

## **How do health effects arise from electromagnetic fields?**

### **A summary of Panagopoulos et al. 2021**

Panagopoulos DJ, Karabarbounis A, Yakymenko I, and Chrousos GP (2021) Human-made electromagnetic fields: Ion forced-oscillation and voltage-gated ion channel dysfunction, oxidative stress and DNA damage (Review). *Int J Oncol* 59: 92; <https://www.spandidos-publications.com/ijo/59/5/92>

In a 2021 paper, Dr. Dimitris J. Panagopoulos, a biophysicist from the National Centre for Scientific Research in Athens, Greece and his team provide for the first time **a complete, plausible and precise biophysical/biochemical mechanism to explain the great number of experimental and epidemiological findings connecting human-made EMF exposure with DNA damage and related pathologies.**

The contents of the paper are as follows:

1. Introduction
2. Biophysical action of polarized/coherent EMFs resulting in voltage-gated ion channel (VGIC) dysfunction and disruption of cell electrochemical balance
3. Biochemical processes activated by irregular gating of VGICs, leading to DNA damage
4. Discussion

1. Introduction and 4. Discussion are not very technical and can be read fairly easily by non-specialists. Sections 2. and 3. are more technical and require some explanation.

What we want to do here is find answers to the following two questions (A. and B. below) in, as far as possible, non-technical language. (Apologies if it is TOO simple – we just want to ensure that as many people as possible will be able to understand this important work and the mechanism described in the paper. Please feel free to contact us if you think there are still parts that are hard to understand.)

A. Exactly how does the biophysical action of polarized/coherent EMFs result in voltage-gated ion channel (VGIC) dysfunction and disruption of cell electrochemical balance?

B. If we understand A., then how do the resulting biochemical processes lead on to health effects, both in humans and in animals?

Let's take a look at A.

Firstly, we have to explain a little about cell membranes and VGICs

All cells are contained within membranes. Cells also have inner membranes, such as around the mitochondria and Golgi apparatus, parts of the cell that perform important functions. These membranes have channels in them that allow ions to pass in or out of the cell (or mitochondria, etc.). (Ions are atoms or molecules with a net electrical charge – more about this later). The flow of ions in and out of the cell is necessary for the cell to maintain an appropriate electrochemical balance inside itself to allow life processes to continue smoothly (homeostasis – the state of steady internal, physical, chemical, and social conditions maintained by living systems).

As we will see later, if this balance is upset, it will very likely result in health effects for the whole body (and not necessarily just humans). These channels are known as VGICs (voltage-gated ion channels) because they are “voltage gated”. What this means is that the channels are not always open, but open and close in response to a voltage (charge) difference between the two sides of the membrane. As there are channels that allow ions to pass *into* the cell and also channels that allow ions to pass *out of* the cell, the cell can maintain its inner electrochemical balance by opening/closing the ingoing or outgoing channels. As the ions possess an electrical charge, allowing ions out of the cell will reduce the charge inside the cell until the charge across the membrane falls below that needed to hold the gate open, and so it closes (and vice versa for ingoing channels). This is a very elegant mechanism for maintaining the electrochemical balance in the cell, and our health depends on it.

What happens when the body is irradiated by a radio frequency electromagnetic field (RF EMF)?

It is well known that visible and infrared natural light cannot break chemical bonds, even though they have higher frequencies and intensities than human-made EMFs. (Observations of DNA damage and related pathologies as a result of human-made EMF exposures are therefore typically rejected as implausible.) However, DNA damaging events do take place at any time in the cells of any living organism due to a variety of events, such as exposure to ultraviolet radiation, natural radioactivity, or chemicals that are toxic to living cells, but efficient DNA repair mechanisms have evolved to provide protection.

So, what is it about human-made EMFs that is causing health effects? The authors say, “There must be a unique property of the human-made EMFs that makes them capable of inducing adverse biological/health effects and ionization, in contrast to natural infrared and visible light. This unique property is that human-made EMFs/radiation are totally polarized and coherent, meaning that they possess net electric and magnetic fields, apart from radiation intensity, which exert forces on any electrically charged (or polar) particle/molecule such as mobile/dissolved ions and charged macromolecules [large molecules, such as proteins] in any biological system.”

Additionally, the authors of the study note, “**Almost all human-made RF EMFs include extremely low frequency (ELF) components in the form of modulation, pulsing and random variability.** Thus, in addition to polarization and coherence, the inclusion of ELF is a common feature of almost all human-made EMFs.” (Emphases added) This is because the **low-frequency electric fields are the part of the signal that carries the information** to be transmitted.

Using known quantities, the authors show from first principles what happens to ions in or near the VGICs when they are irradiated by human-made EMFs. Very simply, when irradiated by human-made EMFs, ions oscillate. When they oscillate, they produce an electrical force that can cause the VGICs to open. Panagopoulos et al. call this an “**ion forced-oscillation mechanism for irregular gating of voltage-gated ion channels on cell membranes by polarized/coherent EMFs.**” This means that these EMFs are “bioactive”. Further, the authors found that “**the bioactivity of a polarized/coherent EMF is proportional to its intensity, inversely proportional to its frequency and doubles for pulsed fields,** meaning that the ELF/ULF [extremely low frequency/ultra low frequency] EMFs and even more the pulsing RF EMFs with ELF pulsations such as all wireless communications (WC) EMFs, are predicted to be the most bioactive [because lower frequencies are more bioactive and because bioactivity doubles for polarized/coherent EMFs]. This explains the recorded effects of purely ELF EMFs...and of modulated/pulsing/variable RF EMFs.” (Emphases added)

Similar numerical examples for magnetic fields “show that it is the electric field that seems to be the bioactive component of an EMF and not the magnetic field, in contrast to what has been considered before by health agencies. The magnetically induced electric field can also be bioactive in the case of ELF pulses of WC signals with short rise/fall times.”

The authors present a bioactivity diagram (Figure 1) showing the bioactive combinations of electric field intensity and frequency capable of inducing biological/health effects according to the ion forced-oscillation mechanism for dysfunction of voltage-gated ion channels in cells. Wi-fi and Bluetooth (10 Hz), power lines (50 Hz), 3G/4G, and DECT (digitally enhanced cordless communications) (100 Hz), and 2G (217 Hz) are all seen to be in the *bioactive region* of the diagram. (1 Hz [Hertz] is one cycle per second.)

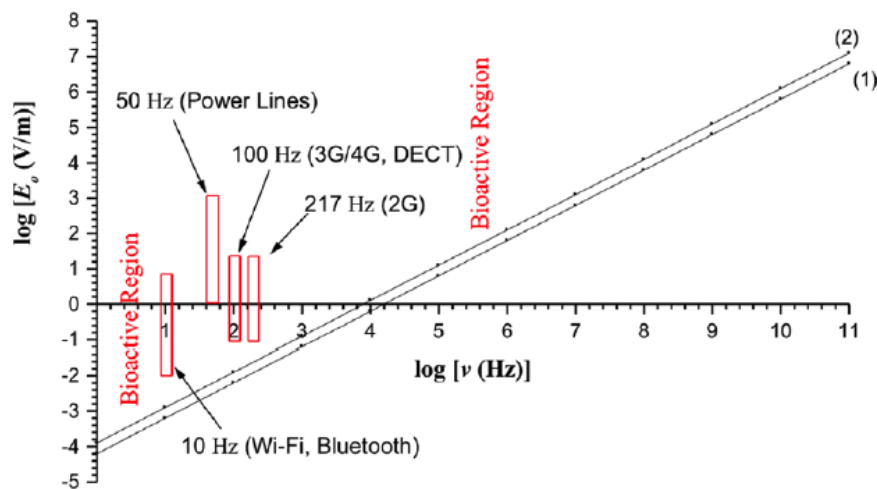


Figure 1. E-field bioactivity diagram showing the bioactive combinations of electric field intensity and frequency capable of inducing biological/health effects according to the ion forced-oscillation mechanism for dysfunction of voltage-gated ion channels in cells. The ELF electric fields of power lines, 2G/3G/4G MT, DECT, Wi-Fi and Bluetooth, are within the bioactive region (above lines 1 and 2). Line 1 refers to pulsed fields, such as the ELF pulsations of WC EMFs (Condition 10), while line 2 refers to continuous (non-pulsed) fields such as those from power lines (Condition 9).

Figure 1. E-field bioactivity diagram showing the bioactive combinations of electric field intensity and frequency capable of inducing biological health effects according to the ion forced-oscillation mechanism for dysfunction of voltage-gated ion channels in cells. The ELF electric fields of power lines, 2G/3G/4G MT, DECT, Wi-Fi and Bluetooth, are within the bioactive region (above lines 1 and 2). Line 1 refers to pulsed fields, such as the ELF pulsations of WC EMFs (Condition 10), while line 2 refers to continuous (non-pulsed) fields such as those from power lines (Condition 9).

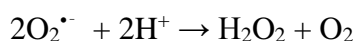
As described above, RF EMFs cause ions near or inside VGICs to oscillate and impose an electrical force on the VGIC gates sufficient to open them, thus allowing ions to pass through the gates. This alters ionic concentrations inside the cell, disrupting the electrochemical balance of the cell, leading to DNA damage.

This answers question A. Now we need to consider question B: If we understand A., then how do the resulting biochemical processes lead on to (human) health effects?

We need to look first at some very basic chemistry. An ion (an atom or molecule with a net electrical charge) is an atom (or in a molecule, one atom in the molecule) that is either “missing” an electron or has an “extra” electron. When the number of protons in the atom’s nucleus is equal to the number of electrons around it, the atom is in a stable state. I.e. it will not react easily with other atoms or molecules. When there are more protons than electrons, the ion will have a positive charge (i.e. it is a “cation” such as Calcium ( $\text{Ca}^{2+}$ )), and when there are more electrons than protons, the ion will have a negative charge (i.e. it is an “anion” such as a chloride ion ( $\text{Cl}^-$ )). The paper mentions sodium (Na, 11 protons), magnesium (Mg, 12 protons), chlorine (Cl, 17 protons), potassium (K, 19 protons) and calcium (Ca, 20 protons), among others.

The authors say that irregular gating of VGICs by oscillating polarized and coherent ELF EMFs ... has been verified experimentally for calcium ( $\text{Ca}^{2+}$ ), potassium ( $\text{K}^+$ ) and sodium ( $\text{Na}^+$ ) VGICs. This can alter intracellular ionic concentrations, disrupting the electrochemical balance (and homeostasis) of the cell, leading to DNA damage by oxidative stress (OS, an imbalance between production and accumulation of reactive oxygen species (ROS)), resulting in an overproduction of ROS.

The authors say, “Most ROS are free radicals. Free radicals are highly unstable molecules containing an unpaired electron [electrons usually “fly around” the nucleus in pairs], which is denoted by a dot ( $\cdot$ ), and have a tremendous tendency to chemically react with surrounding molecules and/or with each other in order to couple the unpaired electron and become stable. This is the reason why they have extremely short lifetimes. Most ROS react rapidly with surrounding biomolecules inducing chemical alterations. Overproduction of ROS in living cells due to EMF exposure has been reliably documented, with two important ROS found after EMF exposure being superoxide anion ( $\text{O}_2^{\cdot-}$ ) and nitric oxide ( $\text{NO}^{\cdot}$ ). These may result in hydroxyl radical ( $\text{OH}^{\cdot}$ ) and peroxynitrite ( $\text{ONOO}^-$ ) correspondingly, both of which ROS are very reactive with biological molecules and specifically DNA...  $\text{ONOO}^-$  may interact directly with DNA, as, similarly with  $\text{NO}^{\cdot}$ , it can be diffused everywhere in the cell. Superoxide anion radical ( $\text{O}_2^{\cdot-}$ ) is catalyzed by superoxide dismutase enzymes in the cytosol [the liquid part of the inside of cell] or the mitochondria and is converted to hydrogen peroxide ( $\text{H}_2\text{O}_2$ ):



$\text{H}_2\text{O}_2$  is a critical molecule in oxidative damage since it can move to any intracellular site (including the nucleus), where it can be converted to the most potent,  $\text{OH}^{\cdot}$ , which can damage any biological molecule, including DNA.

“DNA damage by ROS leading to mutations and disease has been well studied. Pall, in a review of EMF-bioeffects studies with calcium channel blockers, noted a connection between voltage-gated calcium channels (VGCCs) and NO<sup>\*</sup>/ONOO<sup>-</sup> overproduction. This verified earlier observations of EMF-induced effects on intracellular calcium concentrations, and the unique role of VGCCs.”

The above is sufficient to answer question B. It is also significant that this damage occurs even **at levels of exposure significantly below** those permitted by international standards. The remainder of the paper continues in a similar way, providing much more detail.

The burgeoning range of devices in our environment surrounds us with electromagnetic fields, which include ELF fields emitted by powerlines, wiring, electric meters, appliances and so on; as well as RF fields from cellphones, Wi-Fi, tablets and other mobile communication devices and infrastructure.

Based on decades of research on health problems associated with exposure to these fields, the International Agency for Research on Cancer (IARC) has classified both fields as Class 2B possible carcinogens. Low-frequency fields are known to be linked with childhood leukemia, and high-frequency, with brain tumors and skin cancer. Either can cause damage such as cancer, genetic damage, infertility and the cluster of symptoms including headaches and insomnia known as electromagnetic illness or radiowave sickness. The paper by Panagopoulos et al. described here documents exactly how EMFs cause health effects by one known mechanism, and there are arguably other mechanisms in play as well.

The aim of this summary has been to give non-technical readers an explanation of why EMFs result in health effects by summarizing the mechanism described in Panagopoulos et al.'s paper in easily understood language. The reader is encouraged to read the whole paper to see the rich detail, including hundreds of references, the authors have amassed to back up the validity of their mechanism.

(by LEN members)

The authors referred to the article “New insights: the damaging field” on the EMR Australia website while writing this summary. The article can be seen at:

[https://emraustralia.com.au/blogs/news-1/new-insights-the-damaging-field?\\_pos=1&\\_sid=b83a645f4&\\_ss=r](https://emraustralia.com.au/blogs/news-1/new-insights-the-damaging-field?_pos=1&_sid=b83a645f4&_ss=r)