The mechanism of stimulation of nervous system by low-level modulated microwave radiation

Hiie Hinrikus*, Maie Bachmann, Jaanus Lass, and Anna Suhhova
Department of Biomedical Engineering, Technomedicum, Tallinn University of Technology, Tallinn, Estonia
hiie@cb.ttu.ee

INTRODUCTION
Reports on possible effects of low-level microwave radiation (MWR) are often contradictory; moreover, mechanisms behind the effects are still under discussion. Low microwave field strengths in tissue compared to intramolecular fields, high frequencies of radiation compared to physiological processes and contradictory experimental data have caused doubts in low-level effects. Our studies have been aimed to clarification of physical mechanism of low-level MWR effect on the brain bioelectrical activity.

MODEL OF EXCITATION
Neuronal processes are based on the balance of ions movement caused by concentration gradient forces (diffusion) and electric field. Nernst-Planck equation describes the influence of an ionic concentration gradient $\nabla c_i$ and an electric field $E$ on the ions flux density $F_i$ as follows [1]

$$F_i = -D \nabla c_i - c_i q E$$

where $D$ is diffusion coefficient, $c_i$ is ions concentration and $q$ is an ion charge. Microwave field is known to rotate dipolar water molecules. Such rotation results in various changes in living tissue even at constant temperature: the structure of hydrogen bonding is altered and through that diffusion is expected to be affected as well as dielectric polarization of the tissue is changed compared to the natural unperturbable physiological state. Consequently, in equation (1) the diffusion coefficient $D$ and the electric field $E$ are altered by MWR. Disturbance of the balance between ions movement related to diffusion and electric forces results in changes of resting potential of neurons and is expected to cause perturbation of the nervous system.

However, brain can adapt to small permanent alterations in diffusion and polarization. Therefore, modulation of MWR is crucial for the effect. Based on the theory of parametric excitation, even a very small periodic force can result in excitation of the oscillating system at fixed frequencies predetermined by the frequency of the periodic force. The following equation represents a nonlinear system (as the system of brain bioelectric oscillations is) which is being parametrically excited [2]:

$$\frac{d^2 x}{dt^2} + 2\gamma \frac{dx}{dt} + \alpha x^{m1} + \beta x^{m2} + \omega_0^2 (1 - 2m \omega \omega t) = 0$$

where $\gamma$ is the damping constant, $\alpha$ and $\beta$ are the nonlinearity constants at members with $m1$ being odd and $m2$ being even integers, $\omega_0$ is the frequency of the system, $\omega$ is the frequency of parametric excitation, $t$ is time and $m$ is the strength of excitation. Parametric excitation of nonlinear excitable system can occur at the condition $n\omega/4 = \omega_0$, $n= 1, 2, \ldots$
EXPERIMENTAL RESULTS

Our experiments with 450 MHz continuous-wave radiation (the calculated spatial peak SAR value 0.4 W/kg) at constant temperature (standard deviation 0.02 °C during an experiment) demonstrated that microwave exposure makes faster the process of diffusion in water [3]. The time required for reduction of initial resistance of the solution by 10% was 1.7 times shorter with microwave. This result is consistent with the proposed mechanism of low-level microwave effect on diffusion.

Our experiments with 450 MHz MWR modulated at 7, 14, 21, 40 and 70 Hz frequencies (the calculated spatial peak SAR averaged over 1 g was 0.303 W/kg) showed statistically significant increase of the EEG power only at the EEG frequency $f_0$ to modulation frequency $F$ ratios $f_0/F =0.25$, 0.5 and 0.75 [4]. Results of the experimental study are in accordance with the proposed model of parametric excitation of the brain neural oscillations and demonstrate that modulated MWR causes excitation of the brain EEG rhythms at the frequencies predicted by the non-linear model.

Parametric nature of excitation of the EEG rhythms by modulated MWR is also supported by the results of an experiment at two different levels of exposure: decreasing of microwave field by 20 dB reduced the related changes in the EEG only by 5-8 dB and the numbers of affected subjects but did not exclude the effect [5].

CONCLUSIONS

Microwave radiation, rotating dipolar water molecules, causes high-frequency alterations of hydrogen bonds between water molecules, thereby makes faster diffusion and disturbs the neurophysiologic processes at constant temperature. The modulated MWR caused excitation of EEG rhythms at the parametric resonance frequencies.

Various mental disorders and brain diseases are related to characteristic changes in the brain bioelectrical oscillations. Therefore, correction of the oscillation using external stimulation can be beneficial. The results discussed above allow us to suppose that low-level modulated MWR can be used for stimulation of brain oscillation. The physiological effectiveness of such stimulation needs further investigation. Microwave stimulation as relatively simple for application, noninvasive and contact-free method, if proved to be physiologically effective, may have some advantages compared to TMS, tACS or tDCS.

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