Non-Thermal Effects of Electromagnetic Fields in Biology and Medicine

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Abstract— **I discuss several aspects of non-thermal effects of electromagnetic fields while showing results of experiments demonstrating how EMFs influence growth of corn seedlings and growing of cress seeds. Not only EMFs of selected frequencies but also broadband electromagnetic noise affects living organisms Hypersensitivity to EMFs should be a matter of special concern.**

Keywords - **EMFs biological effects, non-thermal interactions, deterministic chaos, hypersensitivity.**

I. Introduction

Research on bioelectromagnetism and its applications in medicine have long history [1], much longer than physical theory of electromagnetism and its technical applications. Galvani's first research papers on 'animal electricity' were published in 1791 while Maxwell's theory of electromagnetic fields were published only in 1865 [2].

Research on effects of electromagnetic fields on living organism were intensified after II World War, in particular after wide introduction of cellular phones. Because human eye can perceive only a very small range of electromagnetic spectrum we often remain largely unaware of the powerful influence EMFs have on our health.

There is a huge amount of information about influence of EMFs that one may find on the web and in print (cf. [3]), so even for a specialist it is not easy to separate 'the wheat from the chaff'. Moreover, many very interesting research have remained hidden in library magazines or have never been made available in English like for example [4]. Also interesting research from 'pre-internet era' remain unknown because they are not found by web browsers.

II. Non-Thermal Effects of EMFs and Chaos

One is aware of the influence of EMF while perceiving thermal effects caused by EM radiation. Electrothermic effect is widely used in medicine, for example in diathermy. Thermal interactions are well characterized by Specific Absorption Rate (SAR). But weak, non-thermal interactions that I call information interactions [5] might be even more important. Low-level microwave radiation also causes non-thermal effects [6].

Information interactions cause non-thermal effects [3] without increasing temperature of the living tissue. Energy is supplied locally from biochemical reactions. Analogically, energy for a radio set or a TV set is supplied from electric socket or a battery while electromagnetic waves bring either encoded useful information (voice, music, image) that needs resonance decoding or just an information noise (crackles, snow on the screen). While there are still ambiguities if EMFs interactions with living organisms are of resonant nature it is obvious that even broadband electromagnetic noise may disturb living processes since perpetual transport of charged particles - electrons, protons, ions - is an inherent characteristics of life.

Living organisms operate far from thermodynamic equilibrium and are 'spaghetti-like'. Like pulling a single long thin string of spaghetti influence practically all other strings on the plate, so a change in one part of the organism influence other parts, changing one process in the organism influence other processes. Living organism is chaotic. That is why fractal methods of biosignal analysis are very useful [7], [8].

As it was stated in a report by European Parliament STOA Panel in 2001 [9]: 'Future research sponsored by the EC, should incorporate the following recommendations: (…) That systematic investigation be made of the influence of different kinds of pulsing (of real phones) on the human EEG, and ideally on the MEG, and of whether any observed changes in power spectra are correlated with changes in the level of deterministic chaos'. This level may be assessed by analyzing biosignals generated by living organisms using appropriate mathematical methods such as Higuchi fractal dimension instead of linear methods (cf. [7]).

For example, assessment of changes of chaos in the brain (of EEG-signal complexity measured by Higuchi's fractal dimension) that are due to influence of EMFs produced by cellular phones may be applied for [7]:

- comparative assessment (homologation, certification) of cell phone apparata of different brands and 'gadgets' such as different neutralizing protective devices;
- screening of individual users on their sensitivity to EMFs.

In consequence of non-linear, non-equilibrium nature of living organisms even the slightest differences in the physiological state assume singular importance. That is why difficulties are actually to be expected in attempts to independently replicate certain non-thermal effects of an infor-

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mational nature of EMFs, both frequency-specific and noise-induced effects. So, each medical treatment with EMFs has to be carefully personalized since all living organisms and humans in particular can be adversely affected by electromagnetic fields in a way that is not entertained or addressed in most of existing safety guidelines - through non-thermal influences of an informational nature [9]. Electromagnetic hypersensitivity (EHS) is similar to allergy to some drugs [10], [11].

Because of huge interpersonal genetical and physiological differences one should not average results obtained while examining a group of persons since it leads to false conclusions. Only comparison of the results obtained for the same person 'before' and 'after' some stimulus or 'without' and 'with' some device may lead to valid conclusions about this person e.g. that this person is hypersensitive (cf. [7]).

That is why experiments on animals and even on plants make sense since it is possible to choose groups genetically homogenous and to keep a control group. Here we present results on influence of EMFs on growth of genetically homogenous corn (maize) seedlings - EMFs of given frequencies but the same constant intensity (Fig. 1) and broadband EMFs of given intensities (Fig. 2) [4].

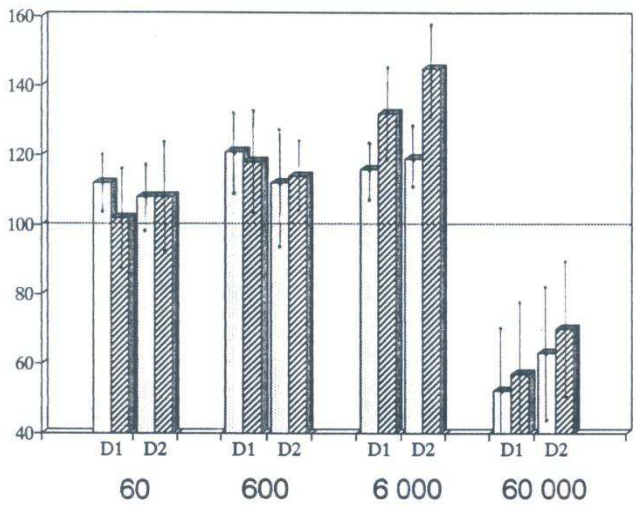
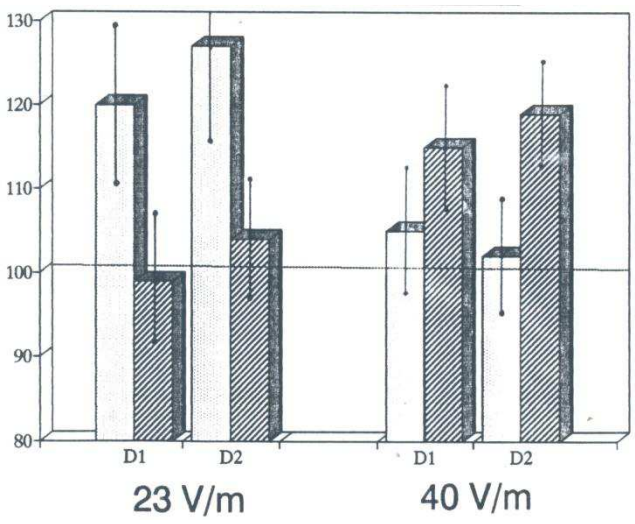
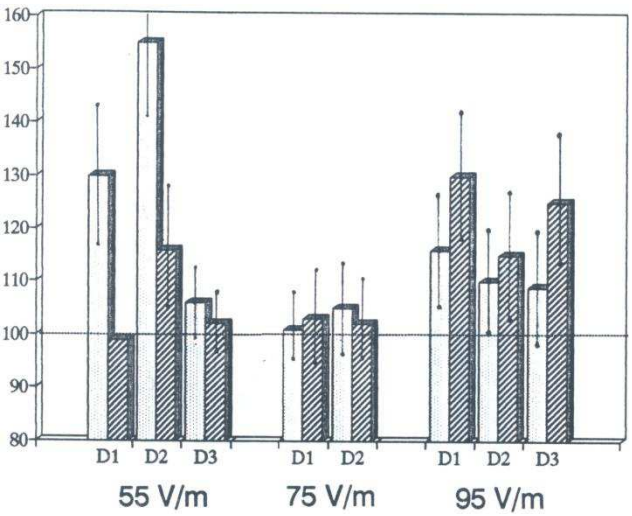


Fig. 1 Accelerated / slowed down growth of corn seedlings compared to control, 100, due to EMFs of given frequencies (60 to 60 000 Hz), same constant intensity (90 V/m); two strains of corn, each genetically homogenous (KLG-22.10 – white columns, Smolimag – shaded columns); two experiments D1, D2; 15 repeats of each experiment in Faraday cage (average values with standard deviations; from [4])

One can observe (Fig. 1) how EMFs influence differently two strains of corn. Frequencies 60, 600, and 6000 Hz do accelerate growth of the seedlings while frequency 60 000 Hz (60 kHz) decelerates (reduces) the rate of growth. Nobody could predict such an outcome.



a.



b.

Fig. 2 Accelerated growth of corn seedlings compared to control, 100, due to broadband EMFs (1 Hz - 30 MHz) of given intensities [V/m] two strains of corn, each genetically homogenous (KLG-22.10 – white columns, Smolimag – shaded columns); a. two experiments D1, D2, 14 repeats of each; background ~2.5 V/m b. two or three experiments, 15 repeats of each; in Faraday cage (average values with standard deviations; from [4])

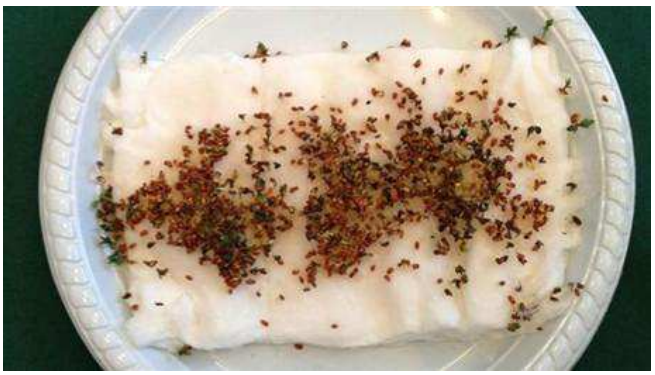
Even more interesting is to observe (Fig. 2) how broadband EMFs (electromagnetic noise) influence this two strains of corn and how it may differ even between experiments with the field of the same intensity as seen especially for the field of 55 V/m.

Also nobody could predict that the field of intensity 75 V/m has negligible influence on the growth of the seedlings while the fields of smaller and larger intensities have much greater influence.

III. Wi-fi influence on growing seeds

Recently a very simple experiment made by the 9th grade Danish students attracted international attention. The girls took cress seeds and place them into 12 trays, 400 seeds in each tray. Six trays of seeds were put into a room next to two Wi-Fi routers, and six trays were put into another room without routers. All trays were kept at the same temperature and obtained the same amount of water and sun over 12 days. Over those 12 days the students observed, measured, took weight and pictures of the trays. And the result was clear: cress seeds placed next to the routers did not grow, and some of them were even mutated or dead ([13], cf. Fig. 3b.). If EMFs emitted by Wi-Fi routers influence growing cress seeds why to allege that these EMFs do not influence human cells?

a.



b.

Fig. 3 The 'healthy' cress without the influence of the routers (a) and the 'sick' cress exposed to the Wi-Fi routers (b) [13]

Such experiments as that made by high-school Danish students [13] are usually disputed by scientists as being 'non-scientific'. Even experiments like those presented in Figs. 1 and 2 are said to be questionable – it is often said that the methodology is doubtful as maybe not standardized enough and the non-thermal effects are debatable. But it is not possible to make 'really scientific' experiments on influence of EMFs on humans, and even if it had been possible the interpersonal genetic differences would have caused huge variation of the results.

IV. Conclusions

Maxwell's theory of electromagnetism [2] works perfectly for EMFs in vacuum or in homogenous media. Living organisms are very inhomogeneous and also encompass many dynamical processes. So, there exist no general theory of EMFs in living systems since there are multiple mechanisms of interactions of EMFs with organisms, on all levels of organization - from submolecular to supraorganismal.

For example, *in vitro* studies suggest that low levels of EMFs may modify cancer cell growth, and this was the base for therapeutic use of so called tumor-specific frequencies; 1524 such frequencies ranging from 0.1 Hz to 114 kHz were identified; each of these frequencies appear to be specific for a single type of tumor [12].

On the other hand, meta analysis of scientific literature supports the hypothesis that long-term (over 10 years) use of mobile phones increases the risk of intracranial tumors [14]. So, sensitivity to non-thermal effects of EMFs may come into the picture only after quite long exposure. Quite recent Canadian report lists more than 200 scientific studies and 6 reviews that demonstrate potential harm at non-thermal levels of radiofrequency/microwave radiation [15].

In the user instruction to so-called 'magnetic mattress' that may be bought on-line I have read that 'it owes its therapeutic effectiveness to scientifically selected time course of electromagnetic pulses it generates', so to the very specific combination of frequencies and phases of simple pulses. On the other hand I remember to read a scientific paper in early 1990s ('pre-internet era') in which the authors claimed that in their research they had used pulses of very different shapes but all having had in their Fourier spectra the identical constant component and just because of that they all had caused the same effect; unfortunately I have lost the appropriate reference and I cannot find on the web neither this paper nor information about any similar research. And as it was demonstrated above (cf. Fig. 2) not only chosen EM frequencies but also electromagnetic noise affects living organisms; moreover, the effects depend on the field strength. Probably different mechanisms act simultaneously.

Methods used and interpretation of the experimental results depend a lot on who is financing the given research. That is why independent basic research financed by public money are extremely important. We did show (cf. [7]) that non-linear fractal methods of biosignal analysis demonstrate non-thermal effects of EMFs that remain unnoticed or misinterpreted when linear methods of analysis are used.

Question 'Do EMFs pose a health risk?' is wrongly posed. The questions that should always be asked are 'Does EMF of given characteristics (like distribution of spectral intensities, polarization, temporal repetitiveness, time of exposition) pose a health risk for this person?'. There are conflicting estimates on what percent of the population suffers from electro-hypersensitivity, with some suggesting that between 5 and 10% of people have the syndrome, and that the incidence is increasing with time [10]. The same conditions that seems to have no influence on one individual may be dangerous for health of another person. Negative effects of non-thermal EMFs may be not less dangerous than adverse effects of some drugs. Do we still need more independent research, not influenced by lobbying of industrial or communication companies, on impact of EMFs on living organisms? And the answer is: '**¥€$**, of course'.

It is no longer possible to deny non-thermal effects of EMFs – existence of such effects is now obvious even for high-school students.

Acknowledgments

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Conflict of Interest

The author declares that he has no conflict of interest.

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