to the scientific knowledge what might not be true. The cost for this is that we might miss possible adverse effects (e.g. we might have too many false negatives.) Therefore Cranor suggests to depart from the 95 percent rule when it comes to "…preventive regulatory proceedings where the major concern is the forward-looking prevention of health harm and there is little fundamental research to be gained or upon which to build."[Cranor 1990]

Regarding limit values for electromagnetic fields in the cell-phone range no distinction has been made between continuous-wave (cw-) radiation and modulated electromagnetic fields. When looked at purely energetically, there is in fact no difference between continuous radiation and modulated radiation. The same amount of energy will be deposited in both cases. Nevertheless there is a difference in the energy generation and dissipation over time.[Neshev and Kirilova 1996] In their paper representing a theoretical model about

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possible environmental health risks of pulsed modulated microwaves Neshev et al. state that "the repetition times of pulsed microwaves that are emitted into the environment should be studied very carefully for possible health hazards."[Neshev and Kirilova 1996]

According to the standards of the DIN/VDE 0848, limit values are based on exposure in the range of 6 minutes, i.e. in the short term range.[Bundesimmissionsschutzgesetz] The ICNIRP adopted these standards. In the ICNIRP Guidelines it states: "…these guidelines are based on short-term, immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF."[ICNIRP 1998] This again is due to the fact that only thermal effects are considered relevant. One could say that the thermal effect only accounts for immediate reactions, but the athermal effect is the long-term effect. This raises the following question: How can those limit values established by the ICNIRP that are based on thermal effects and short term exposure protect from athermal or long-term effects?

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**Specific Absorption Rate (SAR)**

The energy from electromagnetic radiation of high frequency is absorbed by the body and converted to heat, which results in a temperature increase. Above a certain limit, this could cause harm. Accordingly, a limit value was proposed by the ICNIRP and is represented by the specific absorption rate (SAR). The SAR value is dependent on conductivity and density of the tissue of interest, on the electromagnetic field strength, and the geometry of the handset.

The absorption rate cannot be regarded as a reliable measurement of the effects of electromagnetic radiation in the mobile phone frequency range. In 1981 the WHO wrote in its report on radiofrequency and microwaves: “SAR alone cannot be used for the extrapolation of effects from one biological system to another, or for the extrapolation of biological effects from one frequency to another.” and “Curves for exposure which produce equivalent SAR for a given body over the microwave/RF energy spectrum may be used to predict equivalent average heating, provided data concerning heat dissipation indicates equivalent heat dissipation dynamics. Such curves cannot, however, be used as the only basis for predicting biological effects or health risks over the microwave/RF spectrum, since from current knowledge, it is not possible to state that equivalent average energy absorption rate for given radiation frequencies is associated with equivalent biological effects.”[WHO 1981]

The determination of a specific absorption rate as a safety measure is not adequate for living systems. It does not account for athermal effects and ignores the complexity of living organisms.

## Discussion

### Proposal on how to measure Electromagnetic Hypersensitivity

There are possible parameters that could be used to measure electromagnetic hypersensitivity. Thus, ´genuine´ electromagnetic hypersensitive individuals could be distinguished from those who suffer from other conditions. A prerequisite for possible parameters to measure electromagnetic hypersensitivity would be: they must be beyond voluntary control and they must be measureable.

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EHS has been tested mostly on the level of one or more effects such as changing skin temperature, bodily sensations or cognitive efficiency and other psychological events etc. **immediately** on exposure. As such, only short term, e.g. thermal effects, are taken into account as possible outcomes of exposure to electromagnetic fields. Obviously the athermal reaction of biological systems is initiated on the vegetative level as this is where biological functions are basically regulated, e.g. oxygen supply through respiration and blood flow. Following with a considerable time-delay, there might be a change of skin temperature or in behaviour on any cognitive or mental level. Additionally, it is very important that the test parameter is not influenced by autogenous activity, that means for instance changing breathing frequency.

The following non-invasive methods are suitable:

- Heart Rate Variability (HRV)
- Microcirculation (capillary blood flow)
- Electric skin potentials

The determination of HRV is a well-established method to evaluate the activity of bioregulation: The time variance of succeeding heart beats are within an individual time frame. A limited variance points to a disturbance in bioregulation. A constant succession of the single events is not consistent with life. METHOD: time series analysis (see Figure 1) or frequency analysis (Fast Fourier Transformation: FFT) of the subsequent R-waves (ECG) (see Figure 2 and Figure 3).

Wilén et al. could not find significant differences in their power spectral analysis of heart rate variability recordings between self-declared electromagnetic hypersensitive individuals and matched controls.[Wilén et al. 2006] But they did not investigate and compare the **dynamics**

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**of changes** in HRV during and after exposure. In our experience the dynamics of changes in HRV are of vital importance. After recording and analysing them and comparing them with simultaneously recorded measurements of capillary blood flow and electric potential difference of the skin (as described further below), a consistent pattern of changes can be found in 'genuine' electromagnetic hypersensitive individuals.

Yilmaz investigated the effects of EMF from mobile phones on the HRV using nonlinear analysis methods.[Yilmaz and Yildiz 2010] He found significant changes in healthy young volunteers and concluded "that high-level EMF changed the complexity of cardiac system behaviour significantly." We hypothesize that changes would be more pronounced in 'genuine' electromagnetic hypersensitive individuals.

The continuous detection of capillary blood flow (microcirculation) is an important tool for analysing the capacity of autonomous nervous activity (see Figure 4). The very important intestinal motility is particularly reflected in this dynamic of regulation. In EHS patients this regulation shows no activity at all for some time after exposure (see Figure 5). METHOD: Measurement via Doppler Flow Meter at the lobe of the ear

The electric potential difference, measured in a distance over some millimeters on the skin surface of the forearm (see Figure 6), reflects low-amplitude signals like ECG, but only in a stress-free situation (Figure 4). Under stress there is only a zero-line (see Figure 5).

All these three parameters are influenced in EHS patients under exposure within some minutes and remain so after exposure for some minutes up to one hour. The all-in-all matrix with these data is conclusive for EHS-classification (see Figure 1, Figure 3, Figure 4 and

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Figure 5), and allows to distinguish ´genuine´ electromagnetic hypersensitivity from other types of conditions (see table 1 and table 2).

**The Precautionary Principle**

The precautionary principle is: "a ‚better safe than sorry' approach suggesting that action should be taken to avoid harm even when it is not certain to occur".[Kheifets et al. 2001] The Rio Declaration on Environment and Development gives a classical definition: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation"[UN 1992]

The severity of possible harm and the degree of uncertainty are the two main factors influencing the choice if action should be undertaken or not. Renn interprets precaution "as being conservative when making judgements and erring on the side of caution when calculating exposure or determining safety factors".[Renn 2007]
It is widely disputed if and how the precautionary principle should be applied in risk assessment and management, especially when related to governance.[Renn 2007]
According to Peterson, the precautionary principle should not be used for decision-making because of possible conflict with other principles of decision-making. Nevertheless, he acknowledges an important fact when he refers to an epistemic interpretation of the precautionary principle saying that "it is more desirable that risk assessments avoid making false-negative rather than false-positive errors."[Peterson 2007]

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Stirling, seeing the precautionary principle also not as a complete decision rule, rather values it as providing "a general normative guide to the effect that policy-making under uncertainty, ambiguity and ignorance should give the benefit of the doubt to the protection of human health and the environment, rather than to competing organizational or economic interests."[Stirling 2007] How those economic interests can influence even the outcomes of scientific investigation was demonstrated by Huss et al. who investigated how likely a study would show an effect of exposure to electromagnetic fields in relation to funding of the study: Studies funded exclusively by the industry were found to report less likely statistically significant results.[Huss et al. 2008]

Some authors argue that precautionary measures could even trigger public concerns and therefore might impair well-being of the general population.[Wiedemann and Schuetz 2005] Of course, a part of the public is already concerned and knows the divergent opinions in the scientific community. But what makes them concerned? It is their own suffering, it is electromagnetic hypersensitivity, which currently is not well understood by scientists. Ravetz states: "The public has discovered that the claimed scientific facts can be as controversial as the underlying ethical and political principles."[Ravetz 2004]

## CONCLUSION

We suggest to apply the precautionary principle to the health risk associated with the new mobile telecommunication technologies, especially in relation to limit values, guidelines to limit exposure, and network planning. The public should be aware of the uncertainty associated with mobile phone health risks, also because individual precautionary measures are easy to take and could turn out to be justified in the long run. Limit values should be lowered

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to values recommended by The Scientific Panel on Electromagnetic Field Health Risks and adapted in the future according to further research results.[Fragopoulou et al. 2010] The vulnerable group of people suffering from electromagnetic hypersensitivity should no longer be neglected or stigmatised only because there is no accepted model of effect of this condition. What is needed in relation to electromagnetic hypersensitivity is, referring to Stirling, “a salutary spur to greater humility” in science.[Stirling 2007]

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Figure Captions

Figure 1: Heart rate variability in a time series analysis showing active bioregulation (above) and limited bioregulation (below)

The ECG signal is recorded over a time frame of 1,1s (triggered by the R-waves) and displayed in an overlapping manner over a period of 3 min.
The shaded area (light blue) represents all the single events.
The continuous line (dark blue) represents the arithmetic mean of the succeeding heartbeats. The maximum of the continuous line represents the core area of the successive R-waves following the trigger: The higher this mean maximal value in relation to the individual event, the narrower is the bandwidth of the heart rate variability.
In the lower graph the bandwidth of the actions is shortened thus representing a limited bioregulation as it is seen in electromagnetic hypersensitive individuals under or shortly after electromagnetic field exposure from mobile phones.

Figure 2: Determination of the Heart Rate Variability (HRV) using Fast-Fourier-Transformation (FFT)

The variability of the heart rate is determined via frequency analysis (FFT) of the basic signal (distance of individual R-waves in the ECG) and its harmonics.

Figure 3: Results of the Fast Fourier Transformation (FFT) with Power spectrums of ECG, basic frequency of ECG (--) and harmonics

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The narrower the basic frequency of the ECG (limited bioregulation), the more marked the harmonics. The left picture with almost no distinct harmonics is typical for an active bioregulation, the right picture due to the increased amount of harmonics is typical for a limited bioregulation.

Figure 4: Simultaneous display of temporal ECG-changes (on top), electric skin potentials (middle), and microcirculation (below) typical for a normal (healthy) bioregulation

Electric skin potentials (middle) are displayed as temporal sequence of the recorded signals during the different experimental settings (before, during and after exposure). Under normal conditions the electric skin potentials mirror the ECG.

Changes in capillary blood (microcirculation) flow are analysed as a function of time (below). The microcirculation is controlled by the vegetative nervous system. Recorded before, during and after exposure these data thus provide insights into the activity of bioregulation. The basic frequency is the typical periodical biological regulation of approximately 0,15 Hz (one period of about 7s) which correlates with the intestinal motility and gallbladder motility. Superimposed on those signals are high-frequency signals that correlate with the individual heart beats (R-waves).

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Figure 5: Simultaneous display of temporal ECG-changes (on top), electric skin potentials (middle), and microcirculation (below) typical for a pathological bioregulation

With increasing stress the electric skin potential difference shows less and less amplitude until there is no more oscillation. The basic frequency of the microcirculation is diminished as is the high- frequency signal.

Figure 6: Measurement device for determination of the electric potential difference
4 times 4 electrodes serve as sensors and are placed in a distance of 2,4 mm from each other onto the skin surface.

Table 1 and 2: Simplified overview of changes in electrophysiological parameters in healthy individuals, in electromagnetic hypersensitive individuals, in individuals with other conditions, and in individuals that cannot be classified

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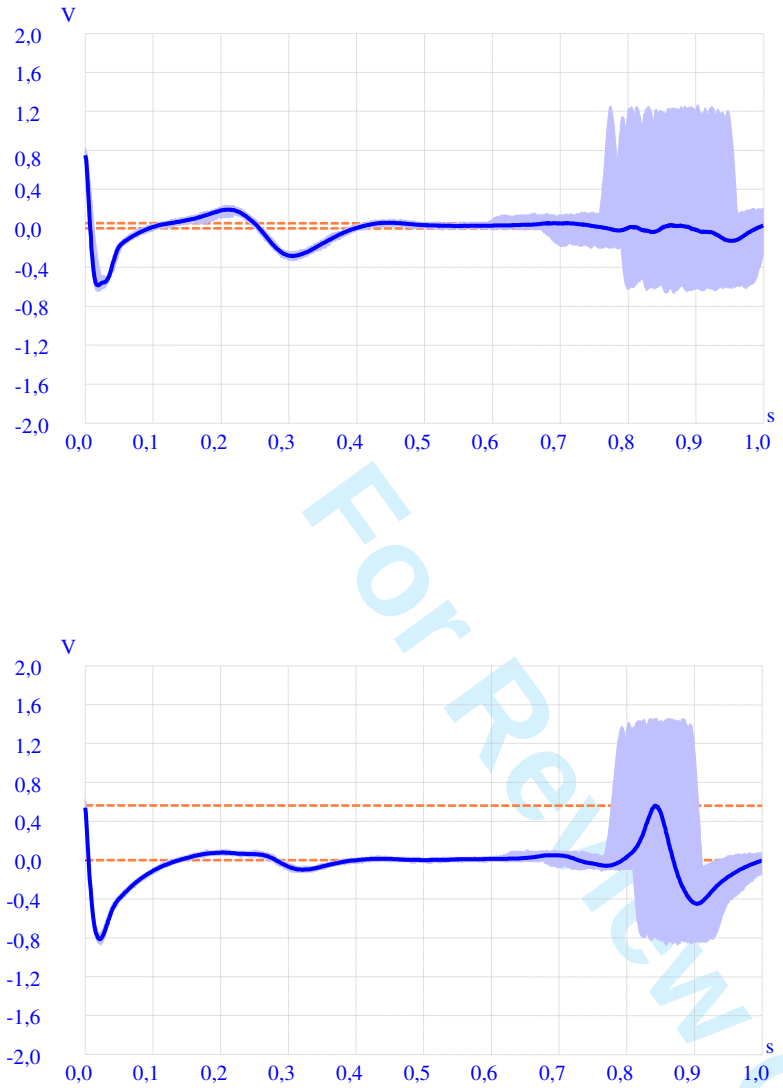



Figure 1

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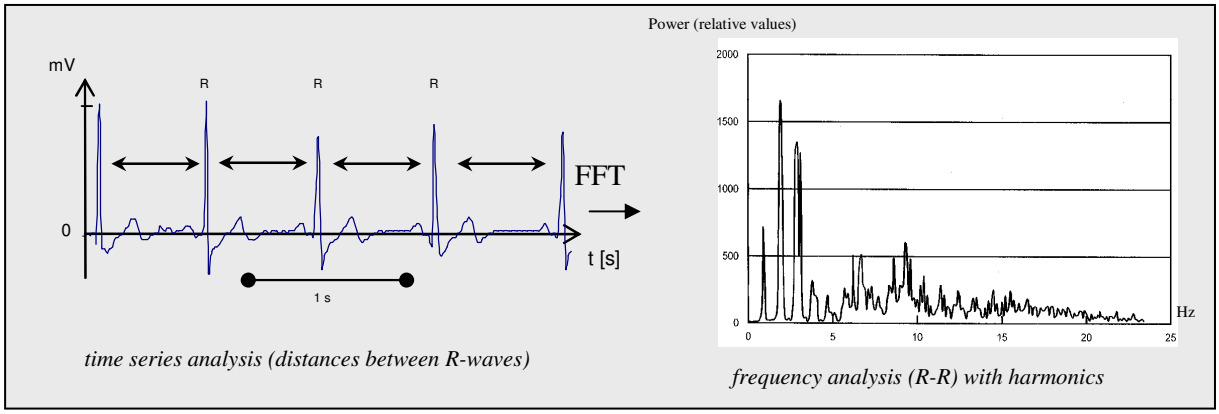



Figure 2

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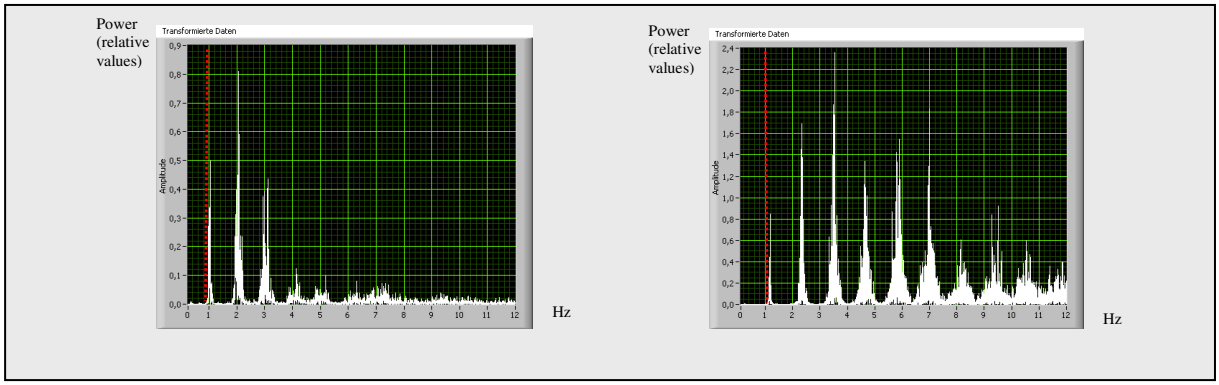



Figure 3

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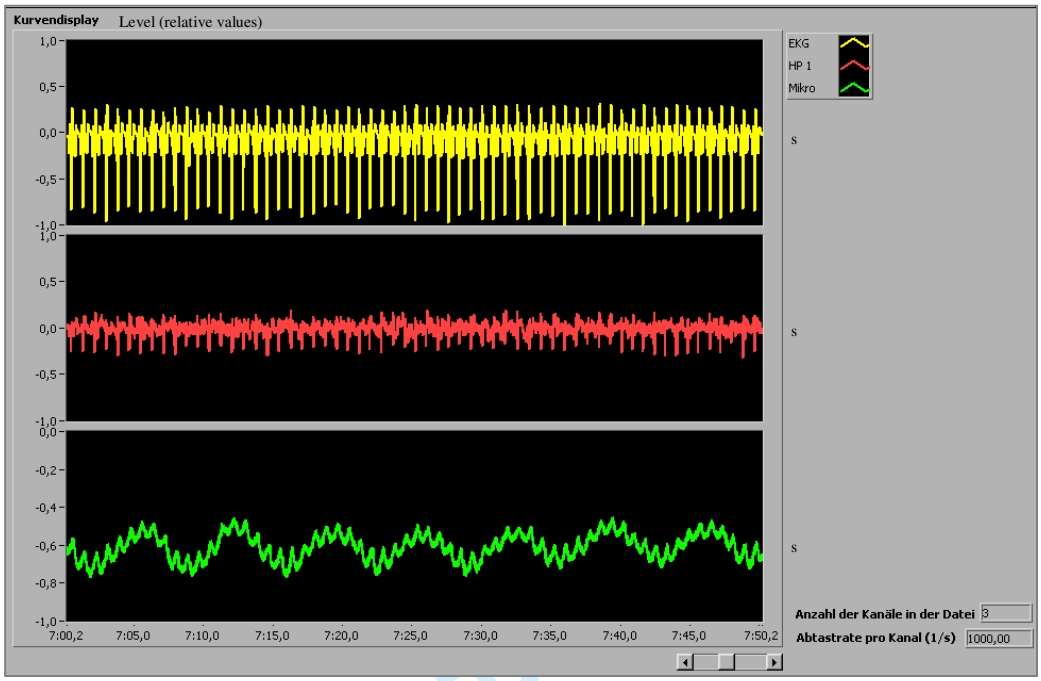



Figure 4

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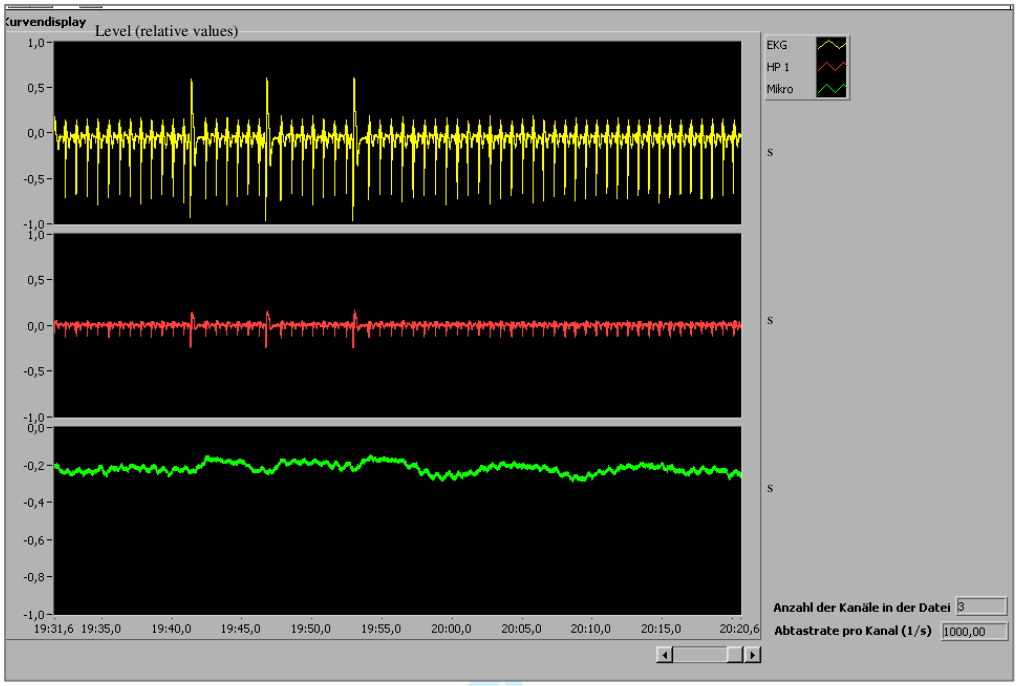



Figure 5

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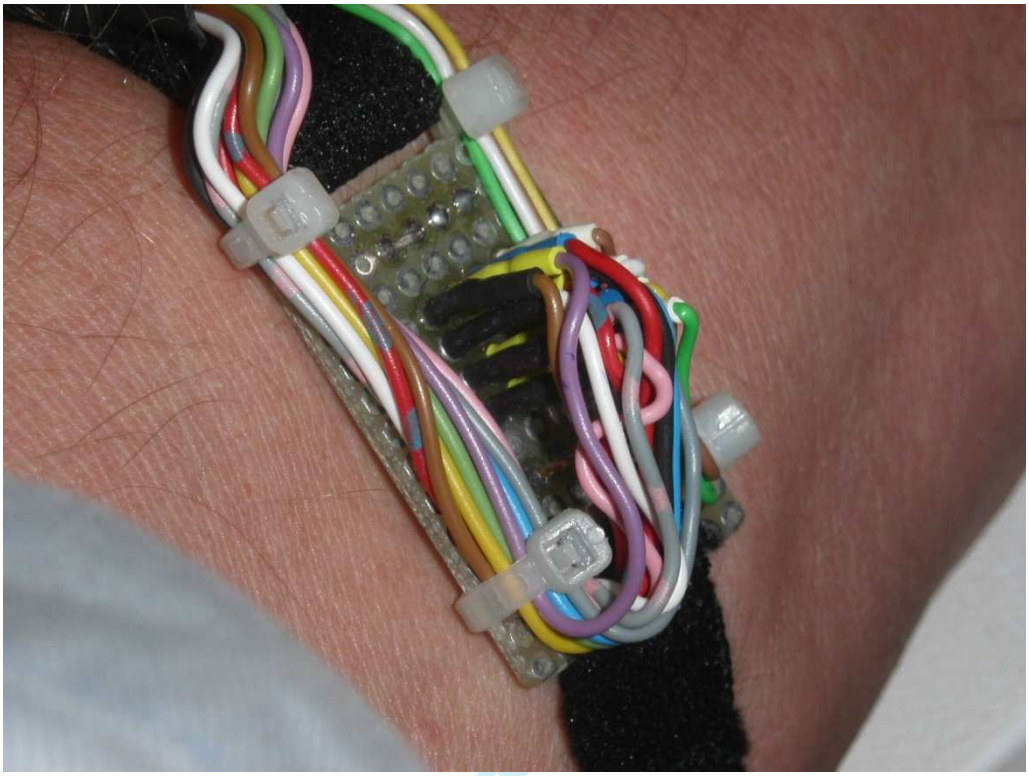


Figure 6

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| | healthy individuals | ´genuine´ electromagnetic hypersensitive individuals | individuals hypersensitive to other substances/agents etc. | individuals, that cannot be classified |
|---|---|---|---|---|
| *without EMF exposure* | | | | |
| • time series analysis of heart rate | -normal bandwidth of HRV | -normal bandwidth of HRV | -narrow bandwidth of HRV | -narrow bandwidth of HRV<br>or normal bandwidth of HRV |
| • FFT | -almost no distinct harmonics | -almost no distinct harmonics | -increased amount of harmonics | -increased amount of harmonics<br>or almost no distinct harmonics |
| • electric skin potentials | -correlation with ECG-waves | -correlation with ECG-waves | -less amplitude | -less amplitude |
| • microcirculation | -basic frequency of approximately 0,15 Hz<br>-high frequency signal correlating with the R-waves of the ECG | -basic frequency of approximately 0,15 Hz<br>-high frequency signal correlating with the R-waves of the ECG | -basic frequency of approximately 0,15 Hz<br>-high frequency signal correlating with the R-waves of the ECG<br>or<br>-basic frequency diminished,<br>-high frequency signal diminished | -basic frequency of approximately 0,15 Hz<br>-high frequency signal correlating with the R-waves of the ECG<br>or<br>-basic frequency diminished,<br>-high frequency signal diminished |

Table 1: Simplified overview of changes in electrophysiological parameters in healthy individuals, in electromagnetic hypersensitive individuals, in individuals with other conditions, and in individuals that cannot be classified (this table: without exposure to electromagnetic fields (EMF)).

For Review Only

| | healthy individuals | ´genuine´ electromagnetic hypersensitive individuals | individuals hypersensitive to other substances/agents etc. | individuals, that cannot be classified |
|---|---|---|---|---|
| *during and after EMF exposure* | | | -either only changes in microcirculation and electric skin potentials are noticed or no changes at all | -individuals do not show typical reactions of the vegetative nervous system |
| • time series analysis of heart rate | -normal bandwidth of HRV | -narrow bandwidth of HRV | | |
| • FFT | -almost no distinct harmonics | -increased amount of harmonics | | |
| • electric skin potentials | -correlation with ECG-waves | -less amplitude | | |
| • microcirculation | -basic frequency of approximately 0,15 Hz -high frequency signal correlating with the R-waves of the ECG | -basic frequency diminished, -high frequency signal diminished or still present | | |

Table 2: Simplified overview of changes in electrophysiological parameters in healthy individuals, in electromagnetic hypersensitive individuals, in individuals with other conditions, and in individuals that cannot be classified (this table: with exposure to electromagnetic fields (EMF)).

For Review Only