SENSITIVITY OF THE RABBIT'S CENTRAL NERVOUS SYSTEM TO A CONTINUOUS SUPERHIGH-FREQUENCY ELECTROMAGNETIC FIELD

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Clinical indications of disorders of the nervous system of persons subjected to the effect of a superhigh-frequency (SHF) electromagnetic field [4], and also appreciable functional shifts occurring in the nervous system upon experimental irradiation with microwaves [3, 5, 8-10, 14, 17], give us grounds to assume a high sensitivity of the central nervous system of man and animals to SHF electromagnetic fields.

A number of authors have demonstrated that in low-frequency electromagnetic fields [15], ultrahigh-frequency fields [13], and a field created by a high voltage cable [6], the EEG of the rabbit undergoes changes. The amount of evidence and the persistence of these reactions increases with an increase of the field power [6, 13].

Most authors who have carried out electrocephalographic investigations of effect of SHF electromagnetic fields on the central nervous system have used only, or primarily, thermal intensities. It has been established in experiments on rabbits and cats [2] that the changes in the bioelectrical activity of the brain, which was subsequently studied, depended on the intensity of the field, time of exposure, and localization of the irradiated part. It has been demonstrated upon recording the EEG immediately at the time of irradiation [1] that the changes of the excitability of the CNS (based on the curves of reactivity) depend on field strength.

Extrathermal SHF field strengths also cause changes in the EEG of animals [11, 12] and man [18], wherein the persistence of these reactions increases with the flux density of the field [11, 12].

The results of these works are not fully comparable, since the authors used electromagnetic fields of different frequency characteristics and regimes (continuous or pulsed). Not one of them made a comparable evaluation of SHF electromegnetic fields of different physical characteristics from the point of view of sensitivity of the central nervous system to them.

The purpose of the present study was to evaluate the sensitivity of the CNS of rabbits to continuous SHF electromagnetic fields of different, primarily nonthermal, intensities at wavelengths of 12.5, 52 cm, and 1m.

EXPERIMENTAL METHOD

The experiments were carried out on 172 chinchilla rabbits weighing not less than 2 kg. Recording of the EEG before, during, and after unilateral 5 min irradiation of animals was accomplished on an ink-writing four-channel electroencephalograph 4-EEG-1 produced by the All-Union Scientific Research Institute of Medical Instruments and Equipment. We used a unipolar occipital lead from the hemisphere contralateral to the irradiated side. In some experiments we recorded the EEG from both hemispheres. We used needle electrodes which were embedded into the skull prior to the experiment. The sources of the continuous electromagnetic field were: 1) an experimental triode generator of the decimeter range with a grounded grid and horn irradiator (wavelength 52 cm); 2) the same generator with an irradiator in the form of a wave guide segment (wavelength 1 m); 3) a Luch-58 therapeutic magnetron generator (wavelength 12.5 cm).

We tested the following power flux densities (PFD): 0.02, 0.08, 0.4, 2, 10, and 50 mW/cm^2 (sometimes with certain deviations from the indicated values owing to technical reasons). We did not test the effect of the PFD, which comprised 50 mW/cm^2, for the 1 m wavelength.

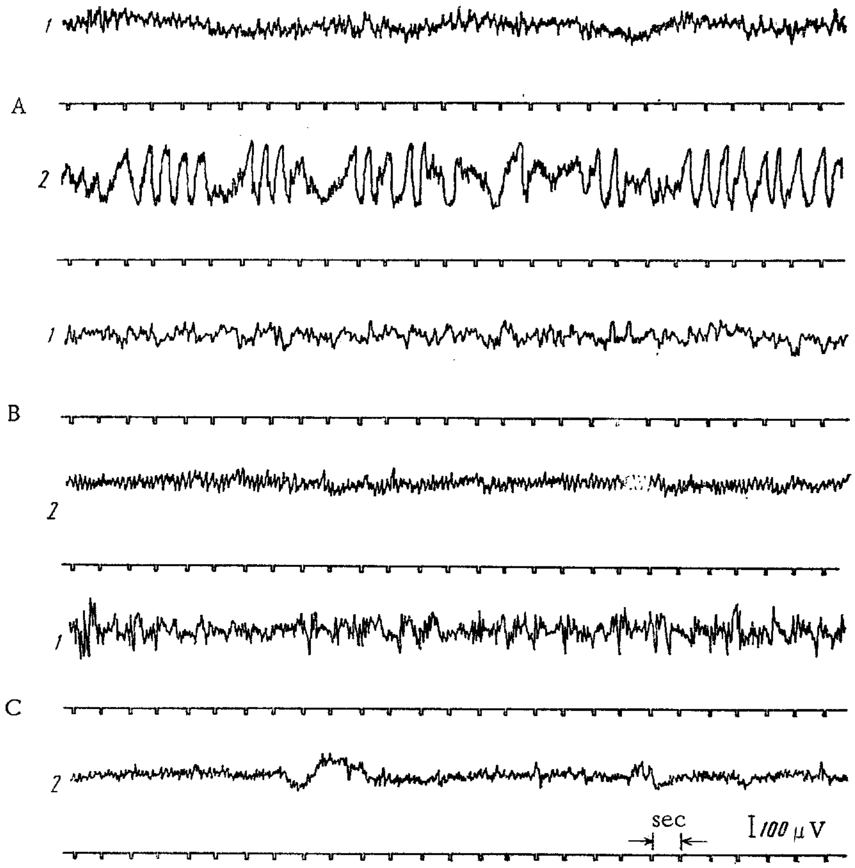

Fig. 1. Changes in the EEG of rabbits in SHF eletromagnetic fields. A) Slowing of main rhythm with simultaneous increase of amplitude; B) increase of frequency of the main rhythm; C) drop of amplitude of biopotentials without noticeable changes of frequency; 1) before irradiation; 2) during irradiation.

EXPERIMENTAL RESULTS

I Series of Experiments (63 rabbits). In the electromagnetic field with a wavelength of 12.5 cm with different PFD, a slowing down of the basic rhythm with a simultaneous increase of amplitude was noted on the EEG of 19 animals; in 14 animals there occurred a quickening of the basic rhythm with a simultaneous drop of amplitude and in 7 we noted a drop of amplitude of the basic rhythm without a change of frequency (Fig. 1). No changes in the EEG were recorded in 23 rabbits.

It is evident from the data shown in the Table that the character of the changes in the EEG does not depend on the PFD of the field, whereas the number of cases of changes in the EEG in a SHF field has a tendency to increase with an increase of the PFD.

In this series of experiments it was impossible to determine the moment of the onset of the reaction in about 50% of the cases. The values of the latent periods were large and frequently exceeded 50 sec. It was not possible to note a distinct dependence of the duration of the latent periods on the PFD.

II Series of Experiments (73 rabbits). In a electromagnetic field with a wavelength of 52 cm, a slowing down of the basic rhythm with an increase of amplitude was observed in 27 cases, and in 22 cases an increase of the frequency of biopotentials with changes in amplitude to both sides. In 7 animals we observed in the EEG a depression of the main rhythm (see table), whereas the EEG of 17 rabbits did not change.

The number of cases with changes of the EEG, just as in the field with a wavelength of 12.5 cm, has a tendency to increase with an increase of the PFD. At the same time we note the high percent of reactions in the field with the lowest of the tested PFD, 0.02 mW/cm^2. A similar phenomenon was observed in the preceding series of experiments.

Distribution of the Number of Cases of Different Changes in the EEG Depending on the PFD of the Field

Wavelength cm	PFD (mW/cm^2)	Number of cases with changes of EEG in SHF field				No. of cases without changes in EEG	Ratio of no. of cases with changes of EEG to total no. of irradiations (%)
		Drop of frequency with increase of amplitude of the main rhythm	Inc. of frequency of main rhythm with changes in amplitude to both sides	Drop of amplitude without change in frequency of main rhythm	Total		
12.5	0.02	4	2	2	8	4	67
	0.08	2	1	1	4	7	36
	0.4	1	4	—	5	6	45
	2	5	3	—	8	2	80
	10	2	3	3	8	2	80
	50	5	1	1	7	2	78
52	0.02	5	5	2	12	2	86
	0.08	3	1	2	6	5	55
	0.4	2	5	2	9	5	64
	2	7	1	—	8	2	80
	30	3	5	1	9	1	90
	50	7	5	—	12	2	85
100	0.02	7	3	—	10	1	90
	0.08	1	2	1	4	6	40
	0.4	6	3	—	9	1	90
	2	4	3	2	9	3	75
	10	7	4	2	18	1	93

The average latent period of the noted changes depends on the PFD and at a PFD of 0.02 mW/cm^2 it is 2 min 4 sec; 0.1 mW/cm^2, 67 sec; 0.5 mW/cm^2 30 sec; 3.5 mW/cm^2, 19 sec; 30 mW/cm^2, 18 sec; and 50 mW/cm^2, 41 sec.

As we see from the graph (Fig. 2), the curve of the sensitivity of the central nervous system of rabbits to a SHF electromagnetic field with a wavelength of 52 cm is analogous to the Weiss-Lapik curve for the action of an electrical current and to the curve for the effect of ionizing radiation [7, 16].

However, the average latent period of the changes in the EEG observed in a field with PFD equal to 50 mW/cm^2 does not fit into the general graphic dependence: with such an irradiation intensity, extremely slow reactions were recorded along with rapidly developing changes. It is necessary to point out that the graphic dependence of the value of the latent period on the PFD was true only for changes toward slowing of the rhythm and increasing of the amplitude of the biopotentials. The latent periods of changes associated with quickening of the basic rhythm were distributed in the following manner: 0.02 mW/cm^2, 1 min 50 sec; 0.08 mW/cm^2, 1 min 54 sec; 0.4 mW/cm^2, 54 sec; 2 mW/cm^2, 58 sec; 30 mW/cm^2, 49 sec; 50 mW/cm^2, 53 sec.

III Series of Experiments (57 rabbits). In an electromagnetic field with a 1 m wavelength, an increase in the amplitude of biopotentials with a simultaneous drop of their frequency was observed in 25 animals; in 15 animals the effect of the SHF field was accompanied by a quickening of the basic rhythm; and in 5 a drop in the amplitude of the EEG without a change of its frequency characteristic was noted. The EEG of 12 rabbits did not change under the effect of irradiation. As in the 2 previous series of experiments, the number of cases of changes of the EEG in a field with a PFD of 0.02 mW/cm^2 was higher than with a PFD of 0.08 mW/cm^2.

In this series of experiments the EEG of 6 rabbits was recorded from both hemispheres. Here, similar changes in the biopotentials in both hemispheres was noted in 5 animals, and in the EEG of the 6th rabbit interhemispheric asymmetry occurred during irradiation: in the irradiated hemisphere there was a depression of the basic rhythm, and in the contralateral hemisphere there were slow waves.

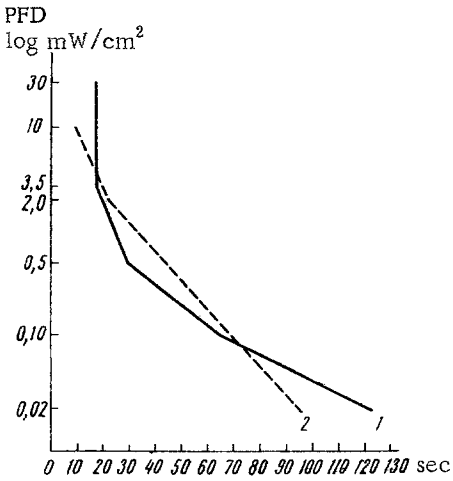

Fig. 2. Curves of the sensitivity of the rabbit CNS to electromagnetic fields with a wavelength of 52 cm (1) and 100 cm (2) of different PFD. The PFD is in a logarithmic scale.

As in the preceding series of experiments, an increase of the PFD from 0.02 to 10 mW/cm^2 was accompanied by a shortening of the average latent period of the bradyrhythmia-type changes from 96 to 10 sec; 0.02 mW/cm^2, 96 sec; 0.5 mW/cm^2, 46 sec; 2 mW/cm^2, 22 sec; 10 mW/cm^2, 10 sec (see Fig. 2). No dependence of the values of the average latent period of the tachyrhythmia-type changes on the PFD was noted: at a PFD of 0.02 mW/cm^2, the latent period was 46 sec; 0.08 mW/cm^2, 82 sec; 0.4 mW/cm^2, 89 sec; 2 mW/cm^2, 40 sec; 10 mW/cm^2, 98 sec.

In the control experiments changes in the EEG were noted in 5 of the 20 animals.

An analysis of these results showed that the latent period of some changes of the EEG that were observed in the SHF field depends on the PFD of the field. These are the bradyrhythmia-type changes that arise in the field with a wavelength of 52 and 100 cm. The distribution of the values of latent periods of all observed changes in the EEG with respect to a time scale (Fig. 3) demonstrates that 58% of the changes occur during the first minute of the effect of the field, 31% during the second min, about 10% during the third min, and only about 1% during the 4th and 5th min of exposure. This fact, as well as the fact that the number of cases of changes in the EEG has a tendency to increase with an increase of the PFD in all series of experiments and is lowest in the control (25%), are in our opinion sufficient grounds to consider the changes of the EEG in the SHF field as a response of the central nervous system to irradiation of the organism.

Fig. 3. Distribution in the number of cases of all changes in the EEG vs. value of latent periods. 1) Wavelength 12.5 cm; 2) 52 cm; 3) 100 cm.

An analysis of the curve of the distribution of latent periods with respect to a time scale (see Fig. 3) permits us to conclude a greater sensitivity of the CNS to electromagnetic fields of the meter range; most reactions on the EEG occur with a latent period up to 20 sec. A field with a wavelength of 52 cm has a lower biological effectiveness. Two peaks at the 20th and 40th second were observed in the distribution of latent periods of the encephalographic reactions in this field. The central nervous system manifests an even lower sensitivity to an electromagnetic field with a wavelength of 12.5 cm. A comparison of the "strength-duration" curves (see Fig. 2) brings us to the same conclusion: in a field with a wavelength of 1 m for extreme values of the flux density (10 and 0.02 mW/cm^2) the average latent period of the electroencephalographic reactions is shorter than in a field with a wavelength of 52 cm. As was indicated above, it was not possible to plot a "strength-duration" curve for a field with a wavelength of 12.5 cm.

SUMMARY

Unilateral 5 min irradiation of rabbits with the ultrahigh-frequency electromagnetic fields caused various EEG changes in the majority of the animals. A graphic relationship was noted between the average latent period of EEG reactions of the bradyrhythmia-type and the flux density for the electromagnetic waves, 100 and 52 cm in length. The greatest sensitivity was manifested by the CNS of the rabbits to the fields with the wave length of 100 cm, a somewhat lower one—to the fields with the wave length of 52 cm, and the least—to the fields with the wave length of 12.5 cm.

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