EFFECTS OF PULSATING MAGNETIC FIELDS ON THE PHYSIOLOGY OF TEST ANIMALS AND MAN

P. V. SANKER NARAYAN, SARADA SUBRAHMANYAM, M. SATYANARAYANA, K. RAJESWARI and T. M. SRINIVASAN*

Voluntary Health Services Medical Centre, Adyar, Madras 600 113, India.

**Indian Institute of Technology, Adyar, Madras 600 036, India.*

ABSTRACT

As part of investigations on possible effects of magnetic fields on biological objects, test animals (albino rats) and healthy humans were exposed to pulsating magnetic fields of extremely low frequency (0.01 to 10 Hz) and very low amplitudes (± 5 and ± 50 nT intensity) with their heads in different orientations with respect to the pulsating and ambient magnetic fields and their electrophysiology, neurochemistry and biochemistry studied. In the north and east orientations both animals and human subjects seem to show decisive changes in their electrophysiology, neurochemistry and biochemistry. These results are briefly described.

INTRODUCTION

INTERACTION of earth's electromagnetic field with biosphere has become a topic of great interest over the last decade largely as a result of the knowledge explosion that has occurred in space sciences. Three decades ago scientists were divided in their opinion on the possible control of our biosphere by the planetary electromagnetic field. Scientific opinion has travelled a long way since then and with radically modified perspectives. The issue now is rather one of understanding the exact mechanism of such interaction in terms of physical/chemical models at the cellular and molecular levels[1]. While some experimental studies on the effects of magnetic fields on animals and humans have been reported from the high magnetic latitudes of the USSR[2,3] no work seems to have been carried out at the low latitude and equatorial regions of earth. To fill this gap studies have been conducted at the low magnetic latitude of Madras (magnetic dip or inclination = + 10°) first on test animals and subsequently on human subjects by exposing them to pulsating magnetic fields of extremely low frequencies and amplitudes with the subjects in different orientations and against different ambient (steady) magnetic fields.

EXPERIMENTAL SETUP

For experiments on human subjects a 4-member Fanselau-Braunbeck coil system with the smaller and larger coil frames of radii 148.5 and 194.5 cm respectively and with the spacing between the inner (larger) coils at 108 cm and between the outer (smaller) coils at 329 cm was fabricated[4]. The common axis of the four coils was aligned along the magnetic meridian, dipping 10° from horizontal towards North so that any magnetic field generated inside the coils by currents through the four coils in series will vectorially add or oppose the local total magnetic field of about 40,000 gammas (nT) (figure 1). An identical, scaled-down model of much smaller dimensions was fabricated for experiments on test animals. Each coil frame carries two sets of windings: (i) a 'steady field' winding of 12 turns, by energizing which with DC of appropriate direction and value, any steady ambient magnetic field can be maintained in the enclosure including the interesting situation of "near-magnetic vacuum" in close simulation of interplanetary magnetic environ-

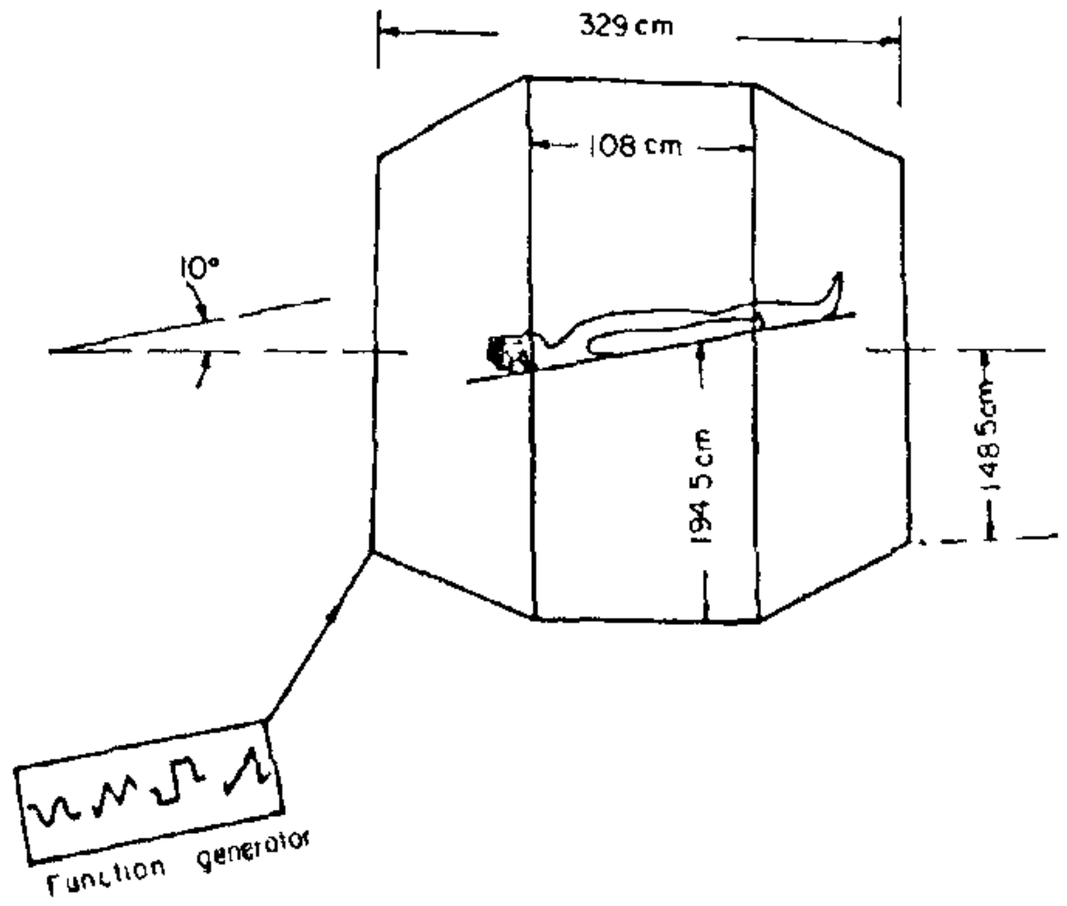

Figure 1. Schematic diagram of controlled magnetic field enclosure.

ment; (ii) a 'pulsation' winding of 3 turns, by feeding which with alternating currents (from a function generator) pulsating magnetic fields of any frequency, amplitude and waveshape can be generated inside the enclosure.

STUDIES ON ANIMALS

Male albino rats, kept at the centre of the CMF enclosure, were exposed to sinusoidally pulsating magnetic fields of frequencies 0.01, 0.1, 1, 10 and 20 Hz and amplitudes of ± 5 and ± 50 gammas (nT) with their heads towards north, east, south and west. The exposures were given with two values of ambient (steady) magnetic fields, namely the full local geomagnetic intensity of about 40,000 gammas and half this value.

During the exposure ECG, EEG, respiration and tail blood flow were continuously recorded on a polygraph. The experimental animals were sacrificed immediately after exposure in each frequency and orientation, the brain removed and the biogenic amines, noradrenaline, adrenaline, dopamine, 5-HT and 5-HIAA assayed from different regions of brain as also from total brain. Blood was collected by cardiac puncture for biochemical studies. In addition, adrenal glands and heart were taken out and the amines assayed. The biochemical investigations covered sugar, cholesterol, PBI and plasma cortisol in blood, and MHPG, VMA, HVA, 5-HIAA, catecholamines and 17-ketosteroids in urine.

RESULTS

(a) *Electrophysiological*: ECG showed marked changes during exposures to 0.01 and 0.1 Hz pulsations when the animals' heads were oriented towards north (figure 2). These changes are suggestive of the impulses originating in an ectopic focus. The animals were restless and aggressive, screeching frequently. Congestion of the conjunctiva was evident in the animals with protrusion of eyeballs. As opposed to this in the east orientation the rats did not show any changes in the ECG, EEG, respiration or tail blood flow. These contrasting effects arising from orientation were evident with an ambient magnetic field of half the local

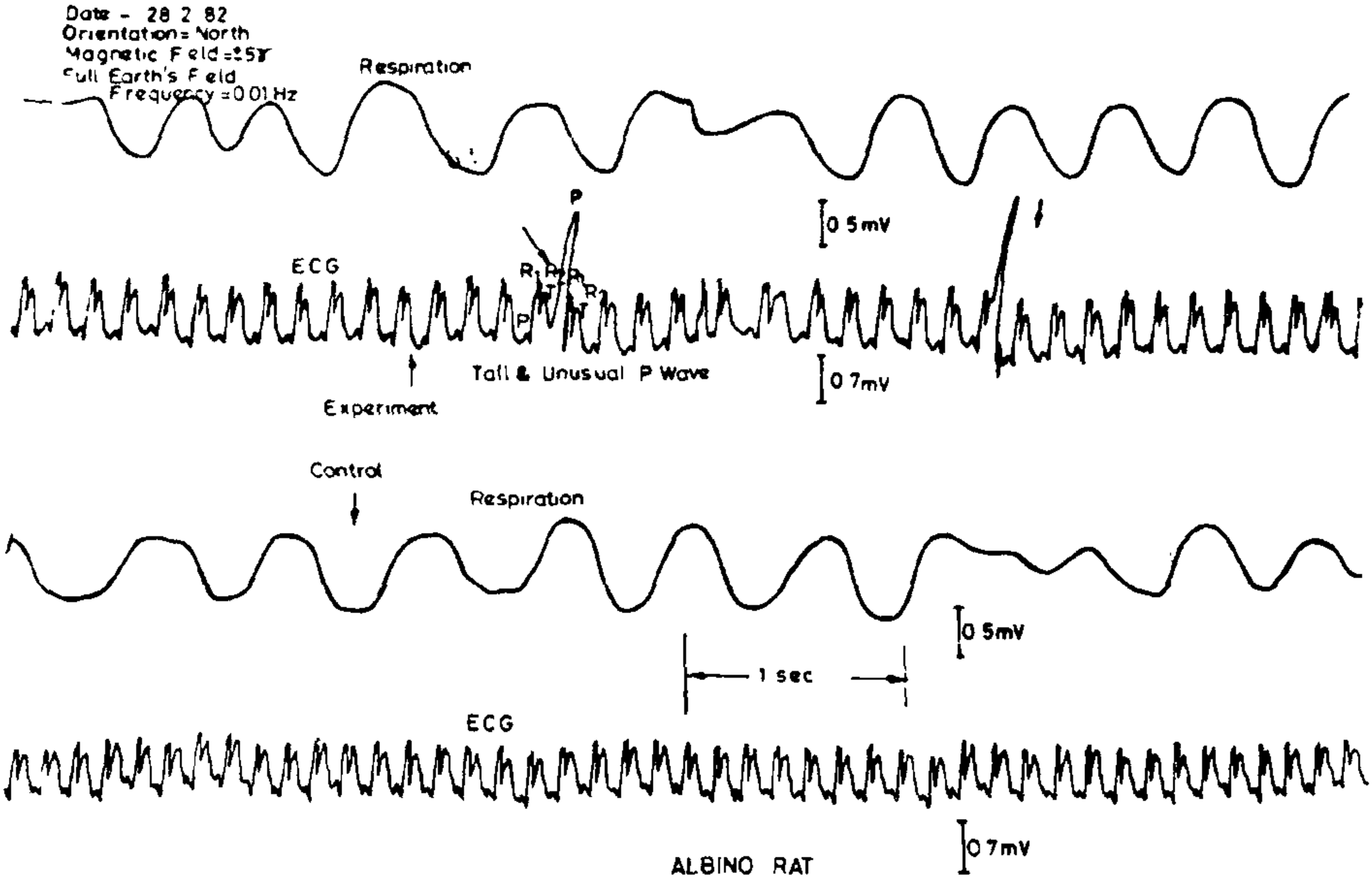

Figure 2. Polygraph record (ECG and respiration) of albino rat (along with control) exposed to 0.01 Hz ± 5 nT pulsations with head towards north in full geomagnetic field.

geomagnetic value also. There were minimal changes in the other two orientations. Motor activity was seen to have increased considerably on exposure in north orientation.

(b) *Neurochemical and biochemical*: In the brain (total brain as well as in different regions) the levels of catecholamines, noradrenaline and dopamine, showed an increase and the indoleamines, 5-HT and 5-HIAA, a decrease with north orientation, whereas east orientation showed hardly any changes (table 1).

Blood sugar showed an increase in north orientation whereas there was no significant change in plasma cortisol and cholesterol. In the adrenal gland and myocardium adrenaline was increased with hardly any change on NA when in north orientation.

STUDIES ON HUMAN SUBJECTS

The subjects, lying supine at the centre of the larger CMF enclosure with heads towards north, west, south and east as also in sitting posture, were exposed to pulsating fields of 0.01, 0.1, 1 and 10 Hz frequency and amplitudes ±5 and ±50 gammas in full ambient geomagnetic field (40,000 gammas) as also half this value. ECG, EEG, respiration and finger blood flow as also pulsating field were continuously recorded on a polygraph. In addition, EEG from different regions of the brain was also recorded on an 8-channel machine with additional splitup of one wave into the alpha, beta, delta and theta components. The subjective experiences of each subject during the exposures were also elicited.

Blood and urine samples were collected from each subject before the start and after exposure in each frequency and amplitude. Sugar, cholesterol, plasma cortisol and PBI were assayed in the blood and MHPG, VMA, HVA, 5-HIAA, total CA as also 17-ketosteroids in the urine.

The following environmental conditions were carefully maintained/observed in the case of human subjects: (a) The subjects were screened from all field-generating and recording equipment and operating personnel so that they were not aware of the set-up or procedural stages of the experiment such as onset or cessation of exposure etc. (b) The CMF room was kept as noise-free as possible; in particular no conversation/instructions between the operators were audible to the subjects. (c) By reference to the geomagnetic and pulsation observatories of the National Geophysical Research Institute at Hyderabad about 500 km to the north-north-west and at Etaiyapuram (Tamil Nadu) about 500 km south-south-west of Madras, it was ensured that there was no major or moderate geomagnetic disturbance (including pulsation activity) during any of the experiments.

Table 1 *Rat brain—full earth's field biogenic amines (0.01 Hz; ±5 Gammas (nT))*

Orientation	No.	µg/g of wet tissue				
		NA	A	DA	5-HT	5-HIAA
Control	10	3.151 ± 0.132	1.193 ± 0.078	9.927 ± 0.126	1.376 ± 0.078	4.427 ± 0.112
North	10	**4.177 ± 0.105	*1.118 ± 0.073	**10.514 ± 0.120	*1.141 ± 0.083	**3.367 ± 0.121
South	10	*3.842 ± 0.185	@1.160 ± 0.052	**10.492 ± 0.110	*1.139 ± 0.075	**3.108 ± 0.101
East	10	@3.210 ± 0.173	@1.174 ± 0.065	@9.890 ± 0.120	@1.326 ± 0.081	*4,123 ± 0.120
West	10	@3.180 ± 0.168	**1.182 ± 0.073	@9.912 ± 0.131	@1.368 ± 0.076	@4.360 ± 0.118

@ *P* value not significant; * *P* value significant (< 0.01); ** *P* value highly significant (< 0.001).

Table 2 *Urine—normal subjects (average of 10)*

Pulsation: Frequency: 0.01 Hz; Amplitude: ±50 nT
Ambient Field: 40,000 nT (Full Geomagnetic)

Orientation \ Parameters	CA (μg %)	MHPG (mg %)	VMA (mg %)	HVA (mg %)	5-HIAA (mg %)	17-keto steroids (mg %)
Control	2.7 ± 0.3	0.18 ± 0 02	0.39 ± 0.01	0.4 ± 0.02	0.32 ± 0.02	1.0 ± 0.4
East	@2.5 ± 0.3	@0.16 ± 0.02	@0.38 ± 0 01	@0.36 ± 0.02	@0.30 ± 0.02	@0.9 ± 0.1
North	**4.6 ± 0.4	**0.30 ± 0.02	**0.58 ± 0.02	**0.58 ± 0.03	**0.22 ± 0.01	*2.0 ± 0.4
Sitting	@3.2 ± 0.3	@0.2 ± 0.02	*0.44 ± 0.02	@0.44 ± 0.02	@0.30 ± 0.01	@1.2 ± 0.4

@ *P* value is not significant; * *P* value is significant (< 0.05); ** *P* value is highly significant (< 0.001).

Abbreviations used in the table: A—Adrenaline; 5-HT—5-Hydroxy tryptamine; 5-HIAA—5-Hydroxy indole acetic acid; HVA—Homovanillic acid; CA—Catecholamines; MHPG—3-Methoxy-4-Hydroxy phenyl-glycol; PBI—Protein-bound iodine.

RESULTS

Electrophysiological: With pulsations of frequency of 0.01 and 0.1 Hz in the north orientation the electrical activity in the brain was abruptly and severely inhibited as seen from the sudden damping of all the waves, particularly the alpha and beta rhythms (figure 3). The subjects experienced uneasiness, confusion and restlessness. There was decreased peripheral blood flow as seen on the polygraph record. In sharp contrast, in east orientation pulsations of the same frequency showed an abrupt enhancement of brain electrical activity—particularly the alpha and beta components, indicative of a state of restful mental alertness (figure 4). The peripheral blood flow also showed a prominent enhancement. The subjects expressed that they felt calm and relaxed in this orientation. No significant changes were seen in the ECG and respiration while in the east orientation.

As in the case of animals the human subjects also did not show any significant changes in the electrophysiology in the south and west orientations. Incidentally, the above observations, described for full ambient geomagnetic field, were also recorded with an ambient field of half this value.

Neurochemical and Biochemical: In the North orientation (with pulsations of 0.01 and 0.1 Hz frequency) the sugar and plasma cortisol levels in the blood increased with no significant change in other orientations. There was no change in other parameters. In the urine 5-HIAA was reduced on exposure in north orientation whereas HVA 17-ketosteroids showed an increase. The biochemical changes seen in north orientation as described above were not seen in any other orientations (table 2).

The authors feel that the results sketched above are still to be considered as preliminary and need more extensive and confirmatory work. It seems fairly certain that, as has been suspected by certain workers in biomagnetism, there may be discrete 'windows' of frequency and possibly amplitude which favour the interaction of pulsing magnetic fields with the living organism. Possibly in these windows the threshold magnetic energy needed to excite the organism at the cellular and molecular level may be exceedingly low since the amplitudes used in the above experiments are as small as ±5 and ±50 gammas or, of the order of 10^{-4} of a gauss or about the same fraction of the geomagnetic field.

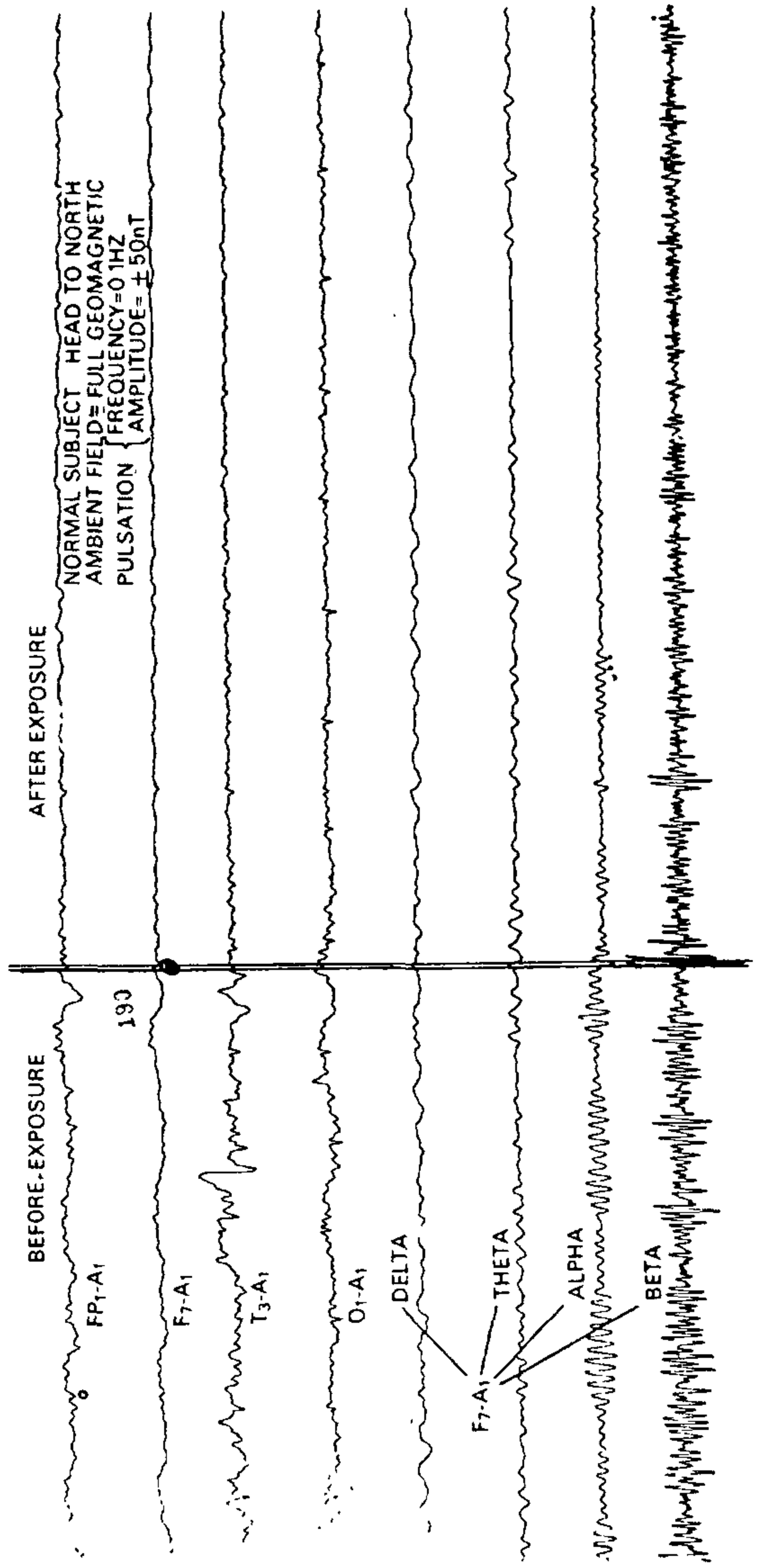

Figure 3. ECG of a normal human subject in north orientation in full geomagnetic field with 0.01 Hz, ±50 nT pulsations.

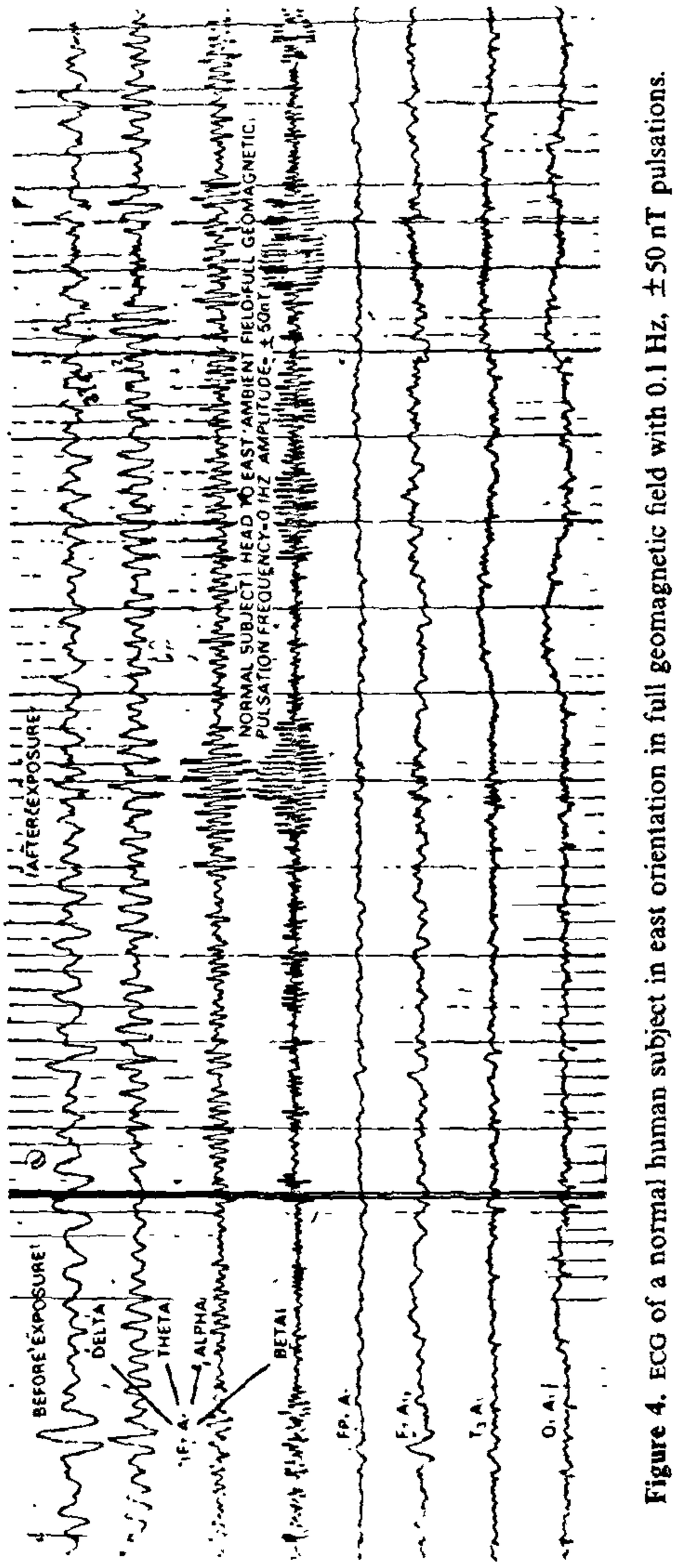

Figure 4. ECG of a normal human subject in east orientation in full geomagnetic field with 0.1 Hz, ±50 nT pulsations.

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ANNOUNCEMENTS

NATIONAL SYMPOSIUM ON VACUUM TECHNOLOGY AND SEALED-OFF DEVICES

The National Symposium on Vacuum Technology and Sealed-off Devices organised by Indian Vacuum Society in collaboration with Indian Institute of Science will be held during 19–21 December, 1984 at the Institution of Engineers Hall, Bangalore.

The topics to be covered can broadly be classified as follows: 1. Vacuum Science and Technology (General), 2. Tube devices, techniques and applications, imaging tubes, transmitting tubes, microwave tubes, picture tubes, x-ray tubes, CRTs, circuit breakers, contactors etc. 3. Lasers/solar energy applications. 4. Lamps, GM Counters, Flasks, 5. Role of vacuum in packaging industry, 6. Materials with specific reference to sealed-off devices, 7. Automation/process control with specific reference to sealed-off devices, 8. Medical applications with specific reference to sealed off devices.

Further information may be had from: Mrs. Devaki Ramanathan, Convener, National Symposium on Vacuum Technology and Sealed-off Devices, Technical Physics & Prototype Engg. Division, Bhabha Atomic Research Centre, Bombay 400 085.

SEMINAR ON PHILOSOPHY OF SCIENCE IN INDIAN CONTEXT

A three day Seminar on "Philosophy on Science in Indian Context" will be held at National Institute of Science Technology and Development Studies (NISTADS), New Delhi during 3–5 December 1984.

The three important sections of the Seminar are as follows: Section A—Philosophy and scientific tradition in India; Section B—Philosophical issue of 'Science, Society and Culture Relation'; Section C—Philosophical issues of particular scientific disciplines.

For further particulars please contact: Navjyoti Singh, NISTADS, Hillside Road, New Delhi 110 012.