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THE EFFECT OF THE CELL PHONE RADIATION ON A FREELY SUSPENDED LIQUID-CRYSTAL FILMS

A. A. Bogdanov[1], S. P. Denisov[2], A. A. Karetnikov[3], A. P. Kovshik[3], V. P. Romanov[3], D. Brukkel [2]

[1]The Federal State Budgetary Institute "The Nikiforov Russian Center of Emergency and Radiation Medicine", Saint Petersburg, Russia

[2]Center of Informatics "GAMMA-7", Moscow, Russia

[3]Saint Petersburg State University, Saint Petersburg, Russia

sashakovshik@yandex.ru

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The article presents the results of an experimental study of the effect of the radiofrequency radiation (RF) of a cell phone on a freely suspended liquid-crystal film (FSLCF) as a system that simulates biological structures. The selection of the FSLCF model is theoretically substantiated. A polarizing microscope with a video camera was used to visualize the process under study. The reaction of the FSLCF was analyzed using a specially developed software. The responses of the FSLCF were studied for exposure to the RF radiation in the presence of protective device Gamma 7.N-RT and for the action of a static magnetic field of strength 500 Oe. The RF radiation of a cell phone was found to change the orientation structure of the FSLCF, which, after some time, returns to the nearly initial level despite the presence of external field. The protective device Gamma 7.N-RT attenuates the reaction of the FSLCF. The response of the FSLCF in a static magnetic field remains unchanged during the exposure to the field. These experimental results are evidence that the structure of the freely suspended liquid-crystal film is a viable model for biological structures, and is capable of adapting to the effect of the RF radiation emitted by a cell phone.

Keywords: biological structures, liquid-crystal film, electromagnetic fields, orientation structure.

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1. Introduction

The intense advancement of wireless technologies and the spread of mobile telecommunication facilities in every-day life are among the primary reasons that people are persistently under the influence of low-energy RF electromagnetic fields. Despite the fact that there are numerous studies [1–4] on the matter, the issue of the biological effects of low-intensity electromagnetic fields on human and other organisms remains debatable [5–7].

The electromagnetic wave energy of a cell phone's RF radiation is known to be insufficient to break chemical bonds. The revealed biological effects are discussed primarily in terms of the thermal exposure of electromagnetic radiation (EMR) [8]. However, a number of nonthermal biological effects caused by low-energy electromagnetic radiation are described in the literature [3,4]. These studies have questioned the hypothesis of the thermal nature of the biological effects and the currently accepted safety levels of the EMR. These effects, caused by the low-energy electromagnetic radiation comprise the increased permeability of the blood-brain barrier, changing the expression of heat shock genes, impaired calcium homeostasis, reduction of melatonin synthesis, etc. [4, 9–11]. These biological effects can modify adaptive processes in the organism. Therefore, studying the adaptive response patterns at different levels for the organism structure under exposure to low-energy EMR is an important and urgent task both in terms of understanding of the biological action mechanisms and assessing the hazard this factor presents to human health.

In addition to the biological research, it is of interest to study the effect of the RF radiation on the systems that simulate real biological objects. The advantage for such studies is that these make it possible to obtain quantitative data, permitting rigorous theoretical analysis.

Many biological structures are known to possess a number of properties which are typical for liquid crystals [12]. These include chloroplasts, visual receptors, muscle, nerve, cell membranes, etc. Therefore, a study of the influence of the RF radiation on the model crystal structures may elucidate some of the mechanisms of biological reactions to this radiation.

Nematic liquid crystals are highly sensitive to the effects of external electric and magnetic fields [13]. This makes liquid crystals the basis for displays as well as systems of information transfer and storage. First of all, these are light modulators, displays, monitors, etc. In these devices, a thin layer of the liquid crystal is placed between the glass surfaces that preset the specific direction of the optical axis of the liquid crystal (the direction of the preferred orientation of the molecules). Under the action of an external electric field of a sufficient strength that exceeds the threshold value, the direction of the optical axis alters, which affects the intensity of light passing through the liquid-crystal layer.

The energy density W required to change the orientation direction of the liquid crystal placed between the glass surfaces is estimated by the relation [14]:

$$W \sim \frac{K}{d^2},$$

where d is the layer thickness and K is the modulus of orientation elasticity of the order of 10^{-6} dyn [13]. For the oriented layers with a thickness of 3 to 30 μm the energy density required to change the direction of orientation of the liquid crystal is on the order of $W \sim 0.1 - 10$ erg/cm^3, which is much larger than that of cell phone RF radiation.

In all likelihood, the orientation of liquid-crystal structures in biological objects is fixed more weakly than on the solid surfaces of technical devices. Therefore, to cope with the stated problem, we used a freely suspended film of a nematic liquid crystal as a liquid-crystal system, which, in our opinion, is most similar to biological structures and could be responsive to the RF radiation of cell phones. In such a film, the process of changing the direction of the preferred orientation of the liquid crystal molecules is nonthreshold [15]. The energy density required for the reorientation of the liquid crystal in a freely suspended film or for the disordered-to-ordered state formation by an external field is estimated as K/L^2, where L is the dimension within which the external field can be considered homogeneous. This value is on the order of several fractions of millimeter to several millimeters. For these fields, the energy density required for the reorientation is on the order of $W \sim K/L^2 \sim 10^{-5} - 10^{-3}$ erg/cm^2, that is, by several orders of magnitude lower than that required for the reorientation of a liquid crystal placed between the solid surfaces. It is the nonthreshold nature of the reorientation in a freely suspended liquid-crystal film that can provide its extremely high sensitivity to the external effects.

Cell phone radiation density near the phone is known to be on the order of 2-20 mW/cm^3. The dielectric constant of liquid crystal at frequencies of several GHz is approximately 3. This means that the energy density acting on the liquid crystal inside the film amounts to $10^{-6} - 10^{-5}$ erg/cm^3. By an order of magnitude, this energy density is comparable with the energy of the orientational ordering. The aim of this study is to investigate the effect of cell phone RF radiation on freely suspended films of a nematic liquid crystal.

2. Materials and Methods

To study the effects of the RF radiation on the freely suspended liquid-crystal film, we used an experimental setup that enabled us to visually observe and record the structural changes in the film. The setup comprised a polarizing microscope POLAM L-213M equipped with a video camera DCM-130 with a 1.3 megapixel photodetector array, and a PC with a display. The liquid-crystal film was composed of a binary mixture of alkylcyanobiphenyls was suspended on the wall of a circular aperture 2 mm in diameter in a plastic plate 0.5-mm thick and placed on the stage of the polarizing microscope. A cell phone Nokia-3110, operating in the signal transmission mode, was placed at a distance of 2 cm from the film. The linearly polarized light flux was directed normal to the film surface and arrived at the video camera through the objective of the microscope. The digitized 40-fold zoomed image was transmitted to the PC for viewing and recording. The light source was an incandescent lamp energized from a rectifier or a battery-powered LED.

The response of the liquid-crystal film to the influence of the RF radiation was assessed visually by changes in the distribution of light intensity and its color spectrum.

To compare the responses to different EM field effects, the freely suspended liquid-crystal film was also subjected to the action of a static magnetic field of strength 500 Oe.

Quantification of the freely suspended liquid-crystal film's reaction was performed using specially developed software. The observation field was selected as a section of the film free of the boundary effects occurring at the contact of the film with the aperture wall [16]. The image analysis technique is based on the count of the number of pixels with different color codes in the RGB24 system. At the first stage, the number of pixels of each color code in each frame was calculated and a histogram was constructed. At the second stage, the number of non-recurrent color codes was determined from the histogram (the number of columns that contain non-zero values).

At the third stage, the ratio of the absolute number of the color codes per frame K and the minimum number of the color codes during the observation period M was calculated. The time dependences of the expression $(K/M) - 1 = N$ were plotted as graphs of the dynamic series.

3. The results of measurements

In the absence of a cell phone electromagnetic field (Fig. 1a), the freely suspended liquid-crystal film has, at equilibrium, an anisotropic structure with a nonuniform spatial distribution of the predominant direction of the long axes of the molecules (the local optical axis). This structure is formed under the action of the orienting forces of the molecules of the surface layer, the cylindrical wall of the aperture at which the film is attached and, possibly, the electromagnetic fields acting in this spatial region. The light flux passing through the system has a nonuniform distribution of the intensity and spectral composition in the field of observation due to the inhomogeneous distribution of the local optical axis of the film.

During the first minute of exposure to the cell phone's electromagnetic field the brightness and color of the film alter (interference fringes appear), which may be associated with a local change in the spatial distribution of the optical axis in the film. Having reached a maximum difference from the initial pattern (Fig. 1b), the image of the film changes again (interference fringes appear) and becomes similar to the original pattern (Fig. 1c). It should be noted that, throughout this time, the film was exposed to the RF radiation of the cell

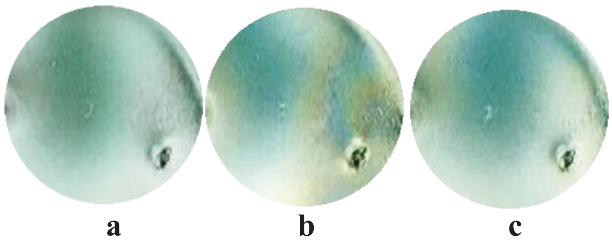


Fig. 1. Photomicrograph of a liquid crystal film before the impact of RF cell phone radiation (a), one minute (b) and two minute (c) after the start of exposure

phone. This may mean that the structure of the liquid-crystal film adapts to the cell phone radiation, and the local distribution of the optical axis recovers to a value similar to the original undisturbed condition.

The results of mathematical processing for the dynamic behavior of the video characteristics of the luminous flux are presented graphically in Fig. 2 (curve 1). It can be seen that, after the onset of liquid-crystal film exposure to cell phone radiation, the value $(K/M) - 1 = N$ which describes the reaction of liquid crystal increases and reaches a maximum in one minute, and then decreases and returns to the baseline level within two minutes from the start of the experiment.

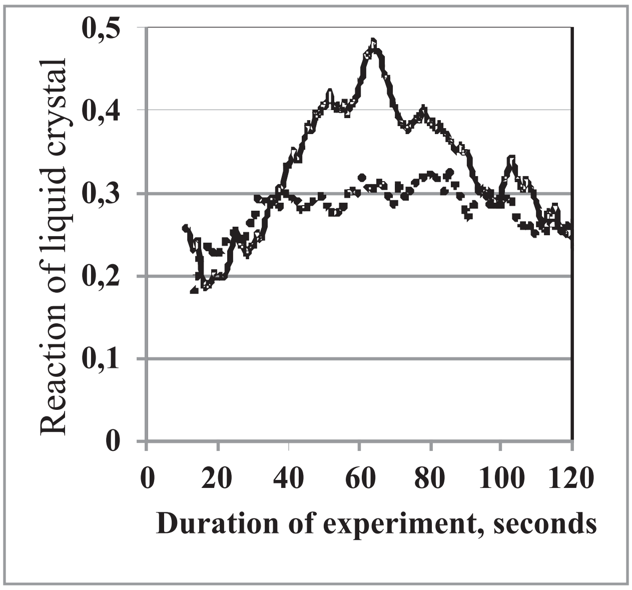
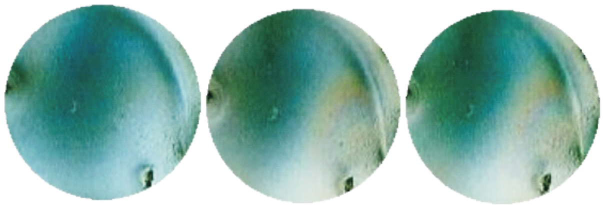


Fig. 2. Graphical display of a liquid crystal film reaction (quantity of image colors relative to the minimum) on the impact from the field of a cell phone in the absence and presence of the device "Gamma-7.N-RT"

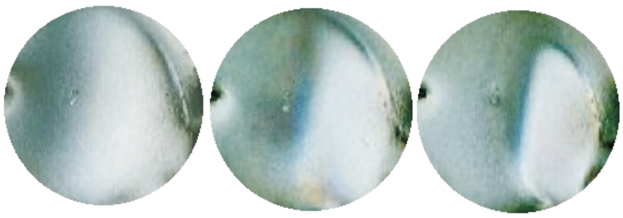
A similar response of the liquid-crystal film was observed for the influence of cell phone EMR equipped with a protective device (Gamma 7.N-RT), which eliminates the negative impact of biotropic components of radiation from mobile phones [17, 18]. Photographs in Fig. 3 show the brightness and color distribution of the film before exposure to the cell phone electromagnetic field (Fig. 3a), and at one minute (Fig. 3b) and two minutes (Fig. 3c) after the onset of the RF radiation. Alteration of the brightness and color of the film in the presence of the protective device Gamma 7.N-RT differs from that in its absence. The observed phenomenon quantitatively confirms the results of the mathematical processing of the dynamic behavior of the video characteristics of the light flux presented graphically in Fig. 2, which demonstrates that, although the value $(K/M)-1 = N$ also increased under the action the mobile phone with the Gamma 7.N-RT device, it was 1.3 times smaller than that in the case without this device. This could mean that the Gamma 7.N-RT device partially attenuates the effect of the cell phone RF radiation on the local distribution of the optical axis in the freely suspended liquid-crystal film.



a b c

FIG. 3. Photomicrograph of a liquid crystal film phone in the presence of the device "Gamma-7.N-RT" before the impact of RF cell phone radiation (a), one minute (b) and two minute (c) after the start of exposure

The observed response of the freely suspended liquid-crystal film to the cell phone's low-energy electromagnetic field significantly differs from the response to a constant magnetic field of high strength. Photographs in Fig. 4 show the brightness and color distribution of the films under the action of a magnetic field of 500 Oe after one minute (Fig. 4b), and three minutes (Fig. 4c) from the start of the experiment.



a b c

FIG. 4. Photomicrograph of a liquid crystal film before the impact of a static magnetic field of strength intensity 500 oersted (a), one minute and two minute (c) after the start of exposure

After the initial sharp change, the characteristics of the light flux remained constant throughout the action of the magnetic field and did not recover to the original undisturbed condition of the liquid-crystal film structure. This is illustrated in Fig. 5, which shows the behavior of the value $(K/M) - 1 = N$ over the course of the experiment.

The structure of the liquid crystal film recovered to the original unperturbed state only after the cessation of the constant magnetic field's action.

4. Conclusion

The experiment revealed that the structure of a freely suspended liquid-crystal film changes in the low-energy electromagnetic field of a cell phone. The liquid crystal transforms

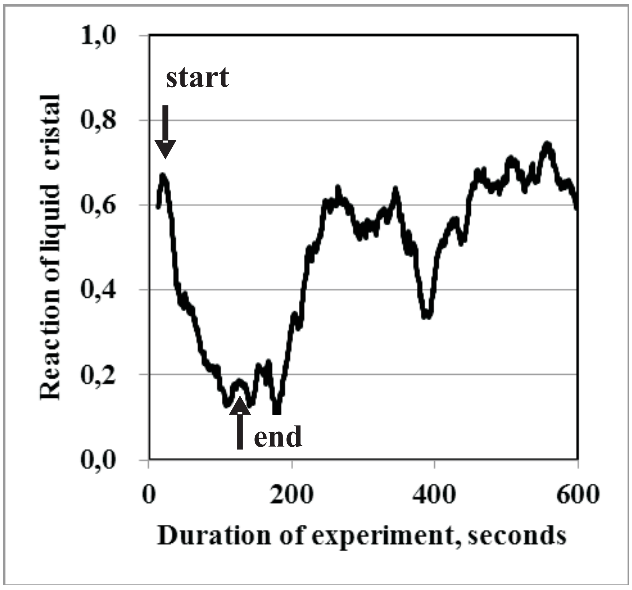


FIG. 5. Graphical display of a liquid crystal film reaction (quantity of image colors relative to the minimum) on the impact from a static magnetic field of strength intensity 500 oersted

to a quasi-equilibrium state, and, in the presence of the same field, recovers to equilibrium after some time. The structure of a freely suspended liquid-crystal film shows the property of adaptation to the effects of the RF radiation of a cell phone. In the presence of protective device Gamma 7.N-RT, the reaction of the liquid crystal is diminished and attenuated, which indirectly indicates a decrease in the energy consumption in the process of adaptation. In earlier studies [19], the data was obtained that provided evidence of a decrease of the tension of functions of the human body under the influence of high physical and psychic loads using devices Gamma 7.N-RT. This observation indirectly reflects the reduction of load on the system of the body responsible for its adaptation to the environment, in particular, to the influence of physical fields of different nature. The totality of the experimental results and published data suggest that the response of the liquid-crystal structure is one of the essential elements of adaptation of organism to the action of the RF radiation of cell phones.

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