c) the effects are observed to depend significantly on time of irradiation.

The results obtained are of great scientific and practical interest. For example, it was established that the vital activity of microorganisms is affected by millimeter-wave irradiation. The effect may be positive or negative, depending on the particular part of the band and the particular conditions of irradiation.

The effects obtained on irradiation of microorganisms may eventually form a basis for new methods of producing vaccines and increasing the productivity of antibiotic-production methods. Another possibility that had not been excluded is that of millimeter-wave irradiation to treat burns and other suppurating wounds in order to accelerate the healing process.

Using as an example one of the studies that we made jointly with K. S. Rozhnov and his staff at the Leningrad Electrical Engineering Institute, I should like to demonstrate graphically the strength of the effect of millimeter-wave electromagnetic irradiation on cell division. A machine for irradiation of microorganisms and direct observation of their behavior during and after irradiation was designed around an MIS-51 comparison microscope.

Various yeast cultures were irradiated. A resonant effect of millimeter-wave irradiation on the division rate of the cells being irradiated was observed. Thus, for example, irradiation of a culture of Rhodotorula rubra for 15 hours at wavelengths of 7.16, 7.17, 7.18, and 7.19 mm (10 experiments were performed for each frequency), showed a sharp frequency dependence (Fig. 1; the ordinate is the ratio of the number of cells in the experiment to the control): cell division is stimulated at 7.18 mm and slightly depressed at the other wavelengths.

Irradiation of a Candida culture caused a marked change in the nature of cell division as compared with the control. Figures 2–4 show clearly the difference between control and experiment at various stages during irradiation.

Figure 5 illustrates the behavior of irradiated and unirradiated (control) cultures after about 15 hours of irradiation (which was administered at 20–21°C. After the 15 hours of irradiation, the culture temperatures were about 16–17°C).

An explanation of the mechanism of the resonant effect of irradiation and some of its other properties would be of enormous interest from the scientific standpoint. As yet, we have no rigorous scientific explanations for the effects of millimeter-band electromagnetic waves. There have been only a few attempts to develop approximate hypotheses to account for the resonant effect, and they require further experimental and theoretical confirmation.

It would be desirable to have scientific manpower at the institutes of the Division of Biochemistry, Biophysics, and Chemistry of Physiologically Active Compounds of the USSR Academy of Sciences put to work on a scientific explanation of the observed phenomena.

In addition to the scientific groundwork, a more active search should be made for fields of practical application of the effects of millimeter-wave irradiation. In this matter again, we look for assistance to the competent specialists at the Institutes of the USSR Academy of Sciences.

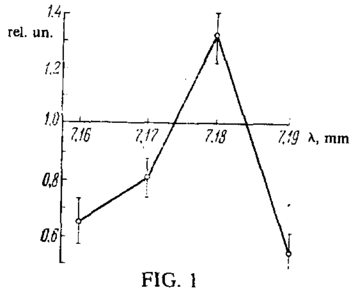

FIG. 1

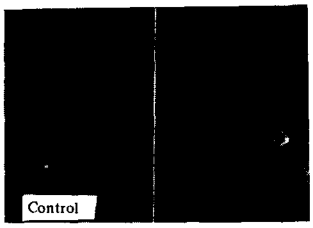

FIG. 2

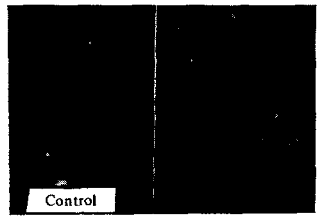

FIG. 3

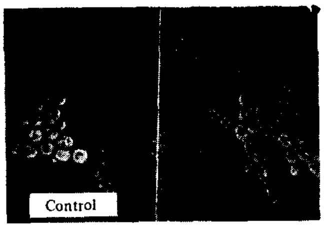

FIG. 4

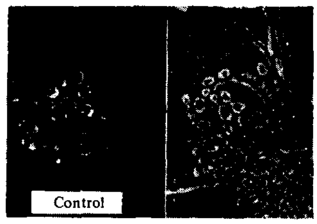

FIG. 5

É. B. Bazanova, A. K. Bryukhova, R. L. Vilenskaya, É. A. Gel'vich, M. B. Golant, N. S. Landau, V. M. Mel'nikova, N. P. Mikaélyan, G. M. Okhokhonina, L. A. Sevast'yanova, A. Z. Smolyanskaya, and N. A. Sycheva (General Editor: N. D. Devyatkov), Certain Methodological Problems and Results of Experimental Investigation of the Effects of Microwaves on Microorganisms and Animals

1. Research methodology problems and general relationships

Since this was the first time that we had worked in the millimeter band, we began by giving serious attention to problems of the experimental method. A diagram of the experiment appears in the figure. The effects of frequency, power flux density, exposure time, ambient temperature, and the identity of biological conditions were investigated in detail and recorded. The polarization was held constant through all experiments. All were performed with continuous irradiation.

It was found in the course of the experiments that the observed effects are not very critical in regard to the incident power flux density. In particular, it was established for a wide variety of microorganisms and tests that, beginning at a certain threshold power flux density of about 0.01 $mW/cm^2$, the effects vary weakly over several (two and five) orders of magnitude when a marked thermal effect is already beginning to make its appearance. We note that heating by other sources did 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

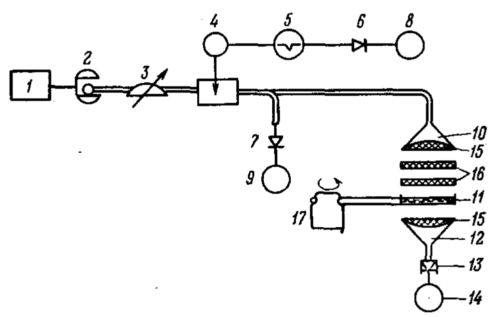


Diagram of experiment. 1–Power supply; 2–OV-612 backwardwave tube; 3–attenuator; 4–measuring line; 5–wavemeter; 6, 7–detector heads; 8–pointer-type indicator; 9–incident-power meter; 10, 12–horns; 11–object; 13–thermistor head; 14–transmitted-power meter; 15–correcting lens; 16–transformer; 17–electric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