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Method and instrumentation for the study of individual human sensitivity to microwave irradiation in the frequency range of modern mobile communications

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Abstract

The safety levels with respect to human exposure to electromagnetic fields (EMF) are defined by National safety standards. However, today serious contradictions have arisen between the existing standards and new experimental data. Firstly, the significant influence of weak EMF on psychophysiology and human health is shown. Secondly, the EMF effects are substantially dependent on the individual sensitivity of a specific person, multiple exposure and dose accumulation. In this article, the methods and instrumental techniques for the experimental research of an individual human's sensitivity to EMF doses are presented. The aggregate of results as a new challenge for today standards of EMF safety is discussed.

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1. Introduction

Now many collected and systematized experimental data confirm the effects of electromagnetic fields (EMF) on bio-objects, including psychophysiology and human health [1]. The maximum permissible levels of exposure are

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defined in the national standards of electromagnetic safety. However, when analyzing and interpreting these data, significant contradictions arose. The main problem – modern safety standards are based on the thermal effects of microwave absorption in biological tissues. This approach leads, in our opinion, to an artificial overestimation of safe absorption levels. For example, in the American standard [2] the maximum power density of the incident microwave energy is in the range of 2 to 10 W/m² (depending on the parts of the human body), and the SAR (Specific Absorption Rate) should not exceed 0.08 W/kg (for the body as a whole). With such irradiation parameters, the tissue is heated significantly, and heating 1 cm³ to 1°C leads to irreversible damage to brain cells [3]. In the Russian standard, which is based on the genetic principle of hazard assessment [4], similar parameters are almost an order of magnitude smaller. It considers that the levels of irradiation of the parent of the animal that lead to the death of its offspring are dangerous. At the same time, numerous studies point to the fact that two orders of magnitude smaller EMF have significant destabilizing, and often dangerous effects on humans [1]. Moreover, modern standards practically do not consider the individual sensitivity of bio-objects to microwave radiation. This is another important contradiction. Individual hypersensitivity can lead to severe consequences and even damage the basic human functional systems [5], [6]. Another contradictory phenomenon is the accumulation of the absorbed dose. In [7] it was shown that the sensitivity of bio-objects to EMF increase, if they were previously exposed to irradiation. In [8] an accumulation process was discovered, in which bio-effects manifest themselves as multiple nonlinear summations of the absorbed dose. The same bio-effect can occur, as with short, but powerful irradiation, so with weak, but prolonged or repeated irradiation. An attempt to address the problems and uncertainties in this scientific field, not only technical, biological, but also philosophical, was undertaken in the review of the International Commission on Protection from Non-Ionizing Radiation (ICNIRP) in 2002 [9]. One of the main conclusions of the ICNIRP review is that the emerging contradictions between the new data and “the existing safety standards should be solved by new research since there is currently no complete understanding of the processes of interaction of EMF with living objects”. In this article we have suggested entering new term called “personal human sensitivity” to microwave irradiation. The individual sensitivity is considered as a person reaction on EMF in group of volunteers. Under the investigation of personal sensitivity, the specific person is exposed repeatedly for a long time and their physiology reactions are averaged.

2. Method and instrumental complex for experimental researches

The new research methods and instruments are based on the follows:

1. The experiment was performed on volunteers, while respecting all the ethical and security rules in free behavior and “blind” mode, when the subject did not know about the EMF exposure beginning and ending.
2. Characteristics of the microwave field were continuously monitored and did not exceed safe levels and corresponded to the mobile communication frequency bands.
3. The cardiovascular system (CVS) was chosen as a research object, as one of the most informative and the most commonly used in similar studies of the human physiological systems. The organism reactions to microwave exposure may be effectively determined by the heart rate variability (HRV) analysis [10].
4. Well-developed algorithms and software for HRV analysis, corresponding to modern international standards [11] were used. The block–diagram of research instrumental complex is shown in Fig. 1.

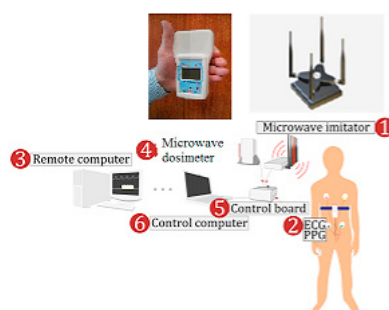


Fig. 1. Block–diagram of the research instrumental complex.

The figure shows: (1) – Microwave imitator that irradiates the volunteer; (2) – Modified Holter-monitor with photoplethysmography sensor that serves as a data acquisition and communication system; (3) – Remote computer for data post processing; (4) – Microwave dosimeter for measuring EMF level; (5) – Control board that serves as router; (6) – Computer that is used for system control.

Physiological research of the individual effect of microwave radiation on human cardio-rhythmic with the use of instrumental complex was carried out at the Institute of Normal Physiology (Moscow). The scheme of the experiment corresponds to Fig. 1, and its time protocol is shown in Fig. 2. It includes 3 periods: 6 minutes in the initial background resting state, 6 minutes with microwave exposure and 6 minutes after the radiation generator is switched off. Radiation parameters were as follows: flux density – $50 \mu\text{W}/\text{cm}^2$, microwave frequency – 960 MHz (GSM band).

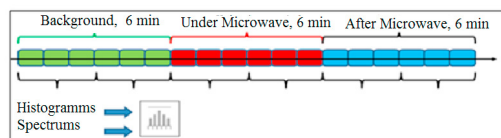


Fig. 2. The time protocol of the experimental studies.

Volunteers of both sexes (15 men and 3 women) from 22 to 70 years of age participated in the experiment. They were not acquainted with the protocol of the experiment and were not informed of the microwave generator switching on. The example of the experimental distribution of cardio-intervals T_{int} for three of 6 minute periods is shown in Fig. 3.

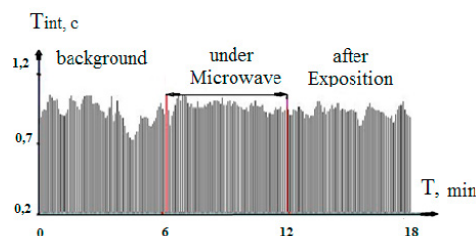


Fig. 3. Cardiointervalogram for three of 6-minute periods. Period from 6 to 12 minutes corresponds to the influence of microwave.

The continuous function of distribution of cardiointervalogram is the object of HRV analysis, in accordance with the international standard [11]. Software package allows the processing of experimental data and calculate more than 40 different statistical and spectral parameters of HRV that have cardiological informativity. One of the most important parameters for assessing the effect of a microwave exposure is the histogram of the intervals distribution. The examples of histogram of the distribution of pulse intervals before and after microwave exposure for specific volunteer are shown in Fig. 4.

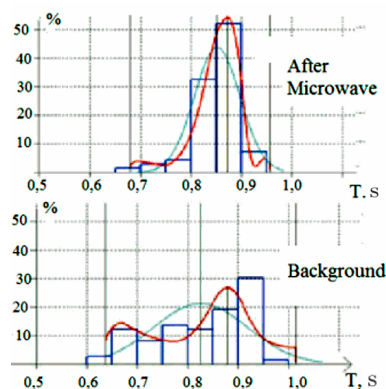


Fig. 4. Histograms of cardio-pulse intervals distribution before and after microwave exposure.

These experiments have shown that in almost 85 percent of volunteers, individual changes in the cardiac rhythm have been revealed. They depend on the initial state and type of regulation of cardiac activity. In persons with an initial slowed rhythm, of cardiac activity the effect of microwave is mainly manifested in an increase of instability. In the people with a normal and rapid rhythm, both the frequency and the variability of the cardio-rhythm change. In most people, within 3 minutes after exposure to microwave radiation, there was practically no restoration of the cardio rhythm stability indicators to the initial values. Among some subjects (28%) the restoration to the initial indices occurred 5–6 minutes after the microwave generator was switched off. And the least amount of changes in the cardiac rhythm occurred in subjects aged 22 to 35 years.

This research allowed the following conclusions:

1. HRV analysis is a very informative and an easy way to evaluate a person's reaction to microwave radiation.
2. The reaction of volunteers in single group experiments has shown the individual nature of a human's response to small irradiation power. The sensitivity threshold of EMF energy flux density is about $10 - 15 \mu\text{W}/\text{cm}^2$.
3. Individual sensitivity essentially depends on different random factors, such as the current psychological state, health, Times of Day, environment.

Thus, the experiments described above make it possible to estimate the current individual sensitivity of a person in a group of volunteers in a short time, which does not consider cumulative dose effects. To consider multiplicity effects, accumulation of the dose and various conditions of the person himself during the day, a method for personal sensitivity research is suggested.

3. Method and Instrumental Complex for Personal Human Sensitivity Research

To assess the personal sensitivity, the above-described measurement sessions are repeated 20 times during the day. The differences of this method from those described above are the following:

1. Experiments were performed while the free human's behaviour in a semi-automatic mode, using the instrumental complex shown in Fig. 1.
2. Several volunteers under the 30 years age participated in the experiment and ran each session by activating a microwave generator.
3. The time protocol in Fig.2 was reduced to two 3-minute duration intervals.
4. HRV data were collected in Holter-monitor's memory during an experiment time and then were post-processed.

In the proposed method of long-term research, the person is free in behavior, and all electronic equipment, just like him, is subjected to external electromagnetic interference. Therefore, special measures were taken to suppress interference while the modernization of the instrumental complex. To exclude electrode motion artifacts [12], and to reduce induced microwave interference, a photoplethysmography readout system with optical isolation was used. Traditional wireless biotelemetry that provides remote data transmission with free behavior of the bio-object cannot be used in that case, since it is itself a source of artifacts, influencing on human cardio rhythm [13]. Therefore, for the accumulation of experimental data, the Holter-monitor was used. As an example, Fig. 5 shows the averaged over 20 session's spectral power density (PSD) of the cardio-interval function (CIF) for two volunteers with following timing: 3 minutes background before exposure; 3 minutes exposure; 3 minutes background after exposure.

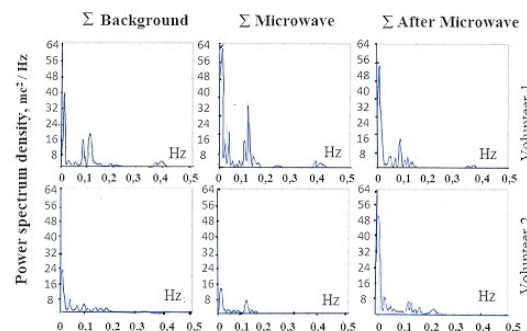


Fig. 5. Graphs of the average power spectrum density of the CIF spectrum for two volunteers.

The greatest changes in PSD occur in the second volunteer. The response of his body to the microwave effect is to shift the balance between the central, vegetative and sympathetic links of the regulation of the cardiovascular system to the region of ultra-low frequencies of the spectrum. This indicates an increase of influence of the central nervous system on HRV.

The results of processing the same personal data using the software of the VARICARD system, which allows the assessment of the functional and adaptive capabilities of the organism, are shown in Fig. 6. Figures clearly demonstrate how the functional state of the second volunteer changes with low-intensity repeated irradiation. After 20-fold exposure, his physiological state passes from the zone of the “Physiological Norm” (Fig. 6, a) to the zone of the “Premorbid state” on the boundary of “Adaptation failure” (Fig.6, b). And this is already a dangerous situation.

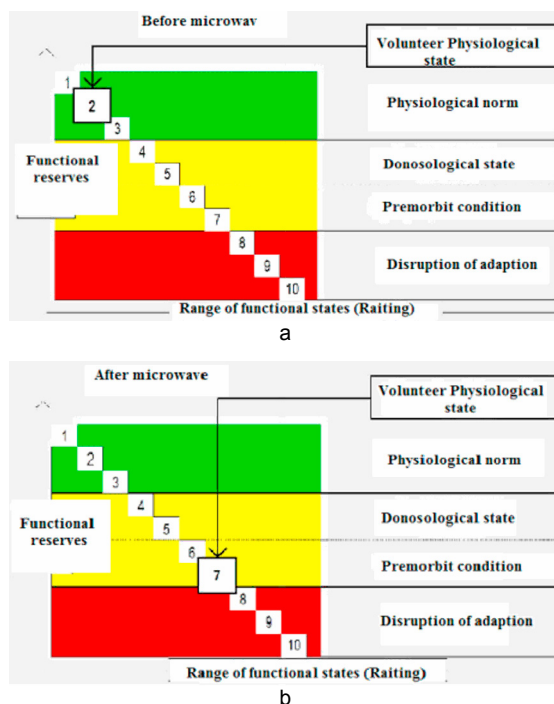


Fig. 6. Diagrams of the changes of functional state of the volunteer with high personal sensitivity (a) before and (b) after microwave irradiation.

Thus, preliminary studies using the new technique show that even weak EMF can be a dangerous external effect for people with high personal sensitivity. In combination with other internal and external factors, for example: cardiovascular and other diseases, multiple and duration of exposure, and intensity of exposure, can lead to serious consequences for well-being and human health. In our opinion, the application of the proposed research methodology in medical practice will allow using information about personal sensitivity for diagnostic purposes and serve as a basis for preventive recommendations for “EMF dependent” patients in the conditions of growing electromagnetic pollution of the environment. The results obtained are another weighty argument for the need to revise and correct modern electromagnetic safety standards.

4. Conclusion

The paper presents methods and an instrumental complex that simultaneously irradiates a human with a microwave radiation, under controlled level and with the recording and rapid analysis of changes in its physiological parameters, in particular, heart rate variability. There are two ways of assessing a human's sensitivity to low-intensity microwave irradiation: experimental research on the person in a group of volunteers, and long-term multiple measurements of the sensitivity of a specific human. The first method allows us to estimate the short-time

instant reactions of an organism on EMF action, but these values do not consider the cumulative dose effects, current well-being, and condition of the human. The second method averages the numerous measurements performed for a long time and suggests the use of personal sensitivity of a particular person to assess the effects of microwave radiation on his psychophysiology and health. The preliminary experimental research performed on basis of the both instrumental methods showed the significant personal influence on cardio-rhythmic of a group of people and of a particular person. Even weak EM field can have a dangerous external effect on people with high personal sensitivity, especially in combination with cardiovascular and other diseases. Anyway, the developments of these problematic and obtained results are an important argument for urgent revision and correction of the existing electromagnetic safety standards.

Acknowledgements

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