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ARE THE EARTH MAGNETIC FIELD AND SCHUMANN RESONANCE RELATED TO GLOBAL HUMAN ACTIVITY?

CZY POLE MAGNETYCZNE ZIEMI I REZONANSE SCHUMANNA MAJĄ ZWIĄZEK Z GLOBALNĄ AKTYWNOŚCIĄ CZŁOWIEKA?

STANISŁAW MICEK*, GRZEGORZ MICEK**

**Zakład Doświadczalnej Fizyki Komputerowej, Instytut Fizyki, Uniwersytet Jagielloński, ul. Reymonta 4, 30-059 Kraków, ufmicek@cyf-kr.edu.pl*
***Zakład Rozwoju Regionalnego, Instytut Geografii i Gospodarki Przestrzennej, Uniwersytet Jagielloński, ul. Grodzka 64, 31-044 Kraków, g.micek@geo.uj.edu.pl*

Abstract. Weak oscillating electromagnetic fields at extremely low frequency (ELF) induced by Schumann (AC) resonance and static (DC) magnetic fields are investigated in exerting a possible effect on biological systems on the Earth. An attempt is made to explain higher human activity on the Earth as the result of ion cyclotron resonance (ICR) conditions. The effect of cyclotron resonance on heart rate variability (HRV) and ion solution of NaCl is also shown. From IGRF model of DC magnetic field on the Earth and from frequency of Schumann resonance AC, regions of cyclotron resonance were estimated. These regions can be correlated with birth rate, population structure and armed conflicts. The result of the analysis indicates that a global human activity could be associated with influence of magnetic fields.

Key words: HRV, ICR, Schumann resonance, IGRF model, geomagnetic field, birth rate, death rate, HIV/AIDS, armed conflict

Streszczenie. W pracy badany jest wpływ na układy biologiczne Ziemi słabych pól elektromagnetycznych o ekstremalnie niskich częstotliwościach (ELF) wytworzonych przez rezonanse Schumanna (AC) w obecności stałych (DC) pól magnetycznych. Przedstawiono próbę wyjaśnienia większej aktywności ludzi na Ziemi przy pomocy efektu jonowego rezonansu cyklotronowego (ICR). Pokazano też wpływ rezonansu cyklotronowego na zmienność rytmu serca i na związek jonowy NaCl. Przyjmując stałe pole magnetyczne na Ziemi zgodnie z modelem IGRF oraz naturalne zmienne pole magnetyczne pochodzące z rezonansów Schumanna, znaleziono obszary występowania rezonansu cyklotronowego. Obszary te można korelować z miejscami o większym współczynniku urodzeń, strukturą wiekową ludności i z konfliktami zbrojnymi. Wynik analizy wskazuje na to, że globalna aktywność człowieka może być połączona z wpływem pól magnetycznych.

Słowa kluczowe: rytm serca, jonowy rezonans cyklotronowy, rezonans Schumanna, współczynnik urodzeń, konflikty zbrojne

1. Introduction

Recent studies in the solar-terrestrial physics led to the recognition of the role of the geomagnetic field as one of the most important characteristics of human environment. The role of magnetic fields in the dynamics of complex biological process is still far from being understood. Some attempts have been made to test different mechanisms of ELF (Extremely Low Frequency 1-50 Hz) magnetic field interactions experimentally. Several mechanisms have been proposed: Hall effect, ion cyclotron resonance ICR, ion parametric resonance, biological electron transfer, forces on endogenous magnetite particles, magnetochemistry (effect on free radical reactions due to electron spin reversals brought about by the magnetic field).

Ions travelling in the external DC magnetic field are deflected by the Lorentz force and generate an electric field. This phenomenon is known as the Hall effect [1], [2], [3].

Lednev [4] has proposed a mechanism of parametric resonance that would allow very weak magnetic fields, at the cyclotron resonance frequency for Ca^{2+} ions in the Earth's field, to induce biological effects. The ion parametric resonance is based on the idea that an ion weakly bound within a protein, notably Ca^{2+} within calmodulin, can be modelled as charge oscillator. An ambient DC magnetic field, such as that of the Earth, would cause Zeeman splitting of each vibrational level into two levels separated by the ion cyclotron frequency. When an alternating magnetic field is applied in parallel with a DC magnetic field, the resulting frequency modulation of levels will change the probability of ion transition from the ground state to the excited state.

Direct effects of applied magnetic fields on DNA are also possible [5]. The electron mobility along the π bonds in the central core of DNA strands can be surprisingly large and it is not known whether it is large enough to make transverse deflection of electron currents due to applied magnetic fields.

Modulators of K^+, Ca^{2+}, and Na^+ currents can influence the intrinsic rate of automatic cells. The passage of Na^+, K^+, Ca^{2+} and Cl^- ions across the cardiac plasma membrane (sarcolemma) through specialised voltage and ligant operated ion channels is the basis of normal excitability and conduction. The process that accounts for opening and closing of ion channels is called gating. Voltage gated ion channels are the largest group of cardiac ion channels. Gating currents have provided considerable insight into the function of ion channels [6]. Voltage gated ion channels may occupy one of two conductance states, open or closed. The direction of movement of a given ion through the open channel is determined not only by its electrochemical gradient but also by magnetic field [7]. Ion movement can be controlled by creating a specific relationship between the strength of the stable magnetic field $\mathbf{B}_{DC}$ (B_x,B_y,B_z) and the frequency of the AC field oscillation $\mathbf{B}_{AC}$ (B_x,B_y,B_z). The ion trajectory can be predicted by calculations. As it will be shown later at the cyclotron resonance, ion pathway is different than out of the resonance.

The purpose of this paper is to show experimental evidence for the Earth's cyclotron resonance effect on entire human population.

2. Cyclotron resonance

A charge q of mass m, which moves at velocity V in a constant (static DC) magnetic field B_{DC}, will follow in vacuum a circular trajectory of the radius R:

$$R = \frac{V}{B_{DC}} * \frac{m}{q} \tag{1}$$

The radius R for ions travelling with small velocity can be very small. The cyclotron frequency f_c will be given by $f_c = (q/m) * B_{DC}/(2\pi)$. It has been noted that cyclotron frequencies of many physiologically important ions fall below 100 Hz in the geomagnetic field (50 μT). For example, $f_c = 38.4$ Hz for $^{40}Ca^{2+}$ ion is seen at B_{CD}=50 μT magnetic field.

Such movement of ions seems to be not possible in the dense, collision-dominated fluids of biological materials. Furthermore, ions in biological fluids are normally hydrated, and the cyclotron frequency depends on the number of water molecules (and their total mass) in the sheath of solvent molecules of each ion. Despite the apparent implausibility of cyclotron resonance as a mechanism of interaction between magnetic field and biological system, many experiments have shown a response to combinations of static and alternating magnetic fields. This response reaches, in different systems, either a maximum or minimum at the cyclotron frequency for various physiologically important ions.

According to the Lorentz force the ion trajectory can be calculated for a given constant and oscillating magnetic field $\mathbf{B}_{DC}$ (B_x,B_y,B_z) and $\mathbf{B}_{AC}$ (B_x,B_y,B_z). Calculated trajectory of the Cl^- ion presented in Fig. 2 depends on the frequency of AC field. For given $\mathbf{B}_{DC}$(15,0,47) μT and $\mathbf{B}_{AC}$(5,0,0) μT we can see two trajectories for 15 Hz and 21 Hz. The ion path for 21 Hz, close to the cyclotron resonance, is concentrated at the origin. For 15 Hz frequency and the initial velocity of $\mathbf{V}$(0.1,0,0)m/s, Cl^- ion is reaching the distance above 150 μm in 5 seconds. Ions collisions change this value but the difference in the path length between 15 Hz and 21 Hz remains.

The length of the ion path depends on its time of life. After time of life, an ion reaches the distance:

$$d = \sqrt{X_o^2 + Y_o^2 + Z_o^2} \tag{2}$$

Trajectory calculations made in 3D space shown in Fig. 1 indicate the pronounced minimum in d at the cyclotron resonance frequency.

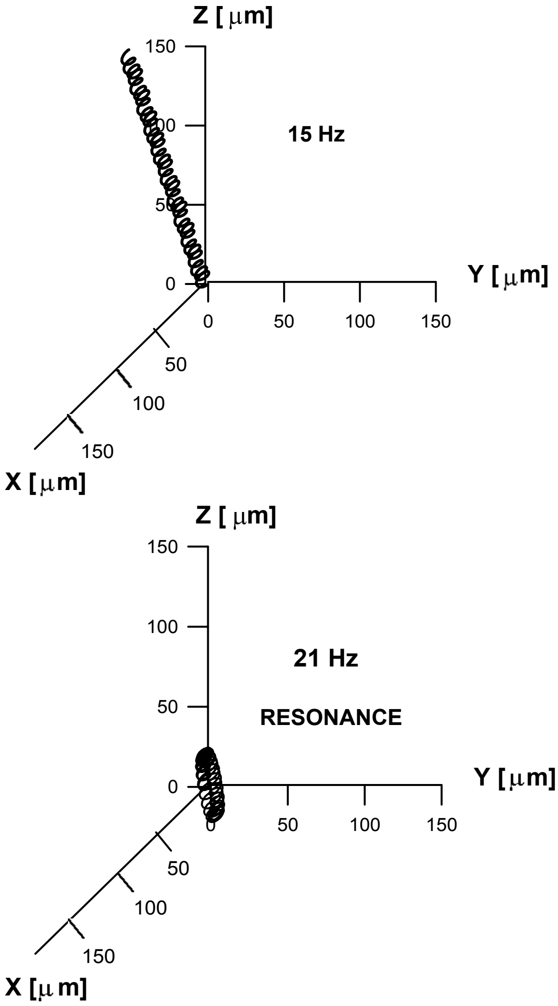

Fig. 1. Trajectory calculation of a free Cl^- ion moving with an initial velocity $\mathbf{V}$(0.1,0,0) m/s in constant $\mathbf{B}_{DC}$(15,0,47) μT and alternating $\mathbf{B}_{AC}$(5,0,0) μT magnetic field at the frequency 15 Hz (upper trajectory) and at 21 Hz (resonance). At the resonance Cl^- ion remains closer to the centre of XYZ axis.

3. Heart rate variability (HRV)

The sinus node has the highest intrinsic rate and acts as the dominant pacemaker and it is the central control element of the autonomic regulation. It generates regular heartbeat rate seen in electrocardiogram. Intervals between two consecutive R waves correspond to one cardiac interbeat interval RR. The change of RR interval in ECG describes the heart rate variability (HRV). The HRV is a very sensitive indicator of living organisms. The analysis of RR time series exhibits different oscillating sources of the variability of heart beat generation. The different regions in the power spectrum are related to special physiological phenomena. The high frequency band (HF) from 0.15 to 0.45 Hz [8] represents the modulation of the vagal activity especially influenced by respiration and low frequency band (LF) from 0.03 to 0.15 Hz reflects modulation of sympathetic or parasympathetic tone by baroflex activity (blood pressure regulation) [9].

The correlation dimension D2 can be derived from methods of non-linear dynamics, also called chaos theory, which describe complex processes and complicated interactions. D2 should be able to record additional information about the state and temporal changes of the autonomic system. Therefore, we have applied the correlation dimension method to distinguish heart rate dynamics in ELF magnetic field. Correlation dimension of RR intervals is a better predictor of risk of sudden cardiac death than a stochastic measure, such as the standard deviation [10]. It was found that reduction of the D2 value in HRV below 1.2 precedes lethal arrhythmia by hours [11]. Calculation of D2 for time series similar to sine wave gives D2=1. For more complicated series D2 > 1.

4. Measurements of HRV

Standard ECG was measured in 8 channels by 12-bit converters with the frequency 200 Hz and stored in 4-minute time series. The magnetic field of a randomized frequency was generated by Helmholtz coils (1 m^2). Subject and investigators were not informed about irradiation frequency and whether the field was switched on. Two independent computer systems: for control and data acquisition were used. The pulse rate of subject was controlled during measurements.

5. Correlation dimension D2 of HRV

For a given ECG time series, RR intervals were calculated. The point defined as R was estimated by looking at the first derivative in ECG time series in comparison to the given pre-set level determined in the preliminary experiment. As a result of measurements the RR data in time steps given by the time difference between consecutive QRS events was received. Next a reference multidimensional vector with dimension m was selected. Similarly the second vector of the same dimension m was constructed starting at a different point of the time series. This operation was performed sequentially for all other starting points. The difference between the reference vector and the second vector was determined and stored. Then reference vector was moved to the next point of the data until all possible vector differences were calculated and stored. The number of vectors whose lengths were lower than r given by C(r) was plotted on log-log scale (log C(r) vs. log r).

The correlation dimension D2 of the time series was calculated as a logC(r)/log r ratio. It was done by linear regression in the linear region of a log-log plot. Then calculations were repeated for the next m dimension. For some values of m, D2 converges if HRV follows deterministic chaotic dynamics. It means that increment of m was no longer correlated with an increase in D2 [12]. Algorithm rejected D2 where there was no linear part of log-log dependence or D2 was not converging. In one calculation 250 RR data points were used.

Measurements and calculations of D2 vs. frequency of magnetic field (Fig. 2) were made for ECG time series with average pulse rate from 61 to 72 bpm. They indicate that D2 has a maximum at frequency of about 3 Hz, 7 Hz and 10 Hz in ELF region. Minimum at 1.6 Hz, 4 Hz and 25 Hz point out that heart pulse rates behave more stable in the ELF magnetic field. Experimental data support the idea that both harmonics and subharmonics of Cl^- and Na^+ ions are involved in HRV.

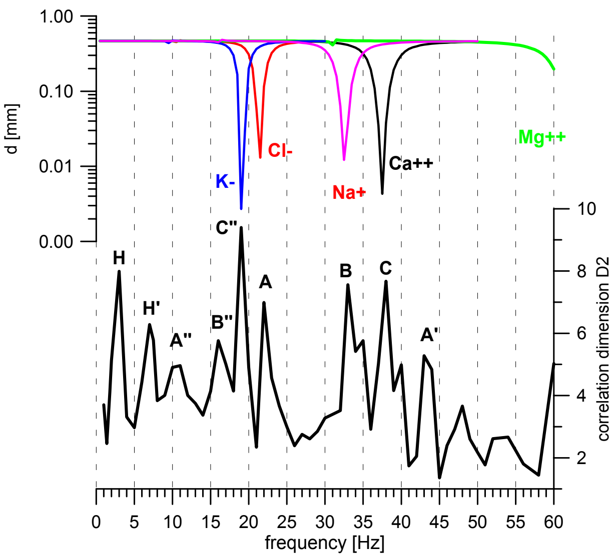

Fig. 2. Correlation dimensions D2 (lower curve) calculated from heart rate variability and model calculations (upper curves) of path length d versus magnetic field frequency. Initial ion velocity in calculations is **V**(0,0,0.1) m/s and $\mathbf{B}_{DC}$(17,0,46) μT, $\mathbf{B}_{AC}$(5,0,0) μT is a constant and alternating magnetic field. Three peaks A, B, C can be identified as Cl, Na, Ca and A'', B'', C'' as subharmonics (A' as harmonics of A).

A presented phenomenon is similar to the Hall effect. The Hall voltage is generated across the conductor perpendicular to both the direction of bulk current flow and to the magnetic field. A similar effect is observed for AC magnetic field. Ions are moving in accordance to current flow. The ion trajectory is very sensitive at the resonance to the relative direction DC and AC magnetic fields.

The comparison of trajectory calculations with the correlation dimension D2 is shown in Fig. 4. The ion identification was made according to m/q ratio. No identification was shown for frequency below 10 Hz. The mass of the ion in this frequency region is higher than 70 atomic mass units.

The haemoglobin with the mass 523 and charge 2^- can be identified as m/q = 523/2= 261.5 and for $\mathbf{B}_{DC}$ = 50 μT. The cyclotron resonance can be seen at about 3 Hz. It is described in Fig. 2 as H with a harmonics H'.

6. ICR mechanism in NaCl

The mechanism of Hall effect [13] at the ELF cyclotron resonance was tested in the solution of NaCl (p.a., 3 mole/L). Ions were moving in the NaCl solution according to the direction of X axis (current 2 mA) irradiated by alternating magnetic fields $\mathbf{B}_{AC}$(0,0,5) μT or $\mathbf{B}_{AC}$(0,0,45) μT and in the stable magnetic field $\mathbf{B}_{DC}$(10,0,37) μT.

During the time of 40 s the voltage V(t) was measured in Y direction perpendicular to X. For each frequency of magnetic field two runs were made (20s+20s). In the first run only oscillating magnetic field B_{AC} was present, the stable magnetic field was zero (± 0.5 μT). In the second run the constant magnetic field $\mathbf{B}_{DC}$(10,0,37) was turned on in the given phase of AC current. During the first period the voltage difference

V(1)-V(19) was calculated and in the second, the difference V(21)-V(40) was calculated (time (s) is in brackets). For the frequency of cyclotron resonance some difference between (V(1)-V(19)) and (V(21)-V(40)) was observed. This difference was measured in the random order of frequency, over 20 times for one frequency. Average values were plotted in Fig.3.

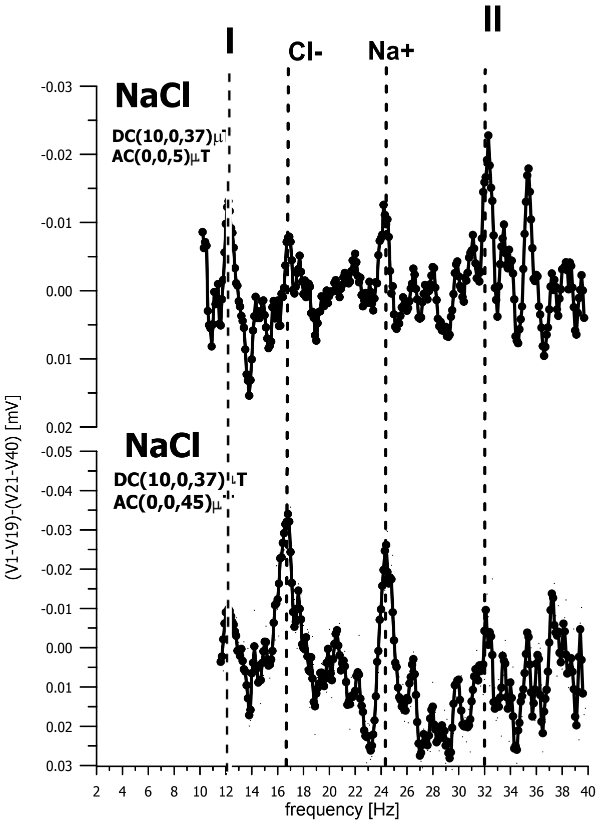

Fig. 3. ELF cyclotron resonance in NaCl for alternating magnetic field 5 μT (upper curve) and 45 μT (lower curve). Resonances for two ions: $^{35}Cl^{-}$, $^{23}Na^{+}$ are indicated by dotted lines. Lines I and II can be explained as ICR subharmonics of Na^{+} and harmonics of Cl^{-}.

Two curves were made for different AC magnetic fields: 5 μT and 45 μT. The amplitude of peaks depends on the AC magnetic field. In measurements for high AC magnetic field (45 μT, lower curve in Fig. 3), peaks at lower frequency have higher amplitude whereas for low magnetic field (5 μT, Fig. 3 upper curve) is reversed. For each ion, there exists a maximum in Hall voltage for different strength of AC magnetic field. In the mass range under consideration the maximum is between 0.5 and 50 μT.

7. The Earth DC and AC magnetic field

The Earth magnetic field model (IGRF) was used for calculating the geomagnetic field DC components at any point of space from the Earth's surface up to the Moon's orbit [14]. Upon specifying the year, day of the year, and universal time as input parameters, the model calculates elements of the Earth magnetic field (DC). It also updates the coefficients of spherical harmonic expansions, approximating the Earth's internal magnetic field. That field was computed in a dipole approximation with the length of expansions automatically controlled to maintain the assumed precision. In our case, every point on the Earth was estimated with a 5-degree precision.

One of the biggest electromagnetic resonance systems generating oscillating magnetic field AC on the Earth is the cavity formed between the Earth and its ionosphere. These phenomena are known as Schumann resonances [15]. Lightning discharges in billions of coulombs provide a broad frequency spectrum modified by the resonance properties of the earth-ionosphere cavity system. The Schumann spectrum contains broad maximum at frequency about 8 Hz, 14 Hz, 21 Hz etc. The spectrum of Schumann resonance shown in Fig. 4 depends on the relative position of discharge source and receiver. It can be calculated by electrical model of cavity designed by A. Kułak [15]. In calculations of ICR area only Schumann peak frequency and amplitude of AC magnetic field derived by model was taken with a resonance width of 0.4 Hz. Three zones of thunderstorm with similar activity (in Africa, Asia and S. America) were used in calculations.

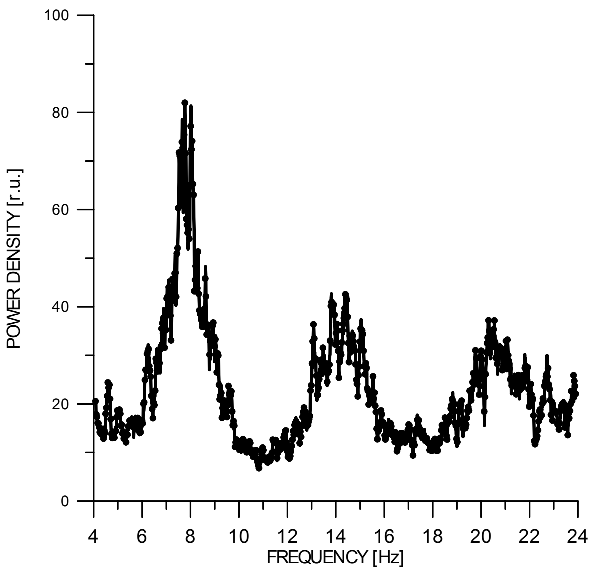

Fig. 4. Natural spectrum of Schumann resonance

8. Cyclotron resonance on the Earth

Variations of the Earth DC magnetic field and a frequency of AC Schumann resonance estimates a range of ions existing in cyclotron resonance conditions. They varied in m/e from 22 to 110. However, not all places on the Earth are under a cyclotron resonance (Fig 5).

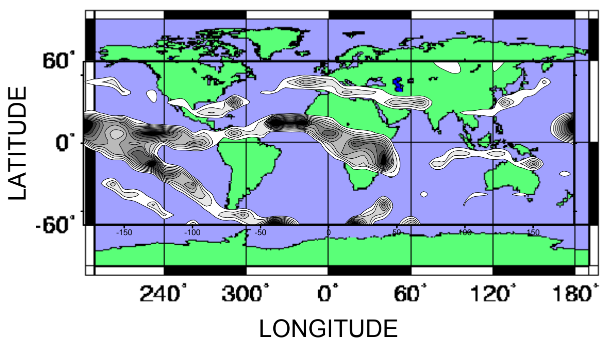

Fig. 5. Spatial distribution pattern of Cl^{-} cyclotron resonance on the Earth (m/q=35, 70 was used).

9. Comparison of ICR model with human activity

A set of data containing birth rates (number of births per 1000 people for over 210 countries was used for analysis (year 2002) [16]. Only Cl^- ions (A in Fig. 2) and a subharmonics (A'') in ICR were taken into calculations. Calculations of ICR indicate that average birth rate where cyclotron resonance is not observed is equal 21.3±1.8 whereas in resonance area it is 28.2±3.3. It means that in the countries with a cyclotron resonance the birth rate is higher by about 32% than in remaining countries. The birth rate may be sensitive to the amplitude of AC magnetic field of Schumann resonance. For 119 countries it is shown in Fig 6. The correlation coefficient between birth rate and AC magnetic field 0.386±0.12 is relatively high. For Africa the correlation coefficient is higher and equals 0.446±0.14.

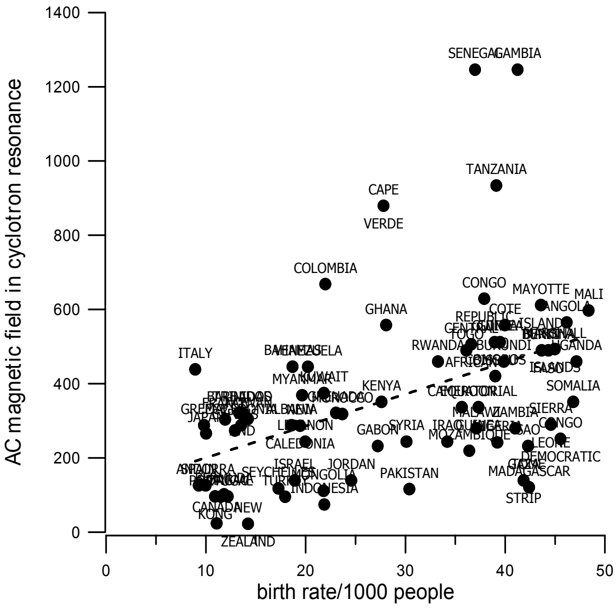

Fig. 6. Birth rate in different countries and amplitude of AC magnetic field from Schumann IRC on the Earth may indicate some relations.

Tab. 1. Average value of birth rate, death rate, population structure and radius of conflict in cyclotron resonance countries for Cl^- ions and out of ICR.

Averaged value data	{1} Countries under cyclotron resonance	{2} Countries free of ICR	{3} Ratio [1]/[2]	{4} Correlation coefficient in [1]
Birth rate	28.2 ±3.3	21.3 ±1.8	1.32	0.386 ±0.12
Death rate	11.5 ±1.5	9.12 ±0.8	1.26	0.227 ±0.12
Population Age >65 in %	6.55 ±0.82	7.75 ±0.68	0.85	-0.347 * ±0.11
Population Age <15 in %	34.71 ±4.37	29.8 ±2.63	1.16	0.371 ±0.11
HIV/AIDS Age 15-24	5.67 ±1.05	2.75 ±0.32	2.05	-0.131 ±0.18
Armed Conflict INT*R	732 ±100	410 ±150	1.78	0.365 ±0.1

* Correlation coefficient of population over 65 years of age has opposite sign than correlation for under 15. This is due to normalisation of each whole population to 100%.

Data set describing Armed Conflicts is taken from Dataset Book version "March 2004" [17] published by International Peace Research Institute, Oslo (PRIO) and Department of Peace and Conflict Research, Uppsala University. It defines intensity parameter INT of conflict and radius R of conflict. Intensity INT of conflict is defined as a two+one level assessment of the number of battle-related casualties per year in the conflict period covered by the observation, plus a special level indicating conflict history in low-intensity conflicts. The radius of conflict R assumes that all conflict areas are circles. Similarly Cl^- ion cyclotron resonance was assumed. The average value of INT*R for countries being in the cyclotron resonance conditions equals 732±100 whereas outside of resonance is 410±150.

Interesting results of HIV/AIDS events in a population in ages 15-24 [18] are seen in Table 1. The average value of HIV/AIDS in countries where we have ICR is higher (5.67) than in other places (2.75). However, no correlation between HIV/AIDS and the magnetic AC field is observed.

10. Conclusion

It is clear that biological effects of the Earth's magnetic field discussed above do not provide a clear answer to the question of whether ELF magnetic fields in cyclotron resonance conditions influence human activity. This is partly due to two problems: 1) Mechanism of ICR model for very low intensity magnetic field induced by Schumann resonance in a dense biological media is unknown, 2) Thermal fluctuations should destroy the weak biological effect of magnetic field conversion. Naturally occurring magnetic fields, which populations are exposed to, are 1-100 pT. The problem of low intensity demands non-linear and very sensitive model of ICR interaction.

Data of human activity are significant, because they refer to a whole population. However, exposure in ICR magnetic field may also be correlated with other factors such as social status. It is possible that we observe an indirect ion cyclotron resonance effect on humans by ELF electromagnetic field exposure of biological environment.

The Earth's DC magnetic field varies within a time and depends on the Sun's activity. The Sun's activity changes ELF wave propagation modulating the Schumann frequency spectrum. All these can affect human activity on the globe. This indicates that observed effect of ICR may depend also on the Sun's activity. Responsible for AC electromagnetic field Schumann resonance excitations called Q-bursts have approximately 1 second duration and typically occur every few minutes. The temporal characteristic of Q-bursts is carrying a specific code in the pulse shape according to the position of a source. However, the principal excitation mechanism of the Earth-ionosphere cavity is lighting occurring at a mean rate of approximately 100 strokes per second. They have a similar frequency spectrum as a Q-burst. An influence of electromagnetic pulses generated in the laboratory, similar to Q-bursts on heart rate has been observed [18]. The natural ELF electromagnetic field is a mixture of Q-burst and lighting. It varies according to the condition of the Earth-ionosphere cavity.

A nonlinear mechanism based on the quantum interference model developed by Binhi [19] can explain some nonlinearity of the transduction mechanisms involved in observed magnetobiological effect. However, the model works for 10-100 μT magnetic field and 10-100 Hz frequency band.

The cyclotron resonance model predicts the frequency of peaks in D2 HRV spectrum for Na^+, K^+, Ca^{2+}, Cl^- ions together with their harmonics (Fig. 2). Membrane transporters such as the Na^+-Ca^{2+} exchanger cause net ion movement across the cell membrane and may contribute to cellular activity automatically [20]. The major difference between cyclotron resonance condition and non-resonance condition lies in the charge distribution of irradiated media. The charge distribution generates the local potential. The potential perturbs ion flux and may cause profound changes in the metabolism of affected cells.

The present study carries considerable weight not only because of the large number of subjects in the whole population, but also because of relatively high correlation coefficient between AC magnetic field and birth rate reaching, for Africa, the value of 0.446±0.14.

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INFORMATYK *MODEL REZONANSU SHUMANN'A*	⟷	**EPIDEMIOLOG , SOCJOLOG** ANALIZA POPULACJI LUDZKIEJ W SKALI GLOBALNEJ