



Inter-Society Technology Panel (ISTP) Session on 5G Health impact – Fiction or Facts?

What are the mechanisms beyond thermal effects
that scientists are currently investigating?

K. Grenier, D. Dubuc

LAAS-CNRS, Université de Toulouse, CNRS, UPS, Toulouse, France





Thermal and athermal effects

Quick heating

Domestic use



@ 2,45 GHz

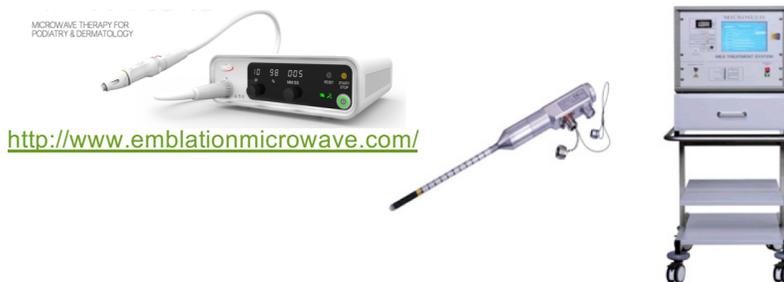
Thermal effects

Industrial microwave ovens
Pistachio roasting machine



hot microwave roasting machine!

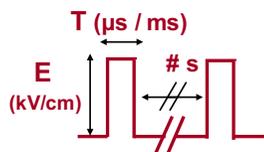
For medicine
Microwave ablation



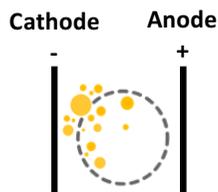
<http://www.emblationmicrowave.com/>

915 MHz (US) and 2.45GHz

Electroporation



Athermal effect



Beneficial impact !

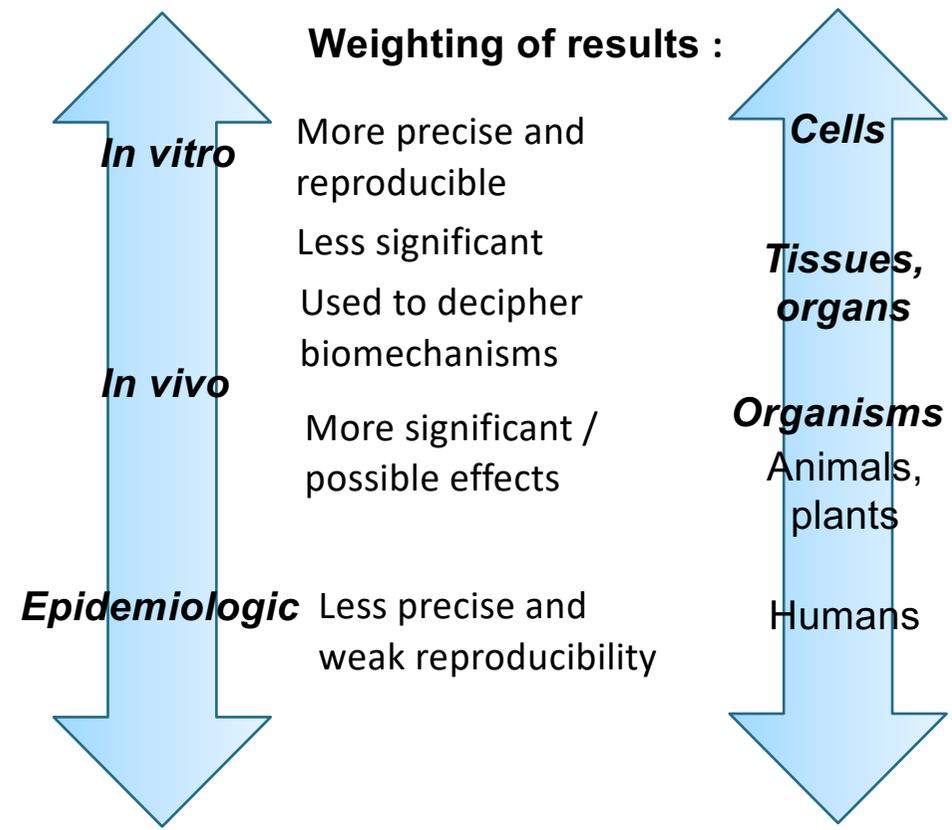


ElectroChemoTherapy ECT: Mélanoma + Bleomycin



Studies at different levels

Research category		Subject	Evaluation criteria
In Vitro Study	Genotoxicity studies	Cells	Chromosomal aberration, Sister chromatid exchange, Micronucleus formation, DNA strand breaks, Mutation, Transformation
	Non-genotoxicity studies	Cells	Cell proliferation, DNA synthesis, Gene expression, Signal transduction, Ion channels, Cell differentiation, Cell cycle distribution, Apoptosis, Immune system, Reactive oxygen species
In Vivo Study		Laboratory animals (rat, mouse, etc.)	Carcinogenesis (lymphoma, leukemia, skin cancer, mammary gland tumor, liver cancer), Reproduction and development (implantation rate, fetal body weight, teratogenesis), Abnormal behavior, Neuroendocrinology mainly melatonin, Immune function, Blood brain barrier
Epidemiological Study		Human	Carcinogenesis and cancer death (brain tumor, childhood and adult leukemia, breast cancer, melanoma, lymphoma), Reproductive ability, Spontaneous abortion, Alzheimer disease
Influence on Human Body		Human	Psychological and physiological influences (fatigue, headache, anxiety, Lack of sleep, Brain waves, Electrocardiogram, memory), Neuroendocrinology mainly melatonin, Immune function



J. Miyakoshi, Proceedings of the IEEE 101, 6 (2013)

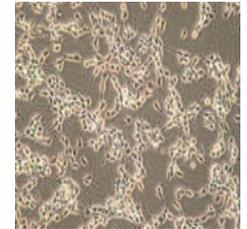


Contradictory results in the SoA

A. Paffi et al. IEEE T-MTT 2010

Out of 182 studies carried out in vitro (cells) and in vivo (animal):

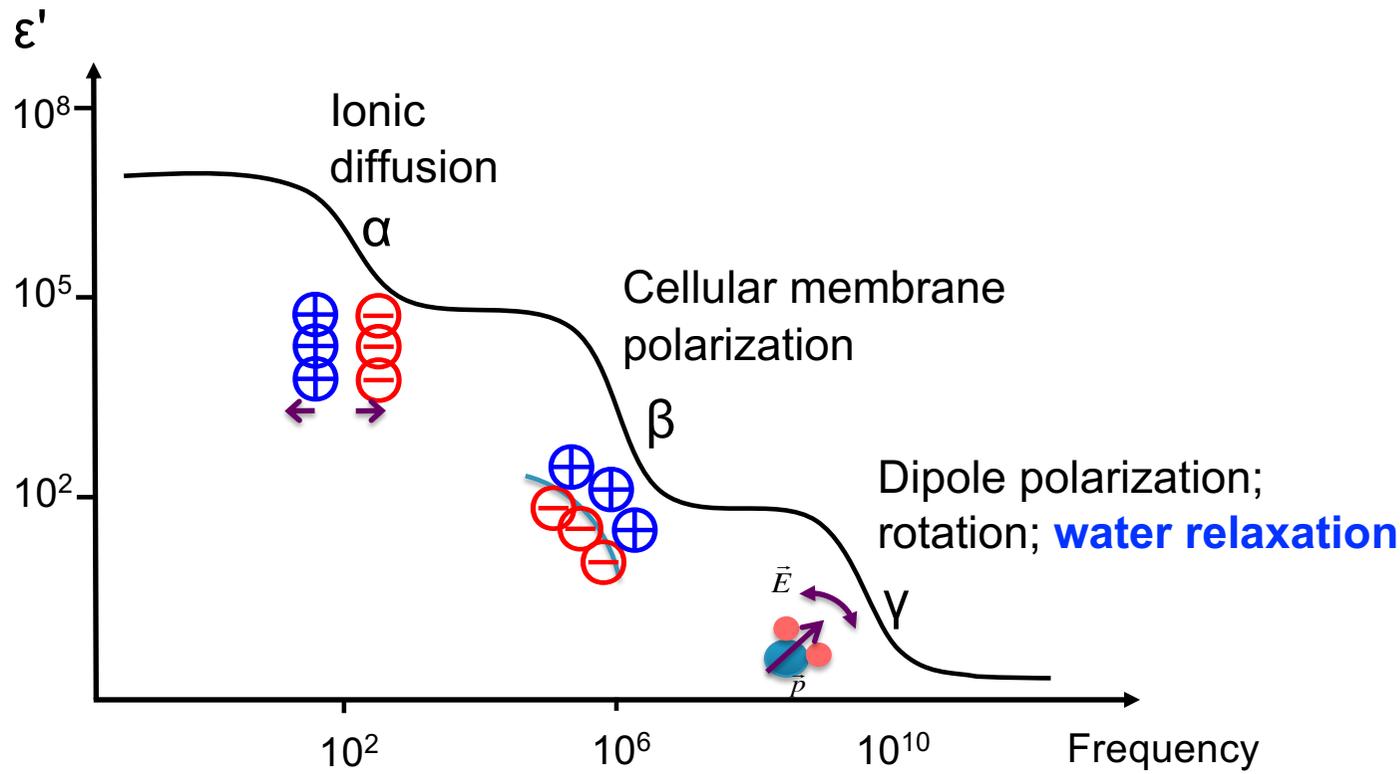
- 82 : evidence of effects
 - 45 with non validated dosimetry
 - 37 with validated dosimetry
 - 9 with a satisfactory methodology, **11%**
- 100 : no effect
 - 13 with non validated dosimetry
 - 87 with validated dosimetry
 - 69 with a satisfactory methodology, **69%**



- ⇒ Need of standardized and controlled RF exposure systems and protocols
- ⇒ Need to reproduce experiments in different labs
- ⇒ Need to take the heterogeneity of the living into account (individual variability)



Electromagnetic wave interaction with the living



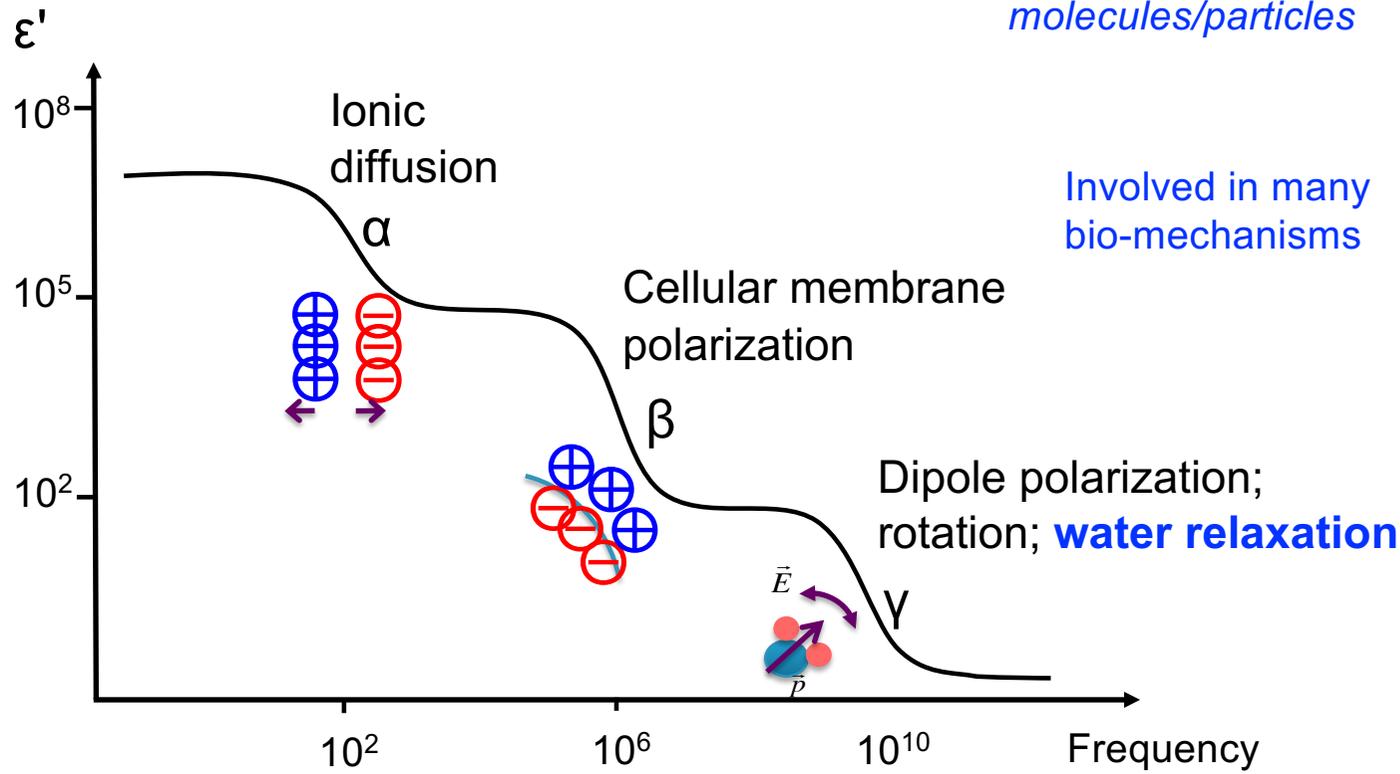
H. Schwan, 1985



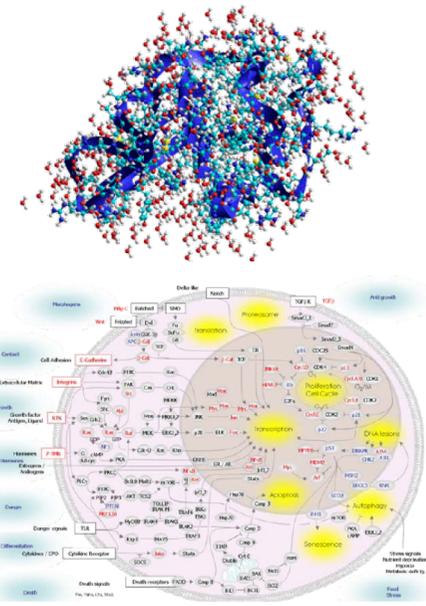
Electromagnetic wave interaction with the living

Water: abundant constituent of the living

Affinity with other molecules/particles



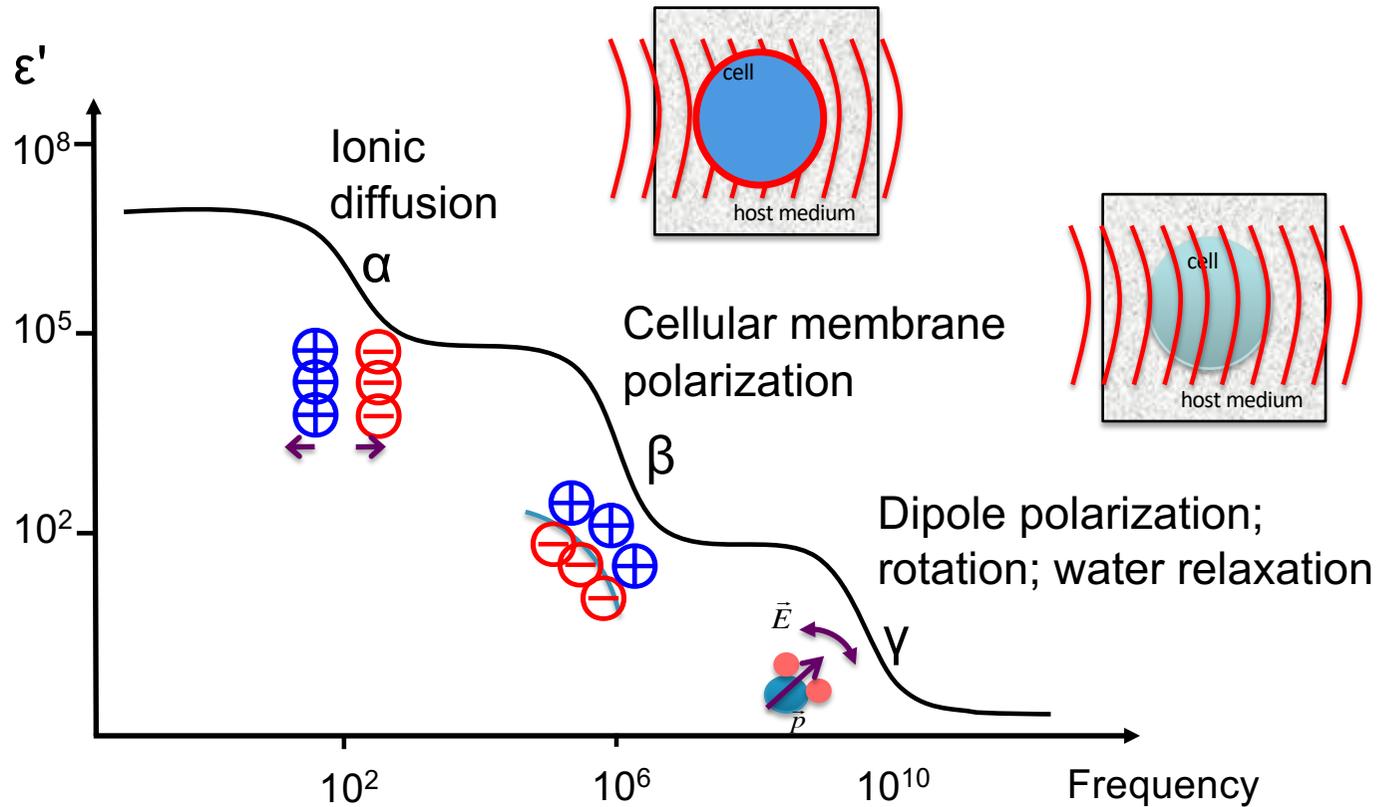
Involved in many bio-mechanisms



H. Schwan, 1985



Electromagnetic wave interaction with the living



H. Schwan, 1985



5G : different frequency bands

3.5 GHz frequency band

- penetration depth of few cm in the body

> 20 GHz

- Limited penetration depth of few mm in the body
→ focus on surface organs with high water content : skin, eyes, neurons, brain
- What about blood and lymph transfers?



Possible cellular effects

A cell : a extremely complex “factory”

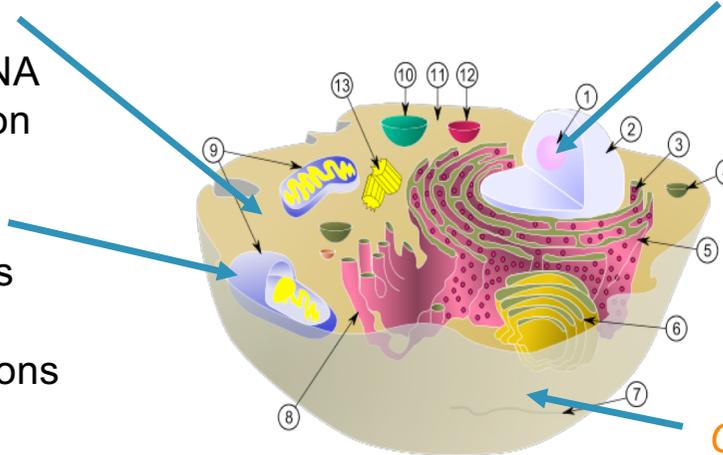
Direct or indirect perturbation(s)

Tools : enzymes, Reactive Oxygen Species (ROS)

→ Oxidative stress;
signalling or DNA, RNA
replication perturbation

Mitochondria

Energy perturbations
→ ATP variations,
metabolic perturbations



Headquarter – Nucleus, DNA

DNA damages, micronuclei formation, mutation –
genotoxicity, genes expression



Proliferation
Cell viability - death (apoptosis)
Carcinogenesis
Fertility

Cell membrane : intra-extra cellular barrier, exchanges
- membrane permeability, transfer perturbation

With in-cell repair systems : cell death, detoxification, immune system

→ Cellular perturbations lead to organs dysfunctions, and then impact the body



DNA damages? Genotoxicity?

B. Houston et al., Scientific reports 2019

DNA damage in mouse spermatozoa via an oxidative mechanism

905 MHz, 2.2 W/kg, for 12 h per day for a period of 1, 3 or 5 weeks
Own exposure setup, dosimetry not presented

→ **Significant impact** :
elevated DNA oxidation and fragmentation across all exposure periods, but no impact on fertility

L. Su et al., Bioelectromagnetics 2016

DNA damage study at 1.8 GHz in different neurogenic cells

1.8 GHz GSM ITIS foundation system, 4.0 W/kg for 1, 6, or 24 h, intermittent exposure : 5 min on, 10 min off

A172, U251, and SH-SY5Y cells lines
quantification of γ H2AX foci, cell cycle progression, proliferation, viability
→ **No significant impact**

L. Verschaeve et al., Mutation research 2010

Review → **Controversial results**

Performed on cancer cell lines → immortalized cells which exhibit strong proliferation and robustness
Limitation of 2D cell culture experiments, difficulties to use primary cultures or animals
Unclear or uncalibrated exposure setups



Animal and epidemiologic studies lead to cerebral impacts

US animal study

M. Wyde et al., 2016

US National Toxicology Program

900 MHz with GSM et CDMA, 1.5, 3 et 6 W/kg, for 2 years, 18h/day with a duty cycle on rats



2 rare cancers observed:

- Cerebral glioma
- Cardiac schwannoma
- Gliomas
- meningiomas

The CERENAT case-control study in France

G. Coureau et al., *Occup Environ Med* 2014

→ positive association between mobile phone use and brain tumours observed for heavy users (54 min/day, during 5 years), higher association for men

Cohort study of Swiss adolescents' memory performance and individual brain dose

M. Foerster et al., *Environmental Health Perspectives*, July 2018

UMTS and GSM use

preliminary evidence of impacted brain
→ Significant decrease in figural memory performance over a 1-year period, with a stronger decrease observed in right-side users



Complexity in evaluating real life exposure conditions

Main performed studies considering only EMF → “isolated” RF exposure

- BUT**
- Various pollutants & toxic stimuli in our daily environment : nanoparticles, chemicals, biologicals, other radiations types with various chronicities, exposure durations
 - Physical state (healthy, stressed) while submitted to EMF
 - Multiple EMF radiations

- Leading possibly to**
- Additive effect : dose addition
 - Synergistic effect : one component increases the impact of the others
 - Potentiation : increase of toxicity or getting toxic
 - Antagonistic effect
 - No interaction nor dose addition

The environment, combined to genetic (human) predispositions, complicates the answer



5G health impacts? Which mechanisms?

- EMF interaction with the living at the different levels (molecular, cellular, with tissues, organisms) is still unclear
- Further experiments to better understand the EMF interaction with the living should be conducted, considering harmful and beneficial impacts
- Standardized exposure systems (at the different levels) are requested to allow extensive testing configurations:
 - RF alone (CW, modulations, pulsed, various carriers, duty cycle, short-term, long-term, with chronicity)
 - In real life conditions: RF with other pollutants, different cellular states, with different environments..., to better take the living complexity into account

Let's keep positive and optimistic, but responsible in the technological developments while keeping the risk-benefit ratio in mind