not produce the effects observed under exposure to microwaves at a low power level. Similar results are also observed in animals, except that the threshold power flux densities are much higher here.

The influence of irradiation time is of a different kind. The longer this time, the stronger is the observed effect, although saturation is noted after several hours. Thus, the total-dose concept that is often used in application to ionizing radiation (the total irradiation energy) does not give a definite answer in this case to the question as to the magnitude of the exposure: changes in power and time act differently.

The dependence of the effects of exposure on frequency is of acutely resonant nature: the width of the bands corresponding to a given exposure effect varies from a fraction of a percent to several percent, depending on the object and the test, and this dictated requirements as to the stability of the power sources and frequency meters used in the equipment.

Biological changes provided the indication of the effect. Investigation of the absorption or emission spectra by the methods conventional to radioelectronics and physics yielded nothing in this case. The losses in the biological systems that were studied were great; in addition, the bands of the individual resonances may overlap one another with the enormous number of degrees of freedom that are present. But when a particular biological test is analyzed, it is found to be influenced by a very limited number of the possible resonances in the object, and this offers an indicator that is highly sensitive and, at the same time, the only one necessary for investigation of the particular test.

The scatter of the results obtained with the method developed was much smaller than the quantity to be measured.

2. Results of exposure of certain biological objects to millimeter-band electromagnetic waves[2)]

a) Increase in production of proteases with fibrinolytic activity by the fungus Asp. aryzal (Moscow State University strain) under radiation exposure. The work was done in collaboration with Moscow State University. The original strain was irradiated at a wavelength of 6.6 mm. The power flux density was 0.1 mW/cm$^2$. Ten two-hour doses were administered. Irradiation caused an increase in the proteolytic activity of the aspergillis by a factor of 1.5–2. Six months of observations verified that the effect was inherited. The increase in fibrinolytic activity was not accompanied by an increase in biomass.

b) Effects of irradiation on staphylococci (strain 209). This study was made jointly with the Central Scientific Research Institute of Traumatology and Orthopedics in collaboration with the Leningrad Institute of Aviation Instruments and the Leningrad Chemical Physics Institute. The culture was irradiated repeatedly for one hour each day at 7.08 mm and a power flux density of 0.1 mW/cm$^2$. Over the course of the multiple exposures, hemolytic activity, the ability to coagulate plasma, lecithinase activity, and the gold pigment disappeared, in that order. In experiments on animals (rabbits) with 8 × 8-cm traumata on their backs that has been infected with staphylococci of the strain indicated, we established a decrease in the inoculability of the staphylococci after a series of daily radiation treatments of the wounds (for 20 minutes each day). The healing time of the wounds was reduced 20% as compared with the control. A normal regeneration process was observed on cytological examination of the secreta from the irradiated wounds. The peripheral blood showed a moderate leukocytosis of neutrophilic nature, monocytosis, and lymphopenia as compared with the control, indicating an augmented protective response of the organism.

This study was carried out under the auspices of the Ministry of the Electronics Industry jointly with the IÉKO, the Central Institute of Traumatology and Orthopedics, and the Moscow State University Biology Department.

**L. A. Sevast'yanova and R. L. Vilenskaya.** A Study of the Effects of Millimeter-Band Microwaves on the Bone Marrow of Mice

We have previously reported the results of studies of the bone marrow of animals that were irradiated with millimeter-band electromagnetic radiation (microwaves) and subsequently with x-rays[1,2]. Despite the fact that millimeter microwaves with $\lambda = 7.1$ mm are absorbed in the surface layer of the skin of the animals at a depth of approximately $3 \times 10^{-2}$ cm[3], we observed a decrease in the number of bone-marrow cells that were damaged by the x-rays when the animals were first exposed to a microwave field. A similar effect was observed when animals were given microwave irradiation prior to administration of toxic antineoplastic substances used in chemotherapy that also destroy bone-marrow cells—such as chrysomallin and sarcolysin[4].

The present paper reports counts of mouse bone-marrow cells that remained undamaged by x-irradiation after prior irradiation with a microwave field in which the exposure time to the microwaves, the power density of the field, and wavelength were varied.

We felt that it would be interesting to investigate the protective effect of the microwave field at various power densities. Counts of the remaining undamaged bone-marrow cells, normalized to the control ($N/N_0$), were plotted against power flux density (P) in the range from 1 to 75 mW/cm$^2$. The exposure time was held constant at one hour. The x-ray dose was 700 rad. The results of these measurements and the increases in the skin temperature of the animals appear in Fig. 1. The figure shows that preliminary microwave irradiation of

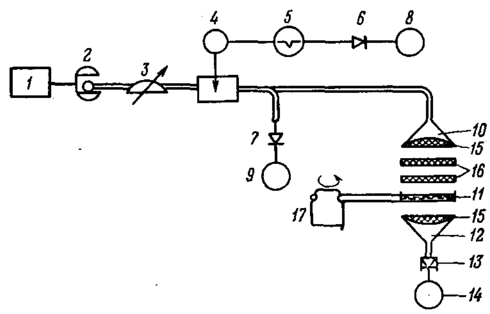


Diagram of experiment. 1–Power supply; 2–OV-612 backwardwave tube; 3–attenuator; 4–measuring line; 5–wavemeter; 6, 7–detector heads; 8–pointer-type indicator; 9–incident-power meter; 10, 12–horns; 11–object; 13–thermistor head; 14–transmitted-power meter; 15–correcting lens; 16–transformer; 17–electric motor to rotate and stir the medium.

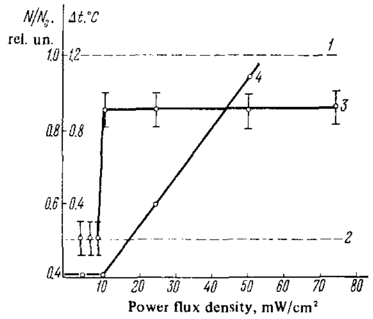


FIG. 1. Changes in number of bone-marrow cells ($N/N_0$) and skin temperature ($\Delta t$) of irradiated animal as functions of power flux density. 1—Number of bone-marrow cells (control); 2—exposure to x-radiation; 3—combined exposure to microwaves and x-rays; 4—change of skin surface temperature.

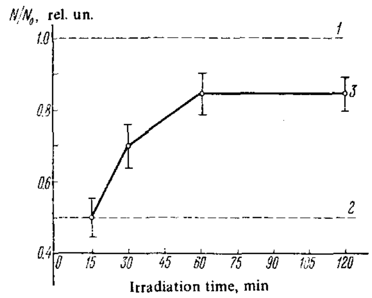


FIG. 2. Variation of number of bone-marrow cells with microwave irradiation time. 1—Control (unirradiated-animals); 2—x-irradiation; 3—microwave field and x-irradiation.

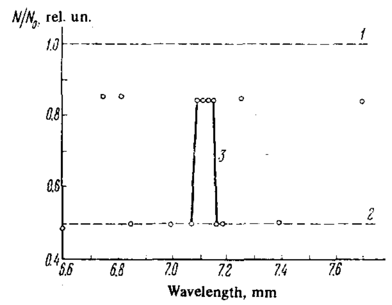


FIG. 3. Variation of number of bone-marrow cells with wavelength. 1—Control (unirradiated animals); 2—x-irradiation; 3—microwave field and x-irradiation.

the animals has no influence whatever on $N/N_0$ up to a power flux density $P = 9$ mW/cm$^2$. Thus, there is a certain threshold power flux density below which the microwave field has no effect. Then, as P is increased, the number of undamaged cells increases practically jumpwise to 0.85. A further increase in P is not accompanied by an increase in $N/N_0$. The same plot indicates the increase in the skin temperature of the irradiated animal as a function of P. Temperature does not change below $P = 10$ mW/cm$^2$. We then observe a slow temperature increase during which the slope of the $\Delta t$ (°C) line is $2.5 \times 10^{-2}$ deg/mW·cm$^{-2}$. We see from comparison of curves 3 and 4 in Fig. 1 that the magnitude of the biological effect does not correlate with the variation of the animal's skin temperature.

Thus, the optimum power flux density, at which the microwaves can be observed to have a protective effect on bone marrow but do not cause heating of the skin, is around 10 mW/cm$^2$. It was this circumstance that dictated selection of a power density of 10 mW/cm$^2$.

When the microwave exposure times of the animals were varied, it was found that no microwave effect appears at all before $t = 30$ min (Fig. 2). As the irradiation time increases to 60 minutes, we observe an increase in the protective effect and $N/N_0$ reaches 0.8. Further increase of the exposure is not accompanied by any appreciable increase in the number of cells that remain undamaged by x-rays. Thus, the optimum irradiation time was found to be 60 minutes.

We were most interested in investigating $N/N_0$ as a function of microwave wavelength in experiments with combined exposure to microwaves and x-rays. The wavelength of the microwaves was varied from 6.6 to 7.7 mm. The results of these measurements appear in Fig. 3. It was found that the protective effect of preliminary microwave exposure of the animals is distinctly selective in nature. Thus, the undamaged-cell count rises from 0.5 to 0.85 at the wavelengths of 6.7 and 6.82 mm, in the range 7.09—7.16 mm, and at 7.26 and 7.7 mm, while there was no protective effect at all at the same microwave power density at the other wavelengths studied (6.6, 6.85, 7.0, 7.07, 7.17, 7.19, and 7.4 mm). This behavior of the $N/N_0(\lambda)$ relationship suggests a resonant mechanism for the action of the microwave field.

[1] L. A. Sevast'yanova, S. L. Potapov, V. G. Adamenko, and R. L. Vilenskaya, Biol. Nauki, No. 6, 46 (1969).
[2] L. A. Sevast'yanova, S. L. Potapov, V. G. Adamenko, and R. L. Vilenskaya, Changes in Hemopoiesis Under the Influence of Microwave and X-Radiation. Morphological and Hematological Aspects of the Biological Effects of Ionizing Radiation and Cytostatic Preparations, Fifth Conference of the Central Scientific Research Laboratory, Tomsk, 1970.
[3] R. L. Vilenskaya, L. A. Sevast'yanova, and A. S. Faleev, A Study of the Absorption of Millimeter Waves in the Skin of Experimental Animals. Elektronnaya Tekhnika, Ser. 1 (Elektronika SVCh), No. 7, 97 (1971).
[4] L. A Sevast'yanova, M. B. Golant, V. G. Adamenko, and R. L. Vilenskaya. Biol. Nauki, No. 6, 58 (1971).
[5] R. L. Vilenskaya, É. A. Gel'vich, M. B. Golant, and A. Z. Smolyanskaya, ibid., No. 7, 69 (1972).

**A. Z. Smolyanskaya and R. L. Vilenskaya.** Effects of Millimeter-band Electromagnetic Radiation on the Functional Activity of Certain Genetic Elements of Bacterial Cells

The effects of millimeter waves on intracellular systems responsible for lethal synthesis in bacteria, i.e., the synthesis of substances that result in the depth of the cell, were investigated. The colicinogenic factor of Bacillus coli was chosen as the test object. The col-factor is an extrachromosomic genetic element. The functional activity of this element is normally repressed. Suppression of the col-factor results in synthesis of a special proteic substance known as colicin; the cell then perishes. The colicin that it has produced has an antibacterial action with respect to other bacteria of the same or similar species.

We studied the influence of millimeter waves on colicin synthesis in the colicinogenic strain E. coli C600 ($E_1$) and in the strain E. coli K12S, which is sensitive to the colicin of the former. The activity of the colicin synthesis was determined by the method of