INTRODUCTION

Liboff (1985) proposed a model which might explain the interaction of undulating electromagnetic fields with ionic species at geomagnetic flux densities. A charged ion moving in a plane normal to the Earth's magnetic field will experience a radial force (Lorentz's force):

$$q \cdot v \cdot B = \frac{m \cdot v^2}{R}$$

where:
- \( q \) is the charge of the ion,
- \( m \) the mass of the ion,
- \( v \) its velocity,
- \( R \) the radius of the curvature of the path.

Because of this force, the ion will execute a circular or a helical path. The velocity can be simply expressed as the product of the frequency of rotation \( f \), and the pathlength, leading to a unique frequency corresponding to the geomagnetic field \( B \):

$$f = \frac{q \cdot B}{2 \pi \cdot m}$$

This is the same condition for accelerating charged particles in a cyclotron and the phenomenon is therefore named "Ion Cyclotron Resonance".

The Earth's geomagnetic field varies from about 70 micro-tesla (\( \mu \)T) at the poles to 25 micro-tesla (\( \mu \)T) at the geomagnetic equator and averages about 50 micro-tesla (\( \mu \)T) at mid latitudes. For such fields, frequencies in the range of 10-100 Hz correspond approximately to charge/mass-ratios of 0.01 to 0.1 electronic charge per atomic
mass unit indicating that biologically important ions, heavier than protons but lighter than enzymes and proteins appear to have geomagnetic cyclotron resonance frequencies.

The "Ion Cyclotron Resonance Hypothesis" was explored by Liboff et al., (1987) in an experiment of incorporation of calcium-45 \(^{45}\text{Ca}^2+\) in mixed human lymphocytes. The geomagnetic horizontal field component was adjusted to 21 micro-tesla (\(\mu\)T). The experiment was first performed at an amplitude of 150 micro-tesla (\(\mu\)T) and a sharp minimum was obtained at the frequency of 14.3 Hz which corresponds to the ion-cyclotron-frequency at 21 micro-tesla (\(\mu\)T). The experiment was then repeated at an amplitude of 21 micro-tesla (\(\mu\)T) and now a sharp narrow maximum occurred at 14.3 Hz.

We found this remarkable interaction mechanism very interesting and have since March 1988 set up experiments to explore the presence of "Ion Cyclotron Resonance" for calcium ions in human normal and transformed lymphocytes and in rat thymocytes.

MATERIALS AND METHODS

Magnet coils. The apparatus used for exposure consisted of two pairs of Helmholtz-coils placed orthogonally to each other. The axis of the vertical coils was oriented in the North-South direction and the axis of the other pair in the horizontal plane. The diameter of the coils was 230 mm wound with 100 turns of 1.5 mm diameter enameled copper wire. The horizontal coils were coupled in series at a distance of 230 mm and used for compensating the vertical component of the Earth's geomagnetic field. A fluxgate magnetometer was used as an indicator and was balanced to zero field in the vertical direction. The vertical component of the geomagnetic field was balanced to 21.0 \(\mu\)T using the bias voltage from the pulse generator. A sinusoidal time varying field with adjustable frequency and amplitude was also applied to the vertical coils. The frequency was monitored by using a frequency meter. The amplitude of the undulating field was checked at the center of the coils using a pickup coil. The induced electromotoric force was recorded on the oscilloscope.

Calcium tracer and radioactivity measurements. Radioactive calcium-45 with a radioactivity concentration of 370 MBq/ml and low stable calcium concentration was used. About 0.2 \(\mu\)l was added to the stock solution of mixed media used in each experimental series. The cells were collected on filter Whatman GFA and washed 7 times with inactive media of the same composition as the one in which the cells were exposed. The filters were mounted on the glasses of diaframes and slided in a reproducible position under an endwindow GM-tube counter.

Cells and media were specially prepared as described for each experiment.

EXPERIMENTS AND RESULTS

Uptake of \(^{45}\text{Ca}\) in normal human lymphocytes. Normal human lymphocytes were prepared to 6\(\times\)10\(^6\) cells per ml in calcium free buffer solution (Hank). Calcium-45 tracer solution was prepared in 0.02 mM Ca to an activity concentration of 40 kBq/ml. Triplicate control and experimental round bottomed microtiter plates were prepared immediately prior to magnetic field exposure by combining 50 \(\mu\)l \(^{45}\text{Ca}\)-tracer solution and