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THE RISKS OF EXTERNAL MODULATION OF ION SIGNALING, MEDIATED BY ELECTROMAGNETIC RADIATION FROM WIRELESS 5G COMMUNICATION TECHNOLOGY IN TRANSMITTING INFORMATION ABOUT BIOLOGICAL PROCESSES IN LIVING ORNANISMS

The widespread urbanization of the human environment has created numerous artificial sources of electromagnetic fields with which living organisms on our planet have to interact. Electromagnetic fields can cause both thermal and non-thermal effects on living organisms, with the non-thermal impact being primarily discussed in this review. Non-thermal effects include the potential influence on the exchange of secondary messengers (Ca2+, K+, Na+, and others) in the cells of living organisms, which may lead to unpredictable effects on biological processes involving these secondary messengers.

It is worth noting that 5G mobile technology, which utilizes millimeter waves and higher frequency bands ranging from 6 GHz to 100 GHz for communication, may exert a certain explicit influence on human health, associated with the information encoding processes transmitted in cellular processes. Research on high-speed THz communication systems is rapidly advancing using various frequency windows, such as 140 GHz and 240 GHz, due to low losses during propagation in the atmosphere. Being widely prevalent in the human environment, the radiation of such frequencies can and, obviously, will penetrate deep into the human body. This carries the risks of possible influence on ion exchange, particularly on calcium (Ca2+) oscillations, which play a part in numerous biological processes of the human body as a secondary messenger, ranging from cellular regeneration to synaptic neuronal activity and memory formation at both cellular and overall brain levels.

Additionally, there are not entirely groundless, but not fully proven, notions that motor neurons may be stimulated by non-ionizing radiation frequencies (which may result from the operation of cellular communication towers and redistributed by mobile phones) to the extent that they can engage brain frequencies capable of motivating cellular or neuronal actions. All of this is possible because a single calcium oscillation can carry an integrated signal, in which encoded information is directed simultaneously to several different processes, and certain resonance effects may exist that influence these oscillations and may disrupt them.

Key words: bioelectricity, secondary messengers, wireless transmission of signals and energy, 5G.

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РИЗИКИ ЗОВНІШНЬОЇ МОДУЛЯЦІЇ ІОННОЇ СИГНАЛІЗАЦІЇ, ОПОСЕРЕДКОВАНОЇ ЕЛЕКТРОМАГНІТНИМ ВИПРОМІНЮВАННЯМ ТЕХНОЛОГІЇ БЕЗДРОТОВОГО ЗВ'ЯЗКУ 5G ПІД ЧАС ПЕРЕДАЧІ ІНФОРМАЦІЇ ПРО БІОЛОГІЧНІ ПРОЦЕСИ В ЖИВИХ ОРГАНІЗМАХ

Повальна урбанізація навколишнього простору людиною створила безліч штучних джерел електромагнітних полів, із якими доводиться взаємодіяти живим організмам нашої планети. Електромагнітне поле може спричиняти термічний і нетермічний вплив на живий організм, і саме здебільшого нетермічний вплив обговорюється у цьому огляді. Нетермічний вплив включає у себе можливий вплив на обмін вторинних мессенжерів(Ca2+, K+, Na+ та ін.) у клітинах живих організмів, що може призвести до непередбачуваного впливу на біологічні процеси, у яких задіяні ці вторинні мессенжери.

Необхідно зазначити, що мобільна технологія 5G, яка використовує для зв'язку міліметрові хвилі та вищий діапазон частот від 6 ГГц до 100 ГГц та інші системи надшвидкісного бездротового зв'язку, може здійснювати певний явний вплив на здоров'я людини, пов'язаний із процесами кодування інформації, що передається у клітинних процесах. Дослідження високошвидкісних систем зв'язку ТГц швидко просуваються з використанням різних частотних вікон, таких як 140 ГГц і 240 ГГц, завдяки низьким втратам під час розповсюдження в атмосфері. Будучи широко розповсюдженим у середовищі існування людини, випромінювання таких частот може і, очевидно, буде проникати вглиб людського тіла. Це несе ризики можливого впливу на іонний обмін, зокрема на коливання кальцію (Ca2+), який бере участь у безлічі біологічних процесів людського тіла як вторинний месенджер, – від клітинної регенерації до синаптичної нейронної активності і формування пам'яті як клітинних процесів, так і загалом людського мозку. Також існують не до кінця безпідставні, але не повністю

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доведені думки, що моторні нейрони можуть стимулюватися частотами неіонізуючого випромінювання (які можуть бути результатом роботи веж стільникового зв'язку та перерозподіляються мобільними телефонами) настільки, що можуть залучати мозкові частоти, які можуть мотивувати клітини або нейронні дії. Усе це можливо тому, що одне коливання кальцію може нести інтегрований сигнал, у якому закодована інформація, спрямована одразу на декілька різних процесів, і можуть існувати певні резонансні ефекти, що впливають на ці коливання і можуть їх порушувати.

Ключові слова: біоелектрика, вторинні мессенжери, бездротова передача сигналів і енергії, 5G.

Introduction

Evolution of life on Earth has occurred in the presence of natural electromagnetic (EM) fields, primarily represented by geomagnetic and atmospheric influences. It is suggested that various behavioral aspects in biology, such as bird navigation during long-distance migrations, are synchronized with Earth's natural electromagnetic fields. Some scientists, for instance Abraham R. Liboff, even propose considering the geomagnetic field as an integral part of human life, introducing terms such as electrohormones and the magnetocrine system [1].

Over the past century, this natural electromagnetic environment has been disrupted due to the extensive influence of various artificial electromagnetic fields and radiation, which have acquired a wide and growing spectrum. Many new technologies, including induction cooktops or wireless transmission of energy and signals, generate electric fields (EF), magnetic fields (MF), or electromagnetic fields (EMF) within the intermediate frequency (IF) range.

Impact of external EF, MF and EMF on living organisms

Despite humanity's long-term use of electrical energy and reports of cancer cases in people living near power lines or working with them, which have been discussed for decades, the impact of magnetic, electric, and electromagnetic fields remains poorly understood. This lack of understanding has led to inconsistent or undefined classifications regarding the beneficial or harmful effects that fields or their combinations may exert [2].

While the impact of the field may be small in the short term, it can have a cumulative effect in the long term. Tracking such effects and specifically linking them to the influence EF, MF, and EMF is not straightforward. According to some studies, EF, MF, and EMF of moderate parameters themselves do not affect living organisms and their viability. However, they can lead to deregulation of cell signaling pathways dependent on specific ions, which in combination with cytotoxins can significantly impair cell viability more than without field influence, as demonstrated in a study by [3], where a combination of static and alternating MF with puromycin was applied to the U937 cell line, resulting in increased cell death probability. Moreover, the ionic response to the action of the alternating field is expected when the ratio of the applied signal frequency to the static magnetic field equals a certain ratio of ion charge to mass according to the hypothesis of ion-cyclotron resonance. Observations suggest that ion-cyclotron resonance effects can be induced by both EF and MF of much lower parameters compared to natural cellular conditions.

A broad impact of homogeneous static external EF is documented in many reports. A static EF can influence cell topology, elongating them to sense minimal gradients. Permanent molecular dipoles oriented in the external EF due to the arrangement of charges can create new fields [4]. In regions associated with active cell division during growth or healing processes, there are voltage gradients, the disruption of which leads to the disruption of the process itself.

Under the influence of strong external EF (0.1–0.15 MV/m for erythrocytes, protoplasts, and spheroplasts), the transmembrane potential of a cell can reach a certain critical value (1 V) and induce a conformational change in phospholipid molecules, resulting in the formation of numerous hydrophilic pores through the cell membrane, leading to its disruption and release of cellular contents [5]. This ability of EF to disrupt cells is applied in electroporation and is considered a convenient method for studying cancer cells. One of the most powerful sources of EF encountered by the average

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person is high-voltage power lines, and studies dedicated to identifying the harm they can cause reveal that their fields have a significantly lower magnitude (kV/m) [6] than that required for electroporation, remaining within the maximum restriction (5 kV/m) set by ICNIRP standards. However, as previously mentioned, numerous cases of cancer among individuals in close proximity to them have been reported, which is not surprising, as high-intensity EMF can induce significant voltages and currents in nearby conducting elements and, most likely, through as yet undetermined physical mechanisms, may affect ion exchange processes in the cell (possibly because the external EF affects the charge distribution, causing ions to move in the transcellular space, thus leading to ion-cyclotron resonance at certain frequencies, altering ion biological activity) and subsequent biological cascades in humans near high-voltage power lines.

It is worth noting that the electrical properties of cancer cells have also been investigated. It is known that cancer cells have altered ion composition, specifically: higher concentrations of sodium and chlorine and lower concentrations of potassium, calcium, zinc, and magnesium (as well as a greater amount of water) compared to healthy cells, which correlates with increased electronegativity of the extracellular surface, leading to a decrease in membrane potential [8].

The direct effect of MF on the human body is particularly probable, considering the existence of biogenic magnetic nanoparticles (BMNs) found in living organisms that can be controlled by externally applied MF [9].

Wireless 5G communication technology

As the means of high-speed wireless communication 5G involves electromagnetic waves of certain frequencies that propagate freely in the human environment, its potential impact on human health (and possibly on the further evolution of the human body) cannot be ignored. Electromagnetic radiation, including in the visible range, is actively researched for medical purposes, such as accelerating wound healing and regeneration. Importantly, the interaction of electromagnetic radiation occurs not only with the superficial layers of the body's skin but also at depths reachable for specific frequencies. This principle underlies non-invasive blood diagnostics methods and laser-stimulated reduction of hemoglobin complexes. Since the wavelength of 5G is greater than that of the visible range, it will penetrate deeper into the human body.

The existence of magnetic magnetite nanoparticles in the human brain has been known for some time, and importantly, their presence is due not only to external exposure but also to internal synthesis, which is evidenced by differences in the topology of their structures and chemical composition [10]. These nanoparticles are dispersed throughout the brain and are believed to participate in the brain's bioelectromagnetic processes overall and in the formation of long-term memory [11] in particular through the preservation of residual magnetization. In addition to cell membrane potential, the concentration of calcium ions in the cell is also associated with the formation of cellular and neuronal memory [12]. This concentration can change through the opening of ion channels under the influence of shear stress caused by the rotation of magnetic nanoparticles in an external magnetic field.

Calcium (Ca^{2+}) serves as an almost universal intracellular messenger controlling various cellular processes, including gene transcription, muscle contraction, and cell proliferation. Frequency modulation of Ca^{2+} oscillations provides an effective means of differentiating biological responses in the cell, both in health and disease. The amplitude of calcium oscillation over time is studied using spectral analysis methods, including Fourier transform [13]. These oscillation parameters represent signals targeting different processes simultaneously, each requiring different calcium concentrations and rates of change over time. It has been shown that cessation of calcium oscillations leads to cell death, while their initiation triggers certain life processes.

In recent reviews addressing the impact of 5G on living organisms [14], the results of studies on the effects of microwave radiation on cell proliferation processes, gene expression, and so forth,

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precisely those processes involving calcium oscillations, have been analyzed. It has been reported that some impact on animals and cells in vitro has been recorded in several cases; however, the lack of strict methodology may raise doubts about these results. Moreover, results obtained in rigorous studies have been contradictory. The lack of independent reproducibility of results also points to a lack of systematic study of the problem.

Nevertheless, it can be assumed that, similar to ion cyclotron resonance created by the action of a combination of static and alternating magnetic fields, there may be correlations in the relationships between the wavelength of electromagnetic radiation and the concentration of ions or their oscillation parameters determined during calcium signal encoding. Since the opposite has not been proven, the possibility cannot be ruled out that even minor disruptions in these signals may have noticeable consequences on cellular processes, especially long-term deviations that would be difficult to capture in a laboratory, and for which a cumulative effect may be significant.

Since calcium is involved in the processes of human memory formation [15] and synaptic neuronal activity, we cannot exclude the possibility of non-ionizing 5G radiation affecting human memory and cognitive function, which in turn may negatively impact human performance overall.

Conclusions

Mechanisms of survival and spatial orientation have evolved in insects, animals, and humans over millions of years and are directly or indirectly dependent on EMF of natural origin, as well as those artificially created by humans to improve their quality of life. Humanity is creating new progressive energy transmission technologies, such as mobile phone charging from a distance of meters away from the source (Mi Air Charge Xiaomi) or electric vehicle charging methods with devices placed directly under road surfaces, which could allow for charging a vehicle while parked or in motion (Electreon). These technologies operate on the principle of electromagnetic induction and involve prolonged exposure of humans to alternating MF.

Authors of scientific articles dedicated to the impact of external electromagnetic radiation on the life and health of living organisms in contact with it emphasize that this topic is under-researched and requires more systematic laboratory research aimed at studying the consequences of this impact.

5G is a highly beneficial technology, and it is predicted that it and subsequent generations will be closely woven into people's daily lives, so it is evident that since the risk is not excluded, but rather proven in several cases, the impact of 5G needs to be investigated more thoroughly, systematically, and without conflicts of interest.

However, undoubtedly, these studies should not be aimed at suppressing the development of human technologies due to their potential threat, but rather at considering the risks and improving technologies for the safe integration into human life and the Earth's biological diversity.

References

1. Liboff, A.R. (2019). ION cyclotron resonance: Geomagnetic strategy for living systems? *Electromagn Biol Med,* 38(2)*,* 143–148. https://doi.org/10.1080/15368378. 2019.1608234.
2. Thill, A., Cammaerts, M.C., & Balmori, A. (2023). Biological effects of electromagnetic fields on insects: a systematic review and meta-Analysis. *Reviews on Environmental Health.* https://doi.org/10.1515/reveh-2023-0072.
3. Wócik-Piotrowicz, K., Kaszuba-Zwoińska, J., Rokita, E., Thor, P., Chrobik, P., Nieckarz, Z., & Michalski, J. (2014). Influence of static and alternating magnetic fields on U937 cell viability. *Folia Medica Cracoviensia,* 54(4), 21–33.
4. Funk, R.H.W., Monsees, T., & Özkucur, N. (2009). Electromagnetic effects - From cell biology to medicine. *Progress in Histochemistry and Cytochemistry,* 43(4), 177–264. https://doi.org/10.1016/j.proghi.2008.07.001.

https://doi.org/10.32782/mathematical-modelling/2024-7-1-4

5. Morshed, B.I., Shams, M., & Mussivand, T. (2013). Electrical lysis: dynamics revisited and advances in on-chip operation. *Critical Reviews in Biomedical Engineering,* 41(1), 37–50. https://doi.org/10.1615/CritRevBiomedEng.2013006378.
6. Tourab, W., & Babouri, A. (2016). Measurement and Modeling of Personal Exposure to the Electric and Magnetic Fields in the Vicinity of High Voltage Power Lines. *Safety and Health at Work,* 7(2), 102–110. https://doi.org/10.1016/j.shaw.2015.11.006
7. Tripathi, S.R., Ben Ishai, P., & Kawase, K. (2018). Frequency of the resonance of the human sweat duct in a normal mode of operation. *Biomedical Optics Express*, 9(3), 1301. https://doi.org/10.1364/boe.9.001301.
8. Al Ahmad, M., Al Natour, Z., Mustafa, F., & Rizvi, T. A. (2018). Electrical Characterization of Normal and Cancer Cells. *IEEE Access,* 6, 25979–25986. https://doi.org/10.1109/ACCESS.2018.2830883.
9. Gorobets, O.Y., Gorobets, S.V., Polyakova, T., & Zablotskii, V. (2024). Modulation of Calcium Signaling and Metabolic Pathways in Endothelial Cells with Magnetic Fields. *Nanoscale Adv.* https://doi.org/10.1039/D3NA01065A.
10. Kirschvink, J.L., Kobayashi-Kirschvink, A., & Woodford, B.J. (1992). Magnetite biomineralization in the human brain. *Proceedings of the National Academy of Sciences of the United States of America,* 89(16), 7683–7687. https://doi.org/10.1073/ pnas.89.16.7683.
11. Martínez-Banaclocha, M.A., Bókkon, I., & Banaclocha, H.M. (2010). Long-term memory in brain magnetite. *Medical Hypotheses,* 74(2), 254–257. https://doi.org/10.1016/ j.mehy.2009.09.024.
12. Forrest, M.D. (2014). Intracellular calcium dynamics permit a Purkinje neuron model to perform toggle and gain computations upon its inputs. *Frontiers in Computational Neuroscience,* 8, 1–19. https://doi.org/10.3389/fncom.2014.00086.
13. Falcke, M. (2004). Reading the patterns in living cells —the physics of ca2+ signaling. *Advances in Physics,* 53(3), 255–440. https://doi.org/10.1080/ 00018730410001703159.
14. Karipidis, K., Mate, R., Urban, D., Tinker, R., & Wood, A. (2021). 5G mobile networks and health – a state-of-the-science review of the research into low-level RF fields above 6 GHz. *Journal of Exposure Science and Environmental Epidemiology,* 31(4), 585–605. https://doi.org/10.1038/s41370-021-00297-6.
15. Martinez-Banaclocha, M. (2020). Astroglial isopotentiality and calcium-associated biomagnetic field effects on cortical neuronal coupling. *Cells,* 9(2). https://doi.org/10.3390/cells9020439.

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