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Workshop: "Electro-Hyper-Sensitivity: The State of Science"

**Man-made Electromagnetic Fields (EMFs),
Voltage-Gated Ion Channel (VGIC) dysfunction in cell membranes,
Oxidative Stress (OS),
DNA damage and related pathologies**

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Abbreviations

DECT: Digitally Enhanced Cordless Telecommunications. E-field: Electric field. EHS: Electro-hypersensitivity. ELF: Extremely Low Frequency. EM: electromagnetic. EMF: Electromagnetic Field. EMR: Electromagnetic Radiation. GSM: Global System for Mobile telecommunications. HPBL: Human peripheral blood lymphocyte. LF: Low Frequency. MT: Mobile Telephony. MW: Microwaves. OS: Oxidative Stress. RF: Radio Frequency. ROS: Reactive Oxygen Species. SAR: Specific Absorption Rate. ULF: Ultra Low Frequency. UMTS: Universal Mobile Telecommunications System. VGIC: Voltage-Gated Ion Channel. VLF: Very Low Frequency. WC: Wireless Communication. Wi-Fi: Wireless Fidelity. 1G/2G/3G/4G/5G: First/Second/Third/Fourth/Fifth Generation of MT.

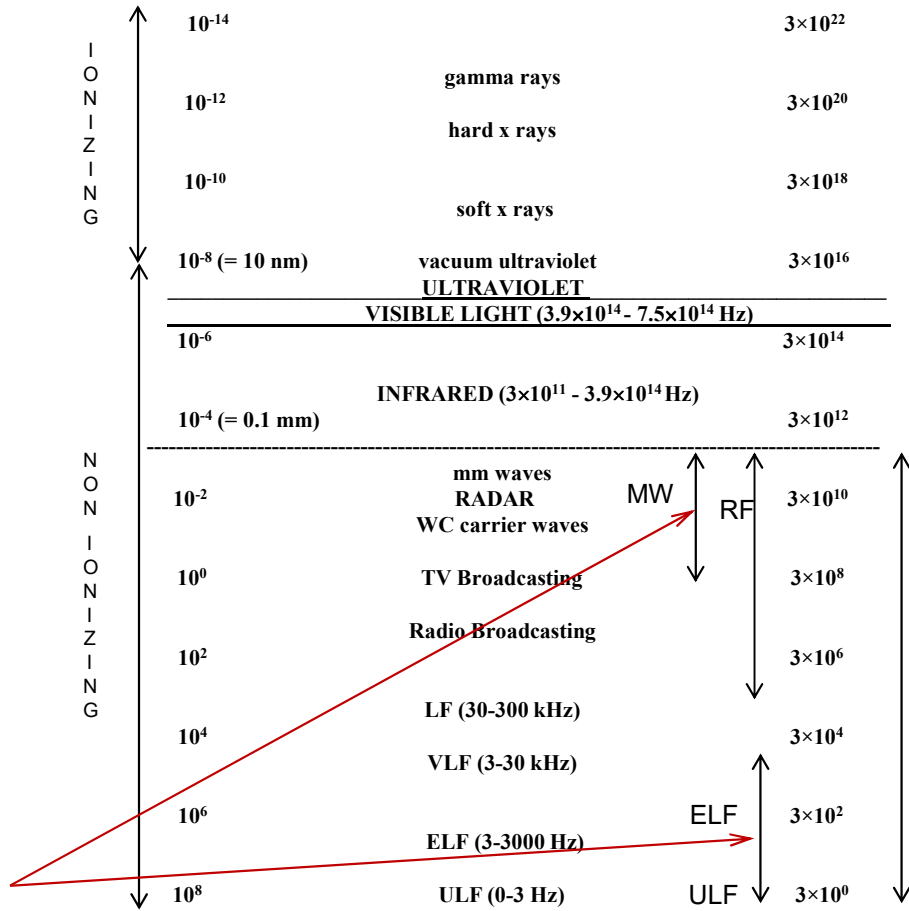
ELECTROMAGNETIC SPECTRUM

WAVELENGTH λ (m)

FREQUENCY ν (Hz)

I
O
N
I
Z
I
N
G

N
O
N
I
O
N
I
Z
I
N
G



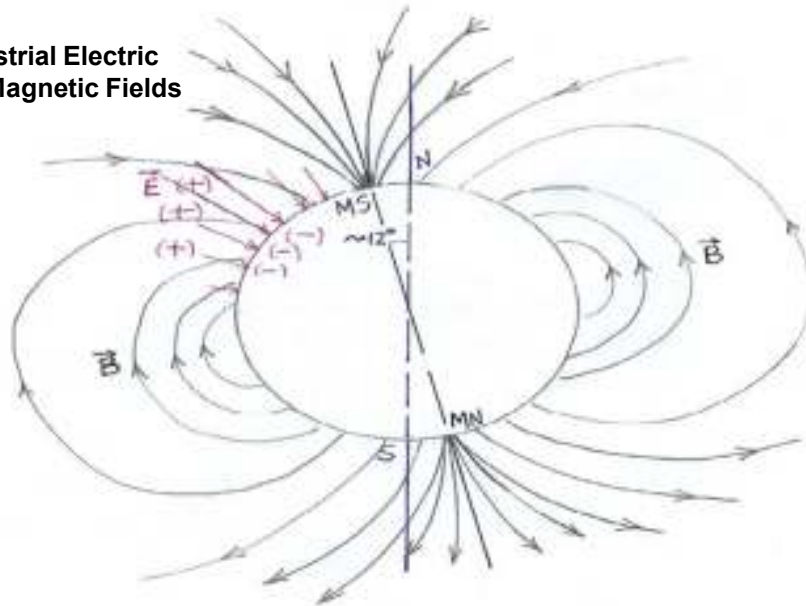
**Wireless Communication (WC)
EMFs (2G-3G-4G-5G Mobile
Telephony-MT, Wi-Fi, DECT, etc)**

**Man-made
EMFs**

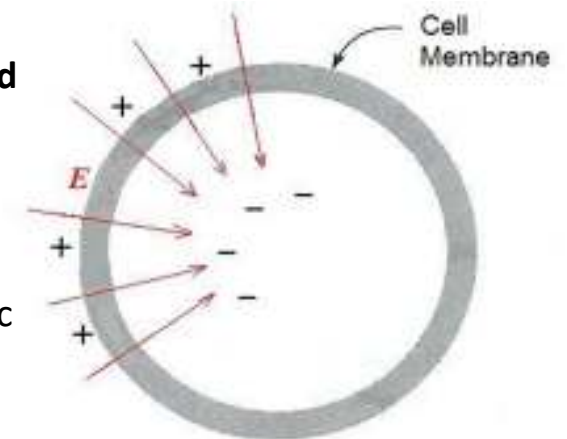
Natural Environment is Electromagnetic (EM) Life is Electromagnetic

All living Organisms have EM Nature (endogenous E-fields in cells/tissues, nerve impulses, brain and heart oscillations, etc.), and live within a Natural EM Environment (terrestrial and atmospheric EMFs)

Terrestrial Electric and Magnetic Fields

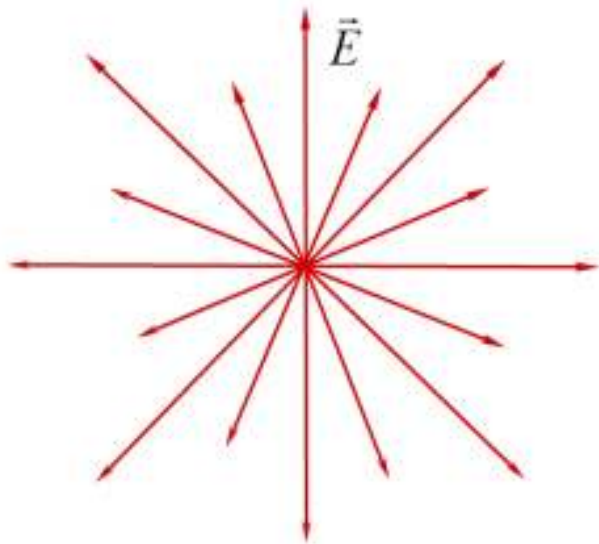


Both terrestrial and cell membrane fields are static and locally polarized, in contrast to the majority of natural EMFs which are oscillating and non-polarized (Schumann oscillations, cosmic microwaves, light, gamma radiation, etc.).
Intensity variations by 20-30% in these fields initiate biological/health effects



Endogenous EMFs in living organisms are in constant interaction with External Natural EMFs [brain oscillations are triggered by the atmospheric (Schumann) oscillations]

Inevitably, Man-Made EMFs interact with Endogenous EMFs in all organisms, and they may distort the biological functions controlled by them



Non-polarized EMF



Polarized EMF

All Man-made EMFs are totally Polarized and Coherent

Natural EMFs are never totally polarized

Terrestrial and Cell Membrane E-fields are locally polarized and static

Unique properties of polarized and coherent (man-made) EMFs

1. They can produce constructive interference and amplify their intensities at certain locations
2. They force all charged particles (e.g. mobile ions) in living cells/tissue to oscillate in parallel and in phase with them

Polarization and Coherence is The reason why EMR $\sim 0.1 \text{ mW/cm}^2$ from a mobile phone is damaging, while solar EMR $\sim 10 \text{ mW/cm}^2$ (100 times stronger) is vital.

[Panagopoulos et al, (2015a): Polarization: A Key Difference between Man-Made and Natural EMFs, in regard to Biological Activity, *Nature, Scientific Reports*, 5, 14914]

Important Observation:

Intensity variations of the order of 20-30% in natural static and polarized/coherent EMFs (terrestrial electric and magnetic fields, cell membrane electric fields) induce cellular/health effects.

Important Suggestion:

Biological/Health Effects initiate when Polarized and Coherent EMFs undergo variations of $\geq 20-30\%$ of their normal intensities

Now, All Man-made EMFs are totally polarized and coherent, and

All Wireless Communication (WC) EMFs are highly variable with unexpected changes exceeding by more than 100% their normal average intensities.

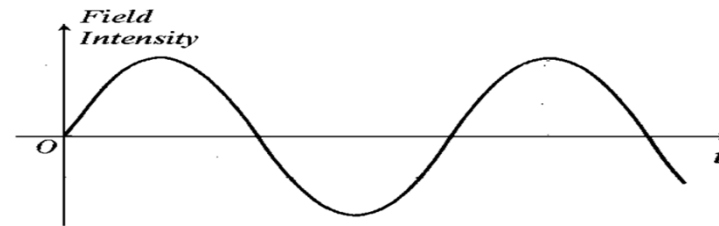
The vast majority of biological/health effects of all man-made EMFs at environmental intensities are NON-THERMAL (they are not accompanied by any significant tissue temperature increases)

[Panagopoulos DJ, (2019a): Comparing DNA Damage Induced by Mobile Telephony and Other Types of Man-Made Electromagnetic Fields. *Mutation Research Reviews*, 781, 53-62.]

Main Sources of EMF pollution



1. High –Voltage Power Line EMFs (50-60 Hz: ELF)

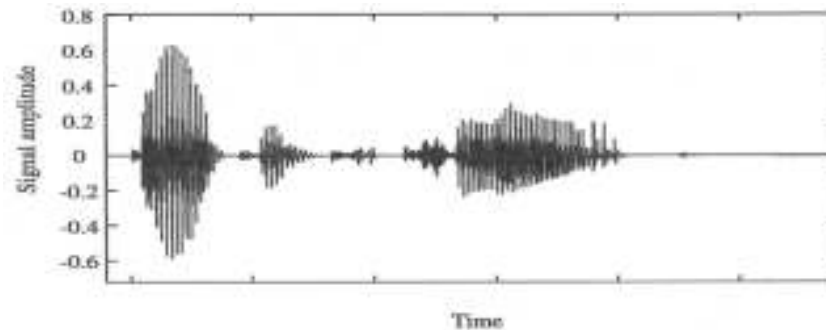


Continuous-wave
ELF EMFs

Increased Cancer Risk is found in epidemiological studies for **Distances up to 600 m** ($E= 10 \text{ V/m}$, $B=2 \text{ mG}$)

2. WC EMFs (2G-3G-4G-5G Mobile Telephony-MT, Wi-Fi, DECT, etc)

They all combine RF/microwave carrier frequencies with ELF/ULF (0-3000 Hz) EMFs in the form of pulsing, modulation, and random variability



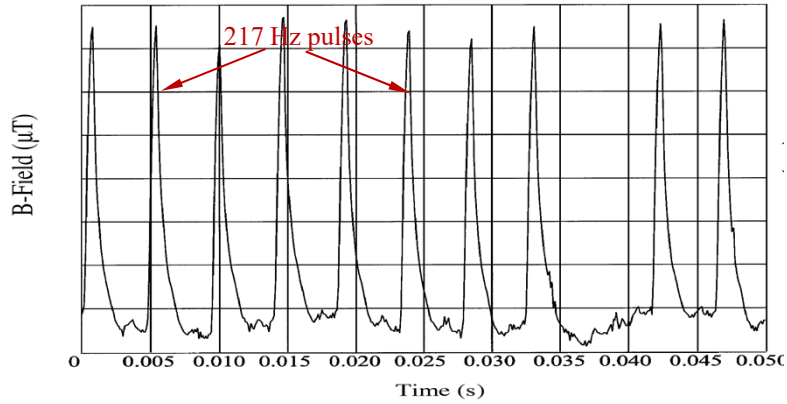
Pulsing RF EMFs with
ELF/ULF pulsation,
modulation, variability

The non-thermal biological effects of WC EMFs are due to the included ELF/ULF EMFs
(Panagopoulos 2023)

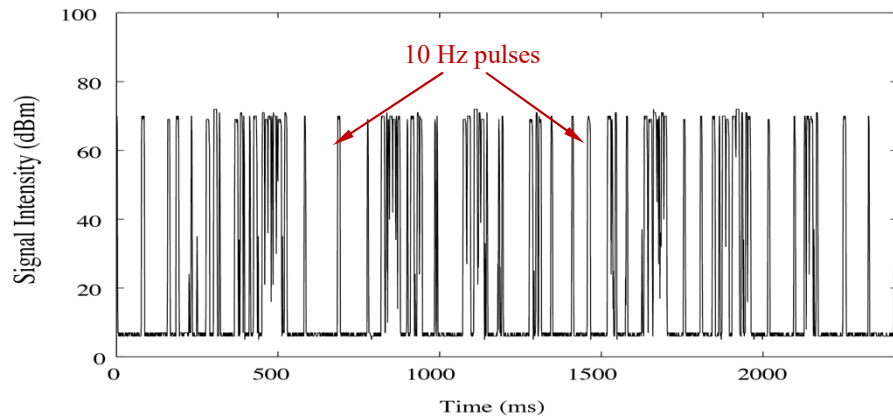
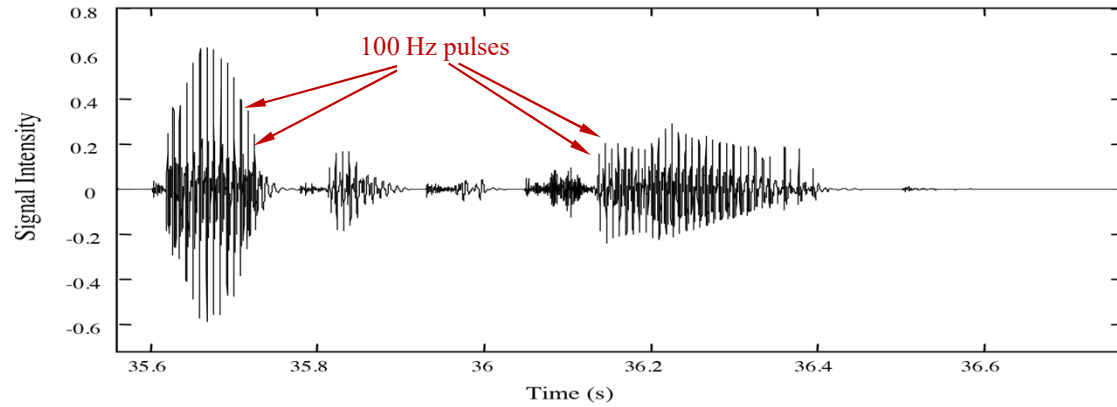
ELF/ULF Pulsation and Variability of WC signals

[Figures from Panagopoulos (2023)]

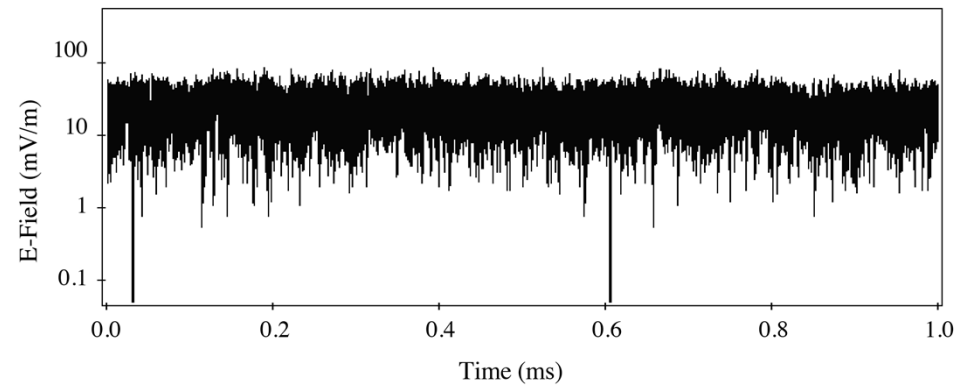
2G 217 Hz pulses



3G/4G 100 Hz pulses



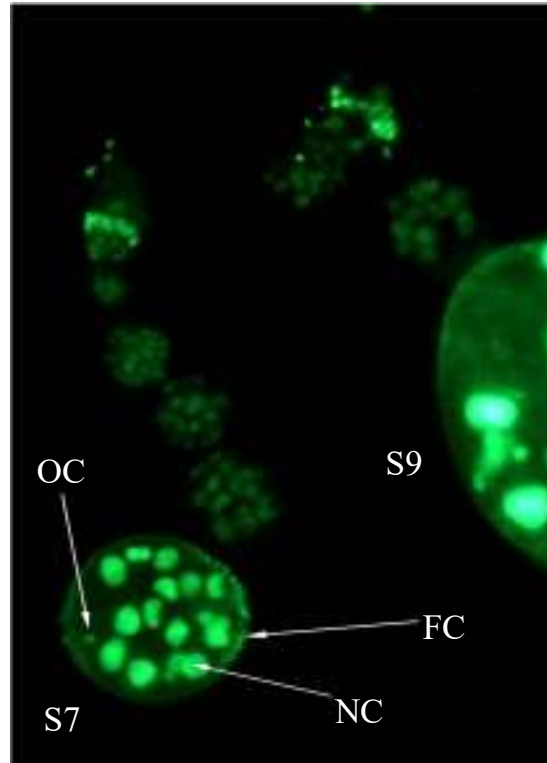
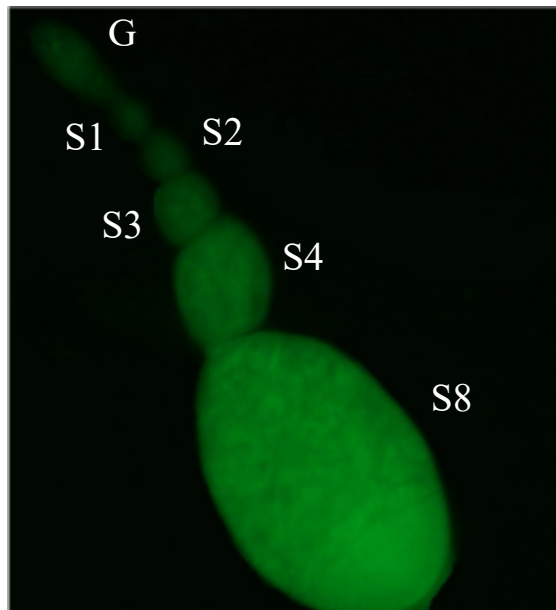
Wi-Fi 10 Hz pulses



Variability of a WC signal

DNA Fragmentation in fruit fly ovarian cells after Exposure to WC EMFs

TUNEL-negative
fluorescent picture of an
ovariole of a Sham-
Exposed female insect,
containing egg chambers
from germarium (G) to
stage 8 (S8), with no
DNA fragmentation.



TUNEL-positive
fluorescent picture of
ovarioles of female
insects Exposed to 2G
(GSM) MT EMFs,
displaying DNA
fragmentation in all
developmental stages
during early- and mid-
oogenesis, and in all
three types of egg
chamber cells:
Nurse cells (NC),
Follicle cells (FC),
Oocyte (OC)

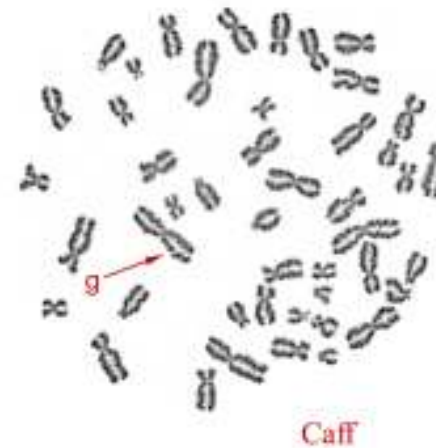
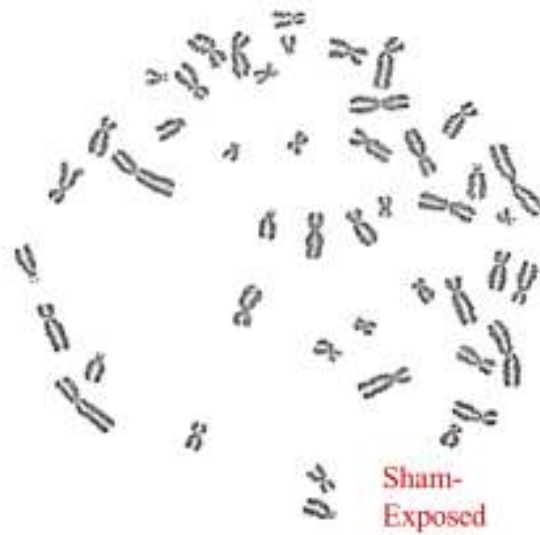
Panagopoulos et al, (2007): Cell Death induced by GSM 900MHz and DCS 1800MHz Mobile Telephony Radiation, *Mutation Research*, 626, 69-78.

Panagopoulos et al, (2010): Bioeffects of Mobile Telephony Radiation in relation to its Intensity or Distance from the Antenna, *Int J Rad Biol*, 86(5), 345-357.

Chromatid gaps (g) and breaks (b) in human cells after Exposure to WC EMFs and/or an extreme Caffeine dose

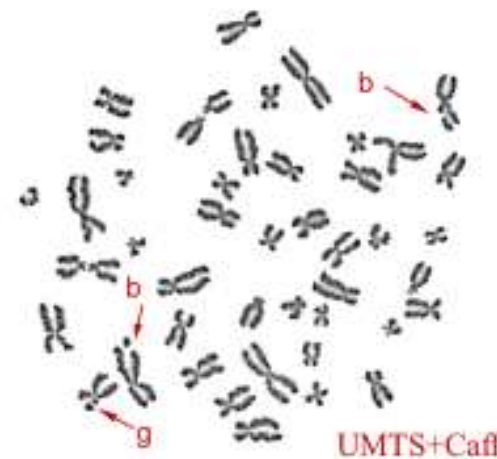
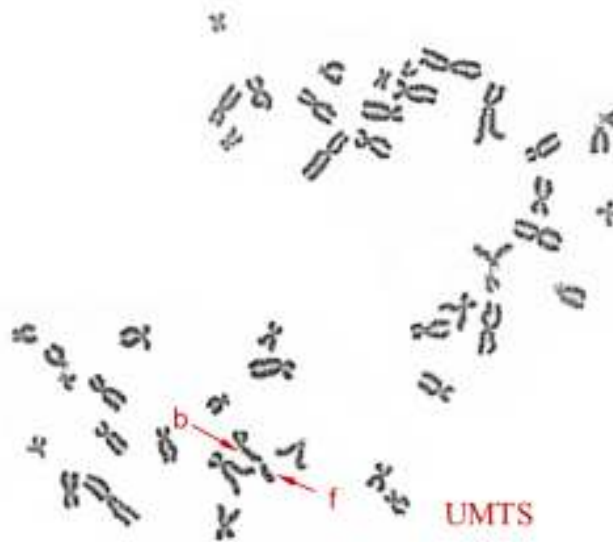
[From Panagopoulos (2019b; 2020)]

Unexposed
human
peripheral
blood
lymphocyte
(HPBL)



HPBL exposed
to Caffeine
dose ~ 290
times greater
than the
permitted
dose for an
adult human

HPBL exposed
to UMTS
(3G/4G) EMF
~ 136 times
below the
latest ICNIRP
(2020) limit



HPBL exposed
to the
combination
of UMTS
(3G/4G) EMF
and Caffeine

Experimental Result:

Real-life WC EMFs are significantly more damaging than other types of man-made EMFs (Panagopoulos 2019a)

~ 65-70 % of all peer review published studies with WC EMFs find effects

Among studies with Simulated Exposures

(as suggested by health authorities):

~ 50% find effects

Among studies with Real-life Exposures:

more than 95% find effects

Important Observation:

**Except for Polarization/Coherence, Intensity, ELF, Duration of exposure,
the Variability of WC EMFs is an important Bioactive Factor**

Panagopoulos DJ, Johansson O, Carlo GL, (2015b): Real versus Simulated Mobile Phone Exposures in Experimental Studies, *BioMed Research International*, 2015:607053.

Panagopoulos DJ, (2019a): Comparing DNA Damage Induced by Mobile Telephony and Other Types of Man-Made Electromagnetic Fields. *Mutation Research Reviews*, 781, 53-62.

Existing Exposure Guidelines based on ICNIRP recommendations provide No Protection

[Table from Panagopoulos (2023)]

Threshold EMF/EMR intensities for indicative biological/health effects and corresponding ICNIRP (2020) limits

Incident EMF	ICNIRP Intensity limit (6 min average, local exposure)	Threshold Intensity for effect initiation	Exposure Duration	Effect	Reference
ELF-E (CW or pulsed) (1-50 Hz)	5000 V/m	0.002 V/m	12 h	Decrease in protein synthesis rate	McLeod et al (1987)
		0.0021 V/m	4 days	Increase in DNA synthesis rate	Cleary et al (1988)
		10 V/m	years	Cancer (humans)	Coghill et al (1996)
ELF-B (50 Hz CW)	2 G (200 μ T)	0.002 G (0. 2 μ T)	years	Cancer (humans)	Feychting and Ahlbom (1994)
Pulsed RF (GSM) 1800 MHz	3655.6 μ W/cm ²	< 1 μ W/cm ²	6 min/day, 6 days	DNA damage, cell death (fruit fly ovarian cells)	Panagopoulos et al (2010)
Pulsed RF (GSM) 900 MHz	2014.0 μ W/cm ²	0.25 μ W/cm ²	158–360 h intermittently	OS, DNA damage, embryonic death (bird embryos)	Burlaka et al (2013)
Pulsed RF (GSM) 1800 MHz	3655.6 μ W/cm ²	0.32 μ W/cm ²	19 days (48s On/12s Off)	OS, DNA damage, embryonic death (bird embryos)	Yakymenko et al (2018)

Explanation of the Genotoxic Action of the Polarized and Coherent (man-made) Oscillating EMFs

Genetic Damage due to man-made EMF Exposure is found to coexist with **Oxidative Stress (OS)** and it is apparently due to OS (Yakymenko et al 2016; Yakymenko and Tsybulin 2022)

Polarized/Coherent and Oscillating/Varying EMFs cause **irregular opening and closing of Voltage-Gated Ion Channels (VGICs)** in cell membranes (Panagopoulos et al 2000; 2002; 2015a; 2021)

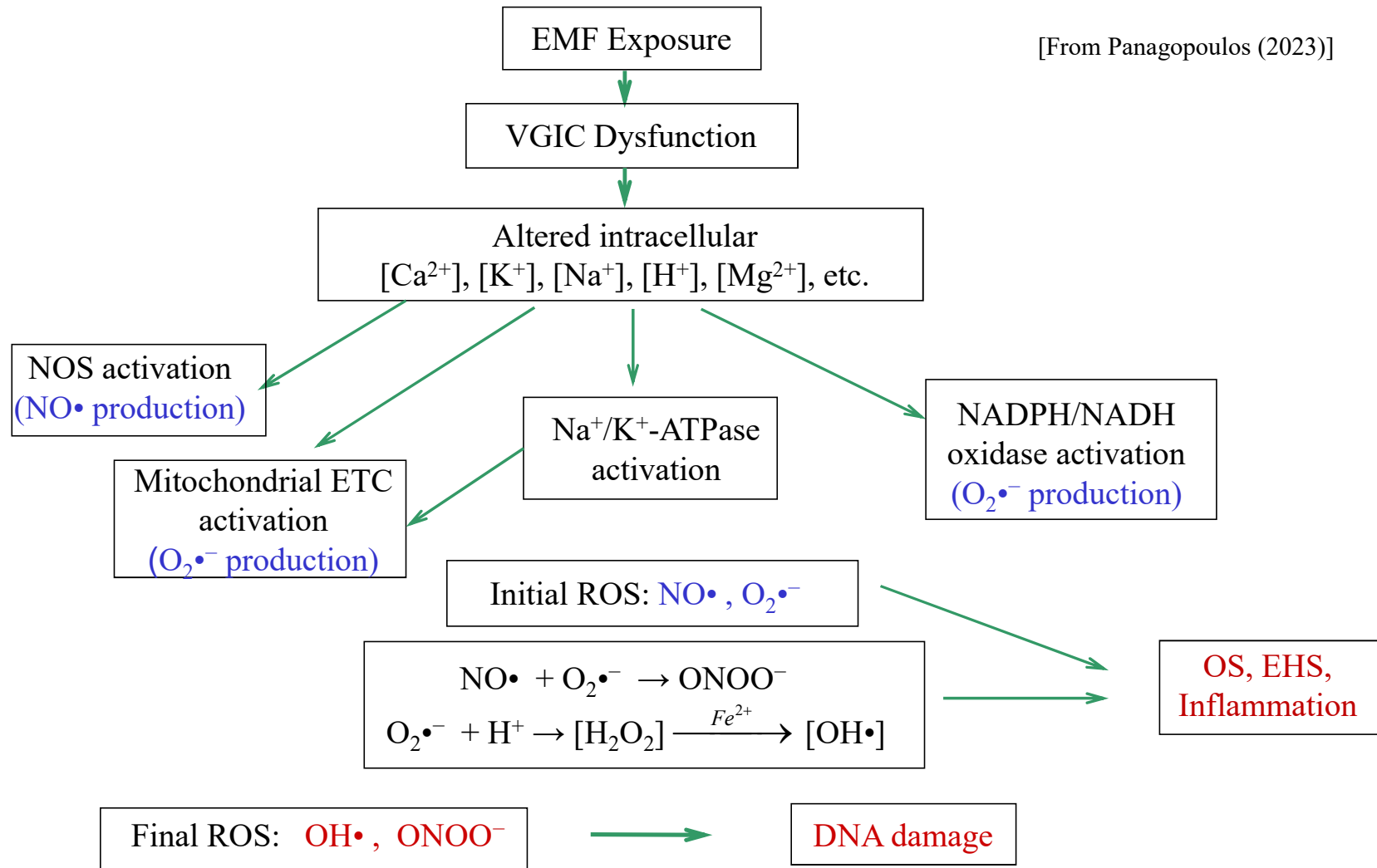
The induced **VGIC dysfunction alters the normal ion concentrations** within the cell. This disrupts the cell's electrochemical balance and homeostasis, and the redox status of the cell.

This causes **(over)production of Reactive Oxygen Species (ROS) and creates OS** within the cell. Initial ROS are the superoxide anion free radical ($O_2\bullet^-$), and the nitric oxide free radical ($NO\bullet$) (Panagopoulos et al 2021)

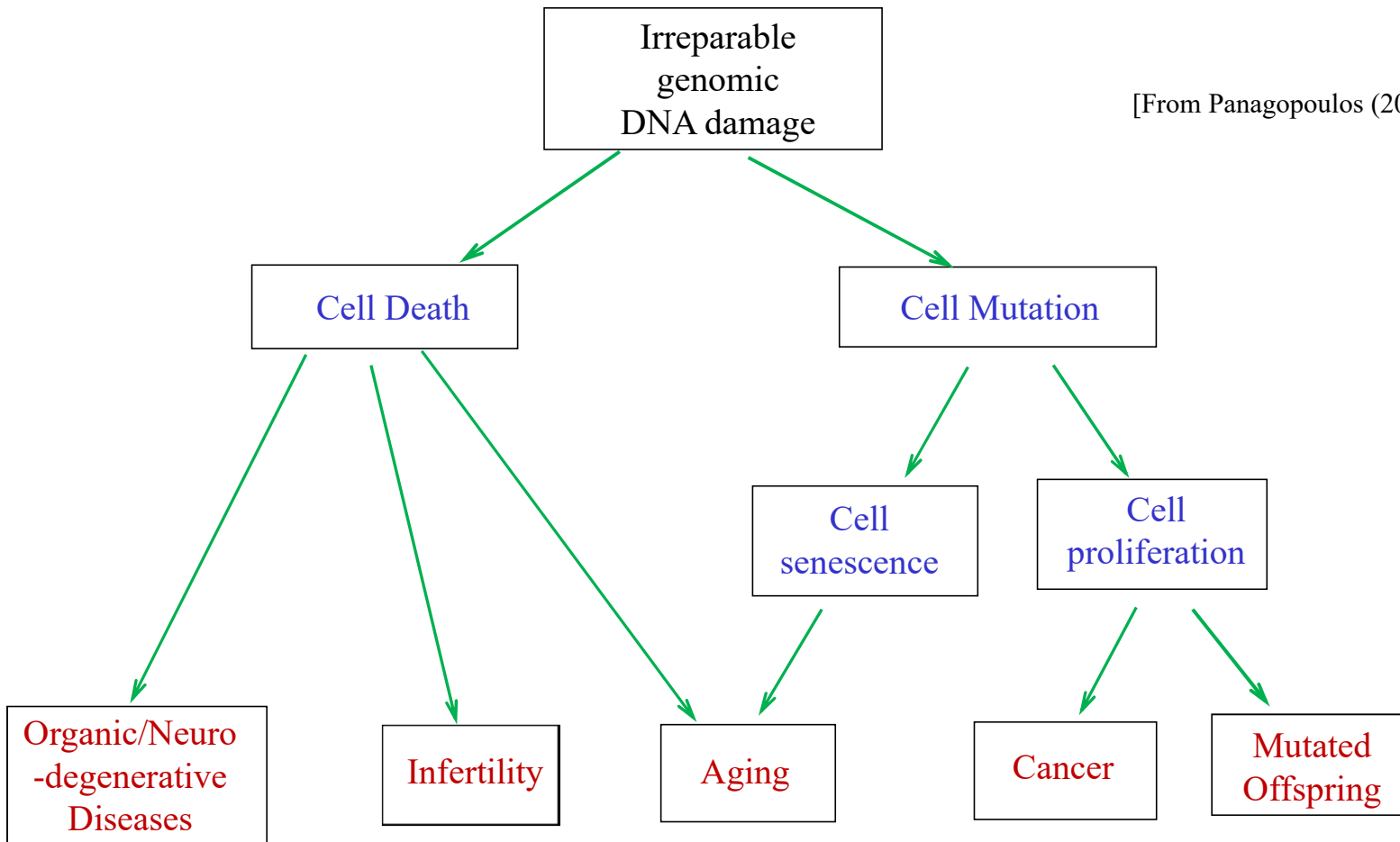
EHS is also connected with chronic OS and tissue inflammation (De Luca et al 2014; Irigaray et al 2018; Belpomme and Irigaray 2022)

The initial ROS can be converted into the most powerful ROS hydroxyl free radical ($OH\bullet$), and peroxynitrite ($ONOO^-$) which are finally those that damage DNA and other critical biomolecules

[From Panagopoulos (2023)]

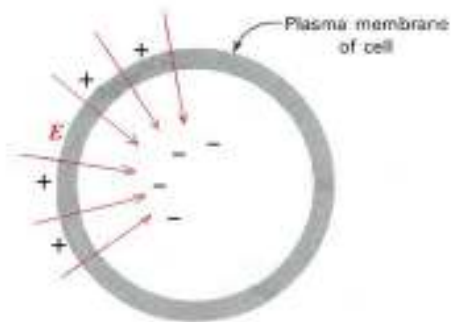


[From Panagopoulos (2023)]

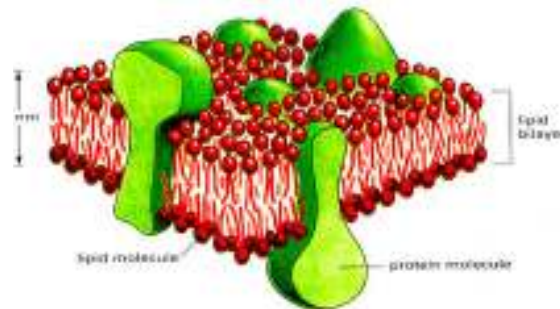


Cell Membranes and Voltage-Gated Ion Channels (VGICs)

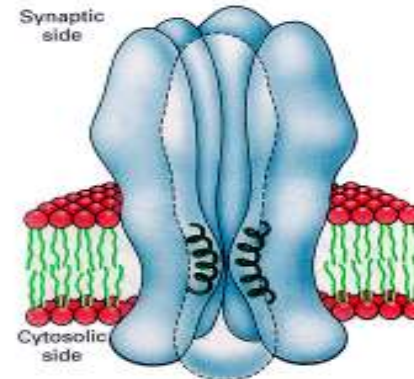
Across all cell membranes there is a strong Electric field, mainly determined by free ion concentration differences between the two sides of the membrane



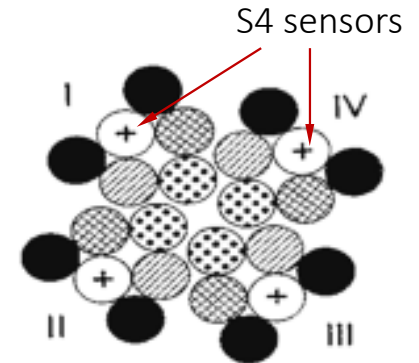
Cell Plasma Membrane and its electric field



Cell Membrane structure



Ion Channel structure



VGIC cross-section and the positively charged S4 helices (voltage-sensors) (Noda et al 1986)

Most Cation Channels in cell membranes are **“Electro-sensitive”** or **“Voltage-Gated” (VGICs)**.

They open or close by electric forces on their voltage-sensors exerted by changes in the transmembrane voltage $\partial V \geq 30 \text{ mV}$.

The voltage sensors are four symmetrically arranged, transmembrane, positively charged α -helices, each one called **S4**

“Ion Forced-Oscillation and VGIC Dysfunction (IFO-VGIC) mechanism”

(Panagopoulos et al 2000; 2002; 2015a; 2021)

Theory's Main Points

- **Forces** exerted by the external field **on the mobile ions** around cell membranes and within VGICs
- **Mobile Ions are Forced to Oscillate** in parallel and in phase with the oscillating polarized EMF
- Oscillating Ions exert **Constructive Forces on the S4 sensors of the VGICs**
- These forces are **similar to those exerted by changes ≥ 30 mV in the membrane voltage** that physiologically open/close VGICs
- This causes **Irregular opening/closing (dysfunction) of VGICs**
- This causes **Disruption of cell's electrochemical balance and ROS overproduction** in the cell

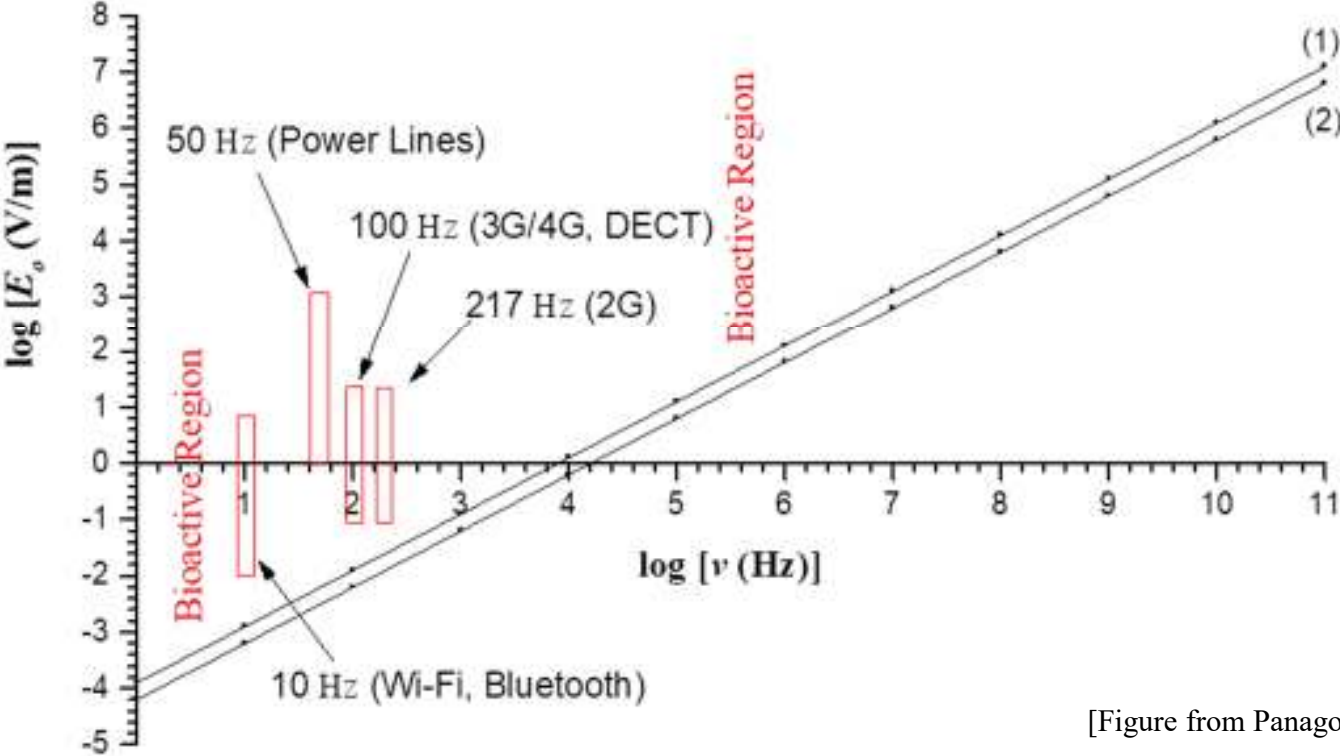
Theory's Predictions

The Bioactivity of Polarized/Coherent and Oscillating EMFs is proportional to the Intensity (E), inversely proportional to the Frequency (ν), and doubles/multiplies for pulsed/varying EMFs

$$EMF \text{ Bioactivity} = \frac{E_o z q_e}{\beta \omega} = k \cdot \frac{E_o}{\nu}$$

- 1. The Higher the Intensity the more bioactive the EMF**
- 2. The Lower the Frequency the more bioactive the EMF** [This explains the experimental data indicating that ELF EMFs are the most bioactive, and that the biological action of RF/Microwave fields is due to their ELFs (pulsing, modulation)]
- 3. Pulsing and Variability multiply the bioactivity.** [This explains the higher bioactivity of pulsed and/or modulated EMFs compared to continuous and/or non-modulated corresponding EMFs reported in many experiments]
- 4. The Electric and not the Magnetic part of an EMF is the most bioactive factor** [in contrast to what was considered by health agencies and most experts]

E-Field Bioactivity Diagram



[Figure from Panagopoulos (2023)]

Protective Suggestions

Avoid any unnecessary exposure to man-made EMFs.

Avoid living close to any antennas or high-voltage power lines

Mobile Phones: 1) Make use of the loudspeaker or air-tube headsets and keep the handset $\geq 40\text{-}50$ cm from the body, 2) Minimize number and duration of calls, 3) Do not carry the device in your hands or on your body while it is On. Set it to airplane mode, 4) Keep it at the greatest possible distance (several meters) at home/work, 5) Turn it off during sleep.

Use Wire Connections for Domestic Phones and Internet

Disable Wi-Fi and Bluetooth from Cars and Devices (mobile phones, printers, etc.)

Educate parents and pregnant women not to expose embryos and kids (possible correlation with autism and autoimmune diseases need to be carefully investigated)

Avoid permanent and complete Shielding as this may cause internal desynchronization (Wever 1979; Panagopoulos and Chroussos 2019)

Urgent Need for drastic Reconsideration of current Exposure Limits especially for ELF, RF/microwaves and activation of Precautionary Principle and ALARA

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