Exposure to microwaves from mobile communication, DNA repair and cancer risk

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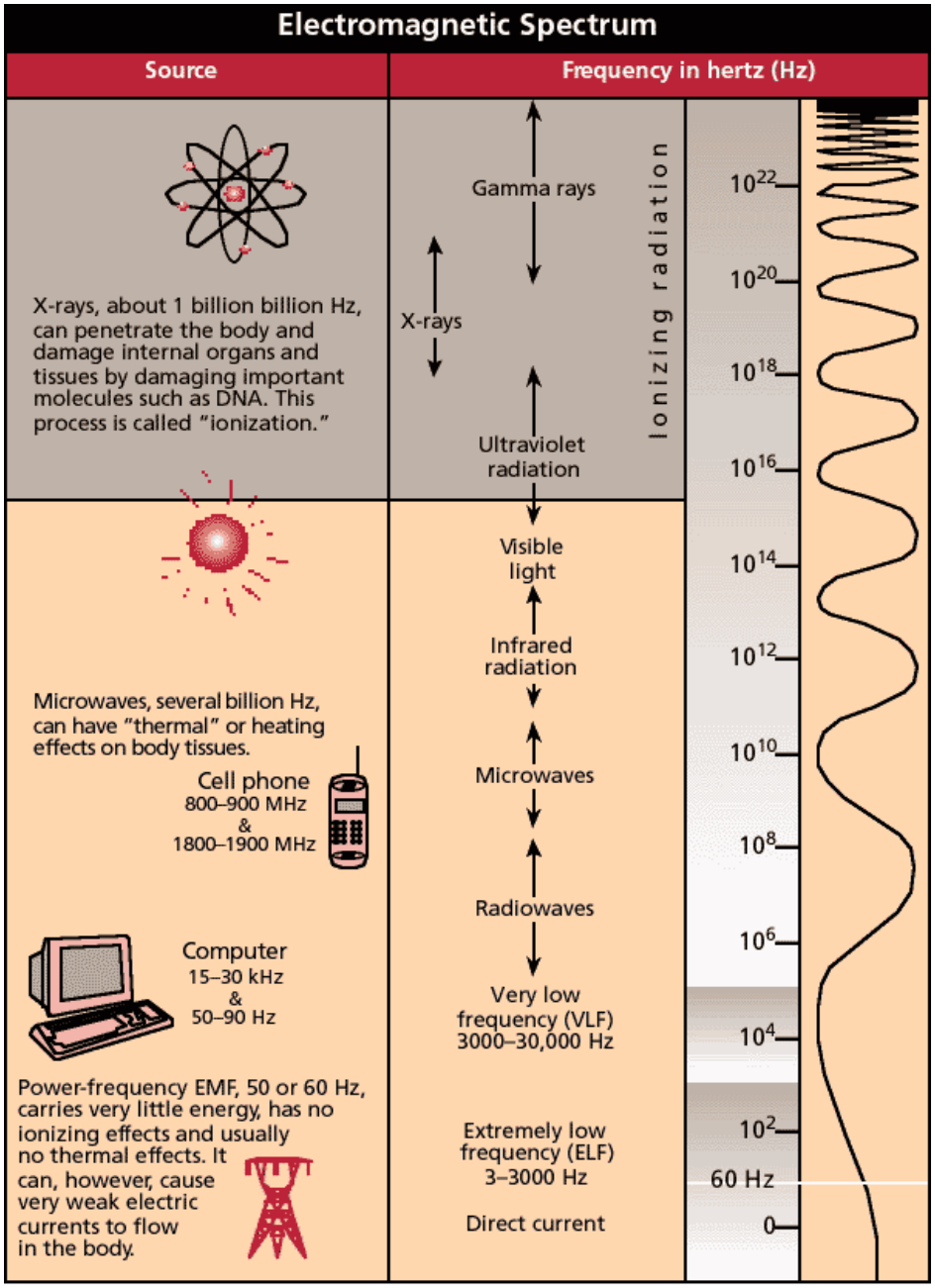
Electromagnetic spectrum

The wavy line at the right illustrates the concept that the higher the frequency, the more rapidly the field varies. The fields do not vary at 0 Hz (direct current) and vary trillions of times per second near the top of the spectrum.

Microwaves from mobile phones

800 MHz - 3 GHz (800 million Hz – 3 billion Hz)

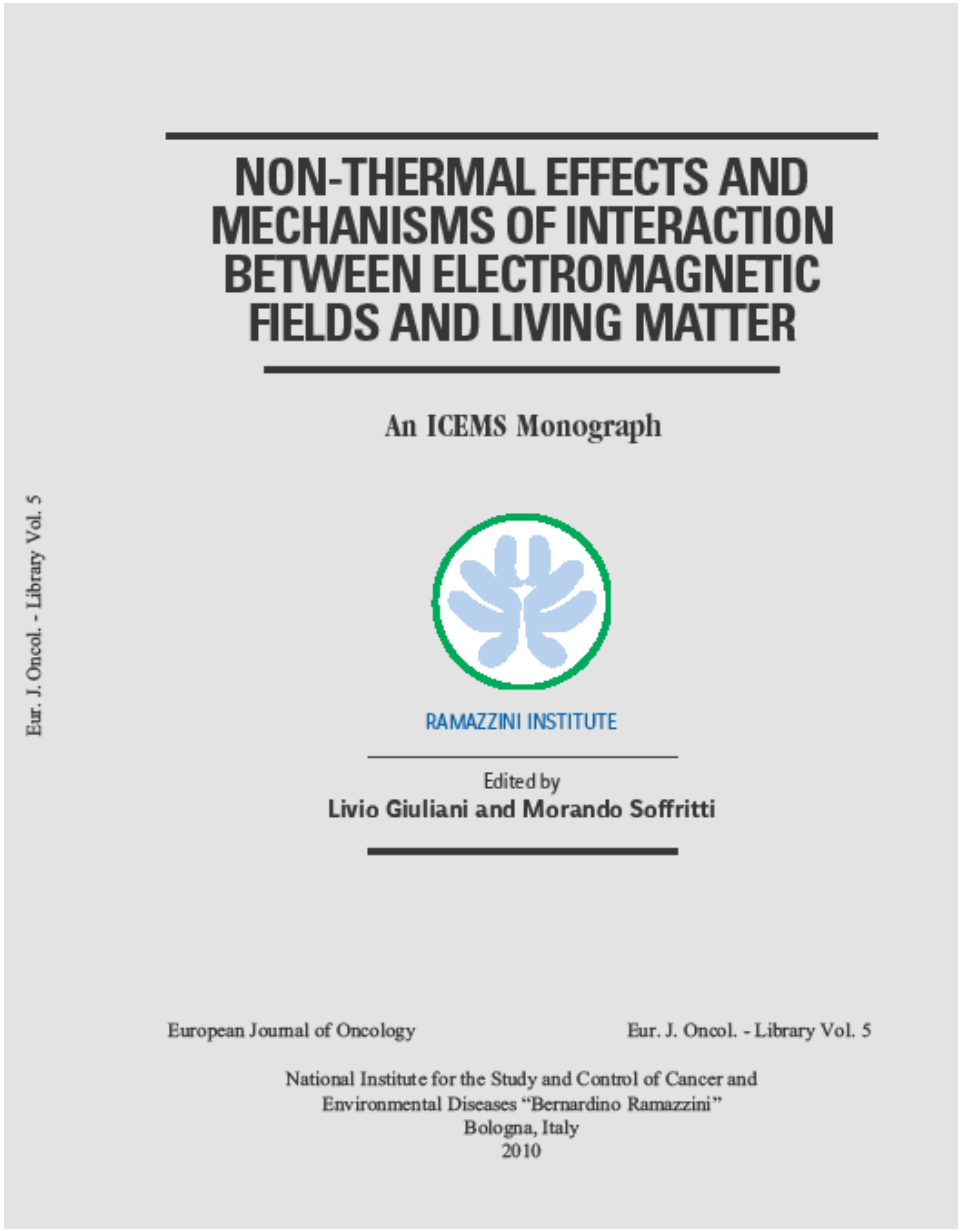


Microwave (MW) exposure safety standards

- Current safety standards are most often based on **thermal effects** of microwaves in **acute** exposures, 2 W/kg **ICNIRP** (International Commission for Non-Ionizing Radiation Protection)
- Power flux density (PD) or specific absorption rate (SAR, "dose rate") is often used for guidelines.
- Dose = (SAR × exposure duration) is not used for assessment of microwave exposures
- Safety standards significantly, up to 1000 times, vary between countries
- Why?

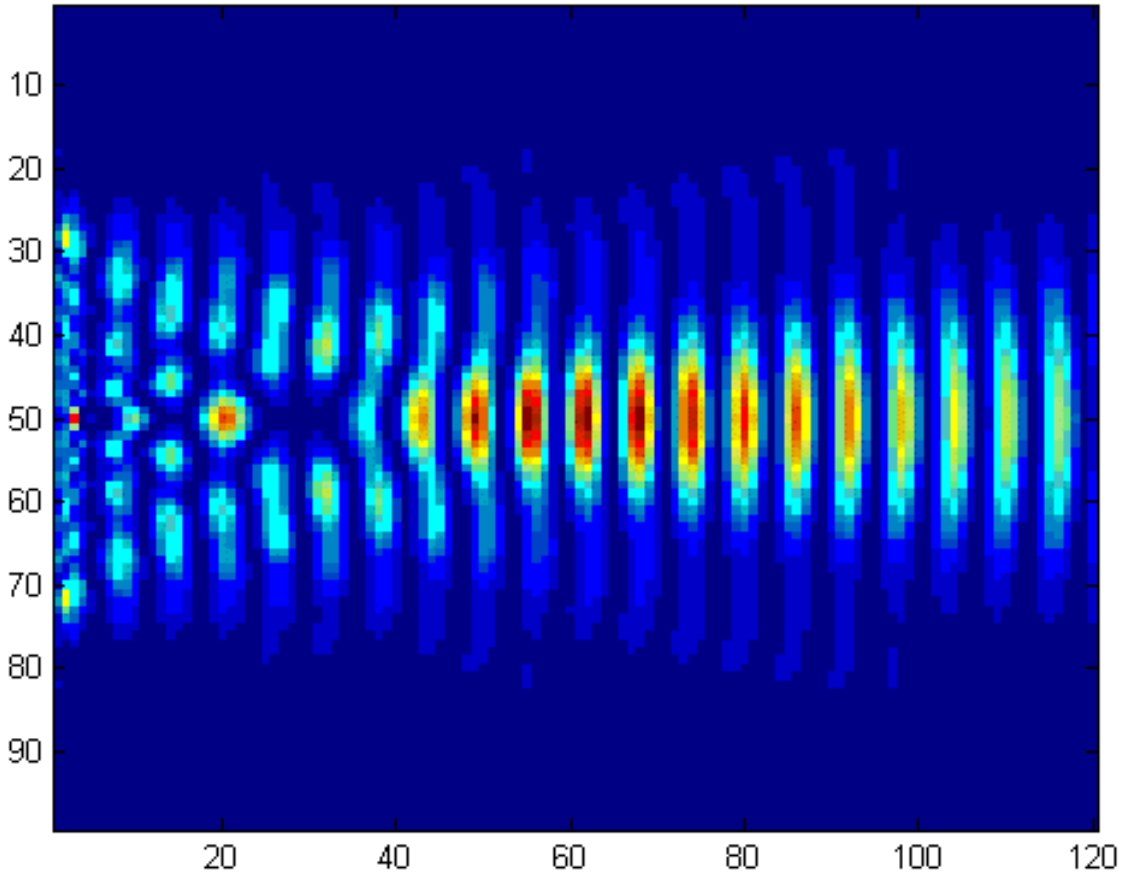
Many groups over the world described various non-thermal biological responses to microwaves (MW) including cancer-related effects.

68 % of available experimental studies report non-thermal biological effects of microwaves
(Huss et al., 2007)



The impact of non-thermal mobile phone radiation depends on the nature of the waves and conditions of exposure

- Frequency
- Modulation
- Polarization
- Coherence time
- Dose and duration
- Intermittence
- Electromagnetic environment

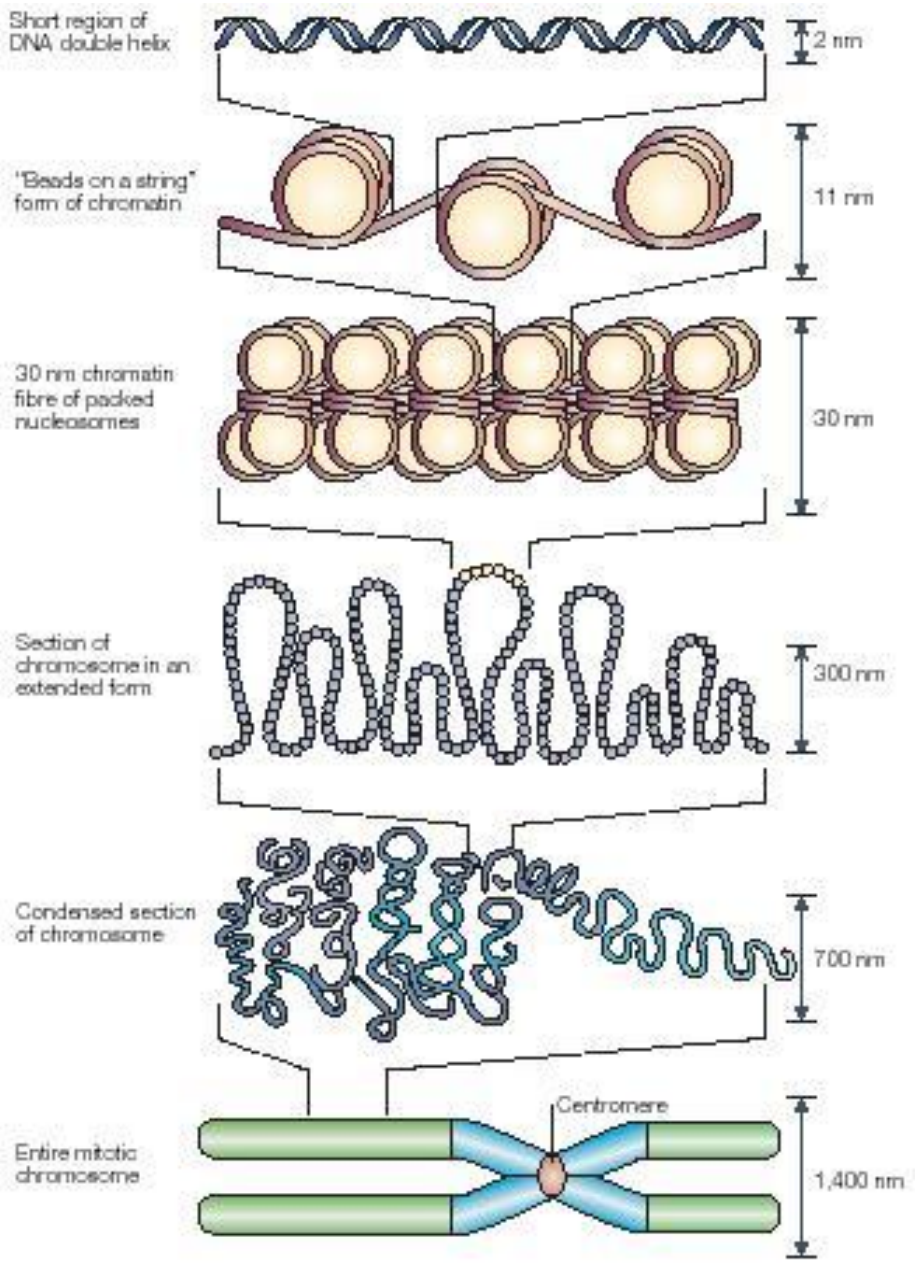


ENVIRONMENTAL HEALTH TRUST

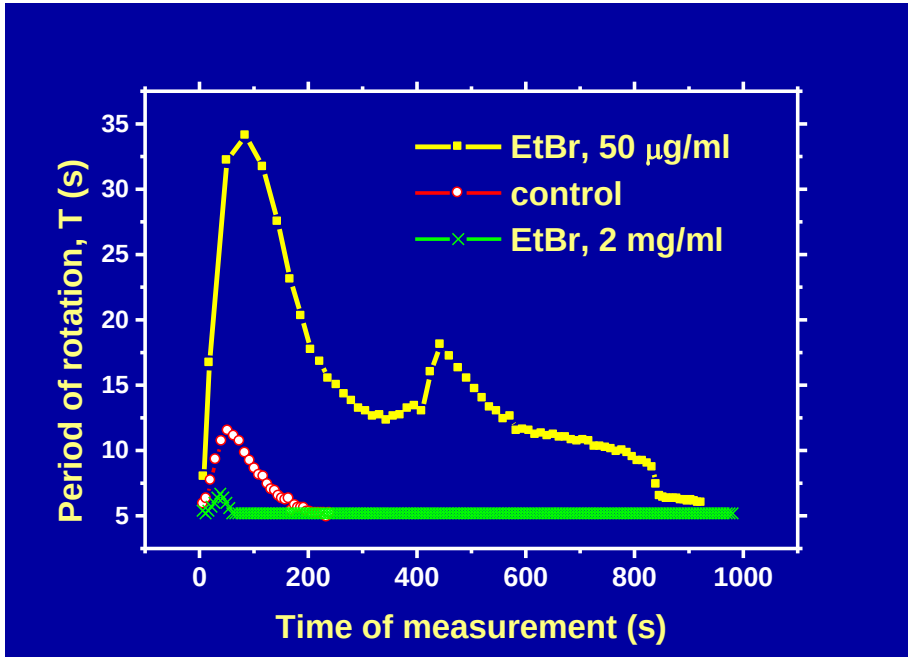
Physical and biological variables/parameters of importance for biological effects of non-thermal microwaves

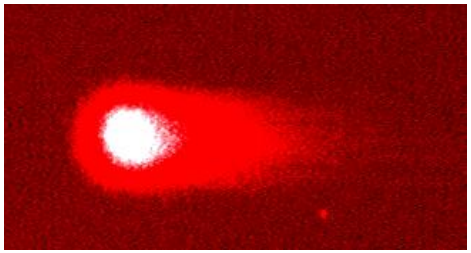
- Reported by many research groups: carrier frequency, modulation, specific absorption rate (dose rate), dose and duration of exposure, post exposure time, genotype and cell type, physiological traits, presence of radical scavengers and antioxidants
- Emerging data suggest dependencies the of the NT MW effects on polarization, intermittence and coherence time of exposure, electromagnetic stray fields, static magnetic field, sex, age, individual traits, and cell density during exposure
- Differences in these variables/parameters between studies might be a simple reason for different outcomes

Different levels of DNA-organization (DNA-loops)

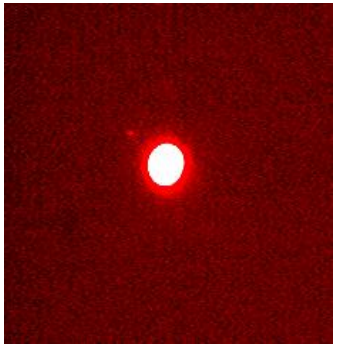


Anomalous viscosity time dependence (AVTD) similar to neutral comet assay measures relaxation and condensation of DNA loops regardless DSB induction

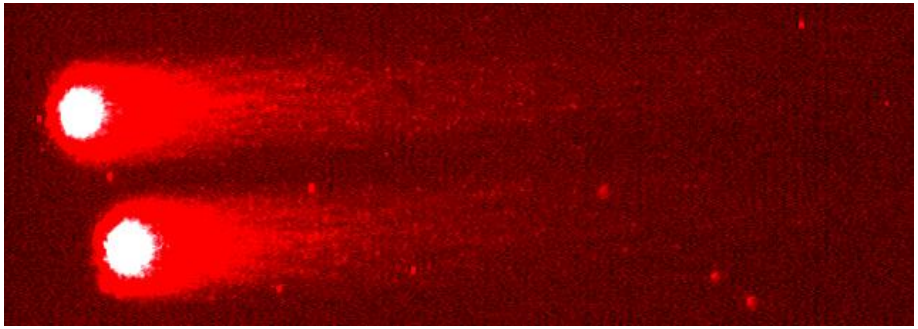




Control



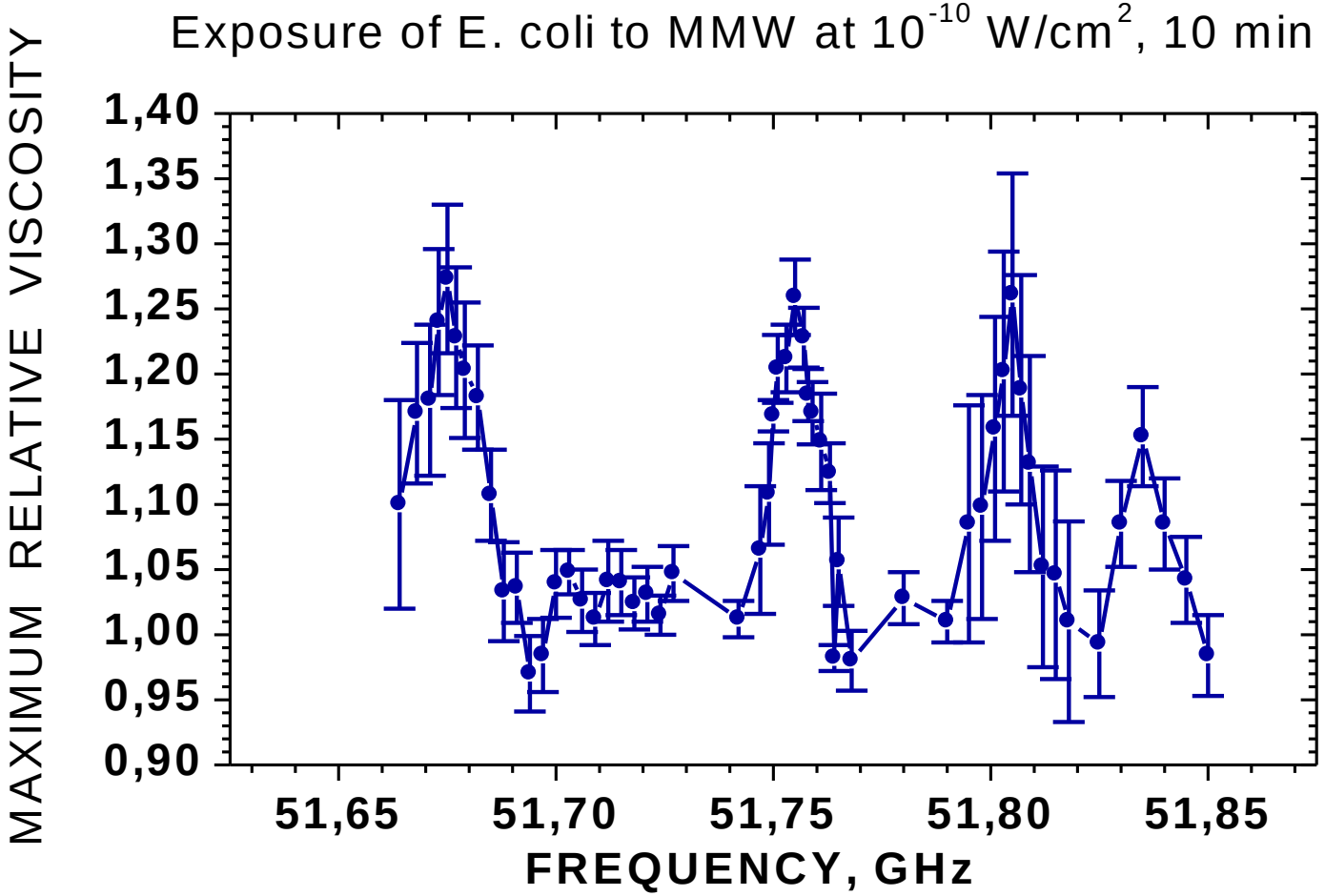
EtBr, 2 mg/ml, condensation



EtBr, 50 μg/ml relaxation

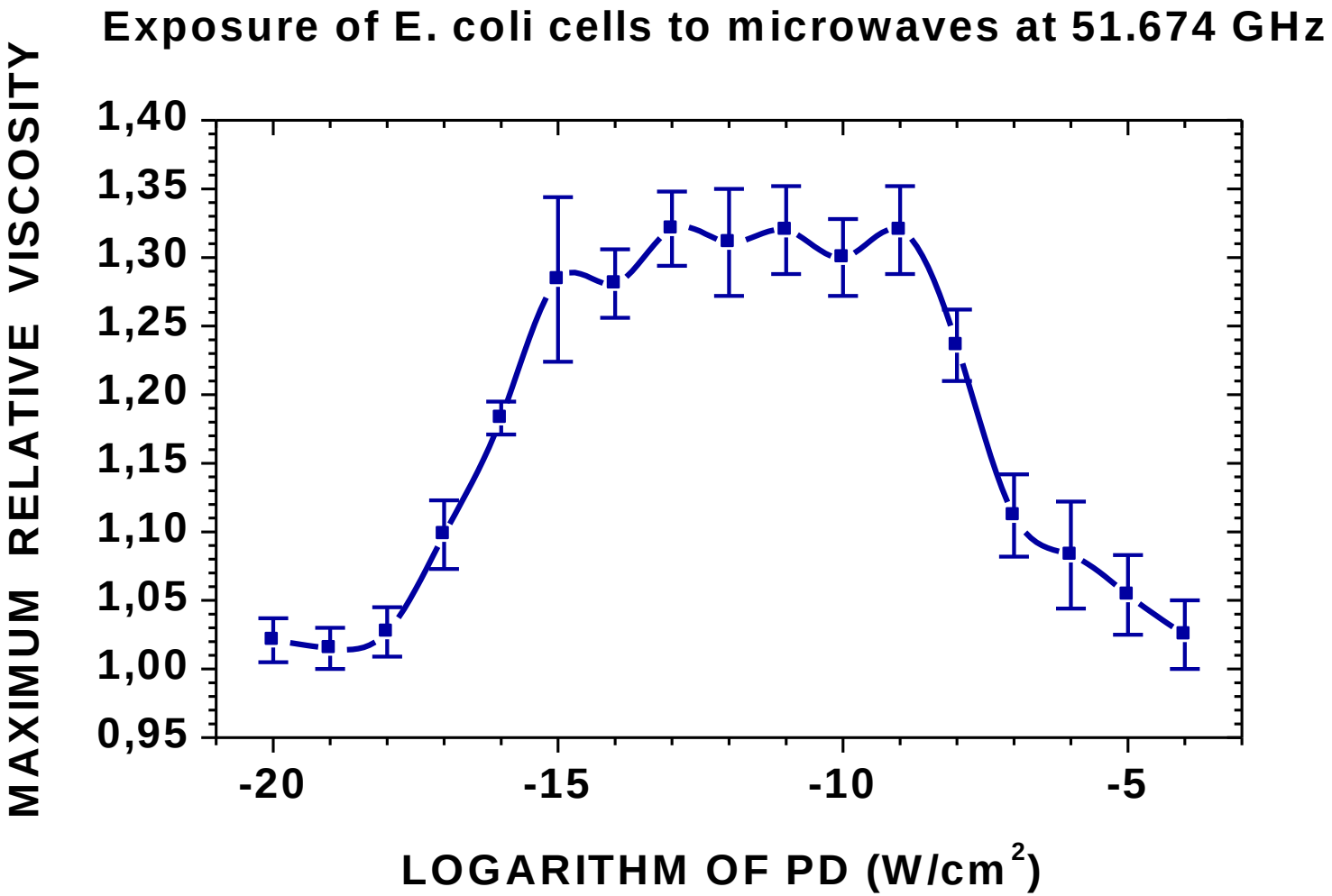
I. Y. Belyaev, S. Eriksson, J. Nygren, J. Torudd, and M. Harms-Ringdahl, *Biochim Biophys Acta*, vol. 1428, pp. 348-356, 1999

“Frequency windows” in effects of MW at low intensities comparable with intensities produced by base stations



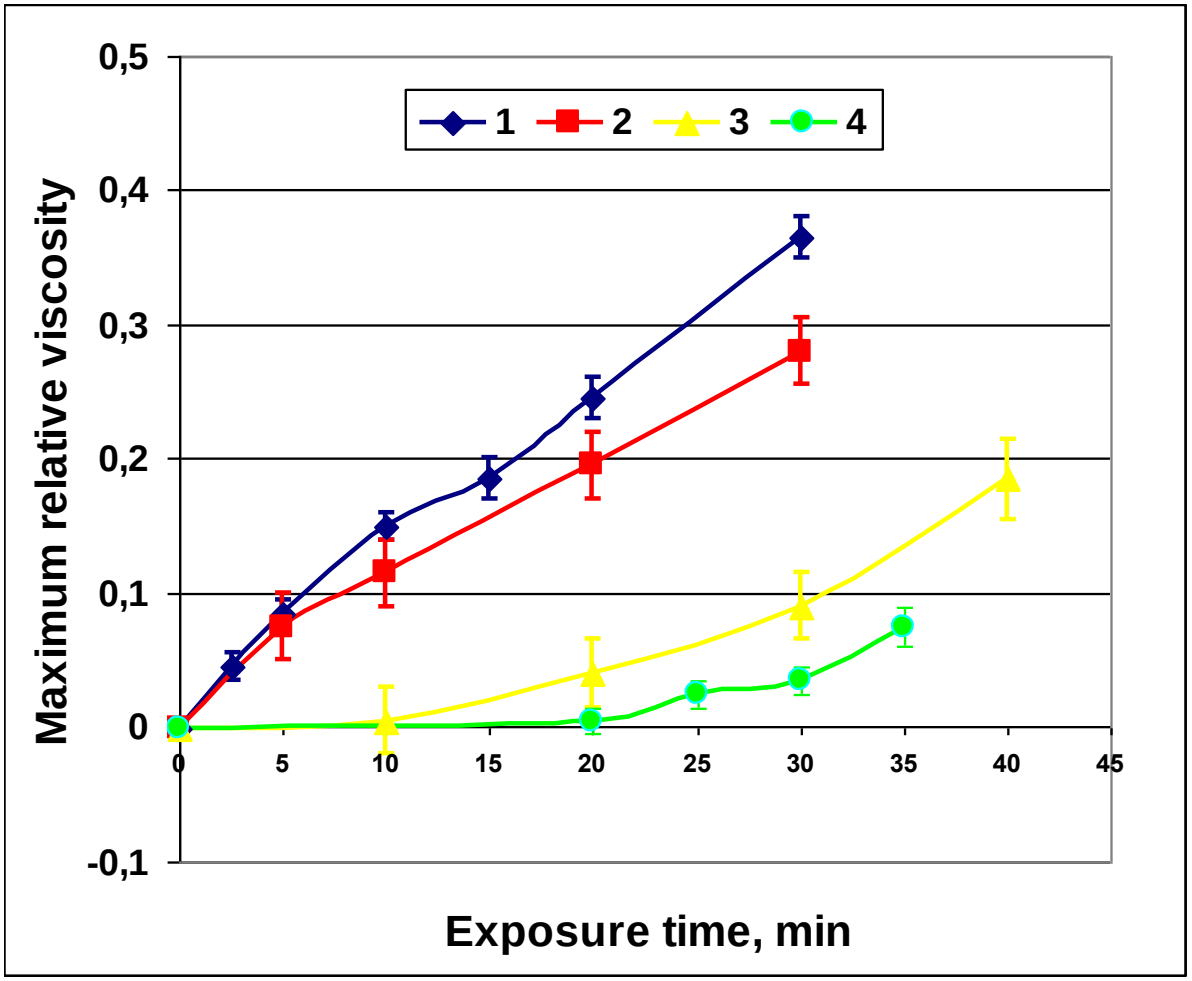
I. Y. Belyaev, V. S. Shcheglov, Y. D. Alipov, and V. A. Polunin, *Bioelectromagnetics*, vol. 17, pp. 312-321, 1996

Microwave effects can be observed at specific ”intensity windows”



V. S. Shcheglov, I. Y. Belyaev, V. L. Ushakov, and Y. D. Alipov, *Electro- and Magnetobiology*, vol. 16, pp. 69-82, 1997

Decreasing of intensity by orders of magnitude was compensated by 4-fold increasing of exposure time



(1) 10^{-14} W/cm^2;

(2) 10^{-16} W/cm^2;

(3) 10^{-17} W/cm^2;

(4) 10^{-18} W/cm^2;

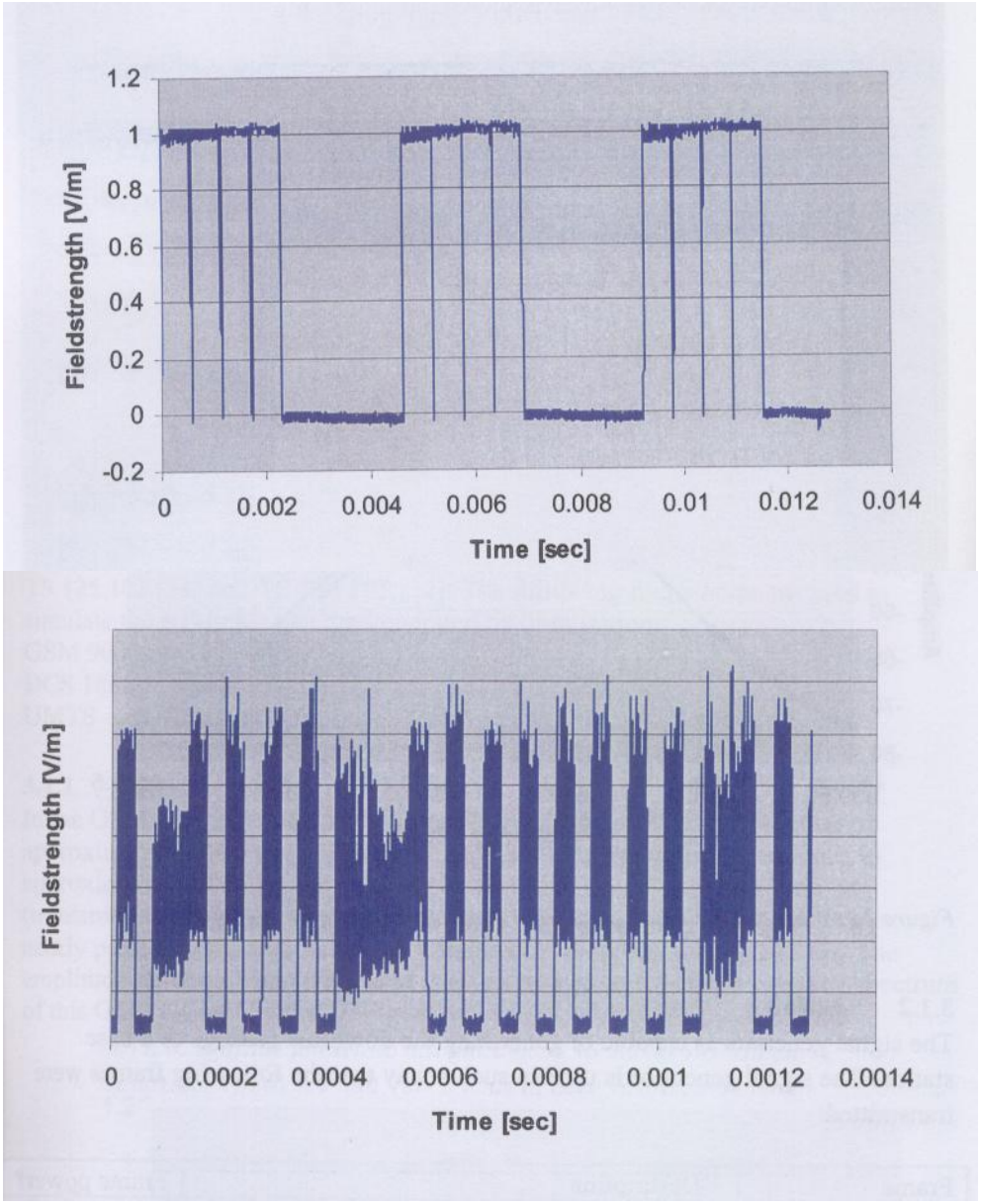
I. Y. Belyaev, Y. D. Alipov, V. S. Shcheglov, V. A. Polunin, and O. A. Aizenberg, *Electro- and Magnetobiology*, vol. 13, pp. 53-66, 1994.

Were the mobile communication signals tested for genotoxicity?

- Very little has been done with real signals. Most of them have not been tested so far

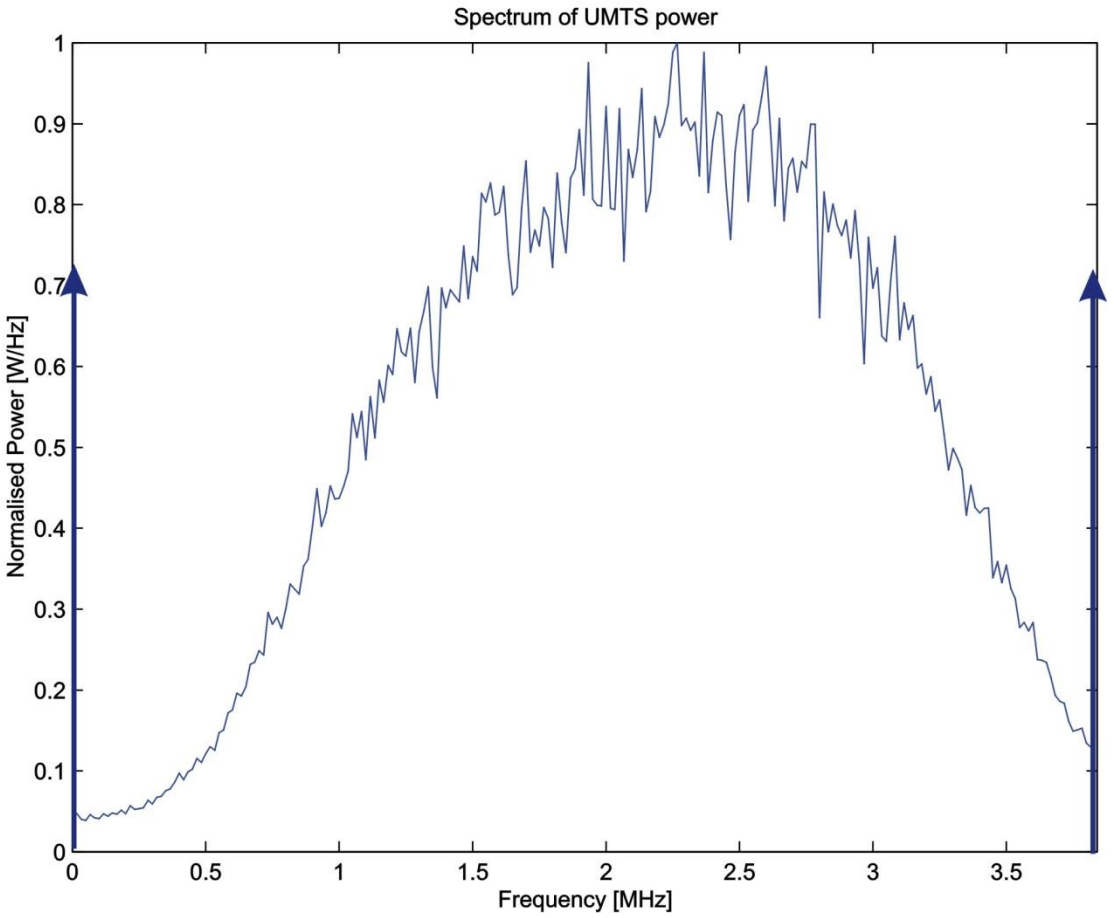
- We tested some signals from GSM (Global System for Mobile Communication) mobile phones of the 2nd generation (2G) and UMTS (Universal Mobile Telecommunications System) mobile phones of the 3rd generation (3G)

- GSM (2G) phones use GMSK modulation (Gaussian Minimum Shift Keying)
- UMTS phones, W-CDMA (3G), use QPSK modulation



UMTS

- 2nd generation GSM phones irradiate in 124 “monochromatic” frequency channels (200 kHz).
- mobile phones of the 3rd generation irradiate UMTS (Universal Mobile Telecommunications System) wide-band signal, about 5 MHz.

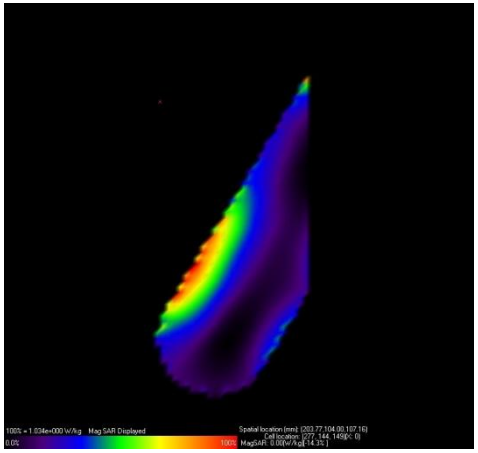


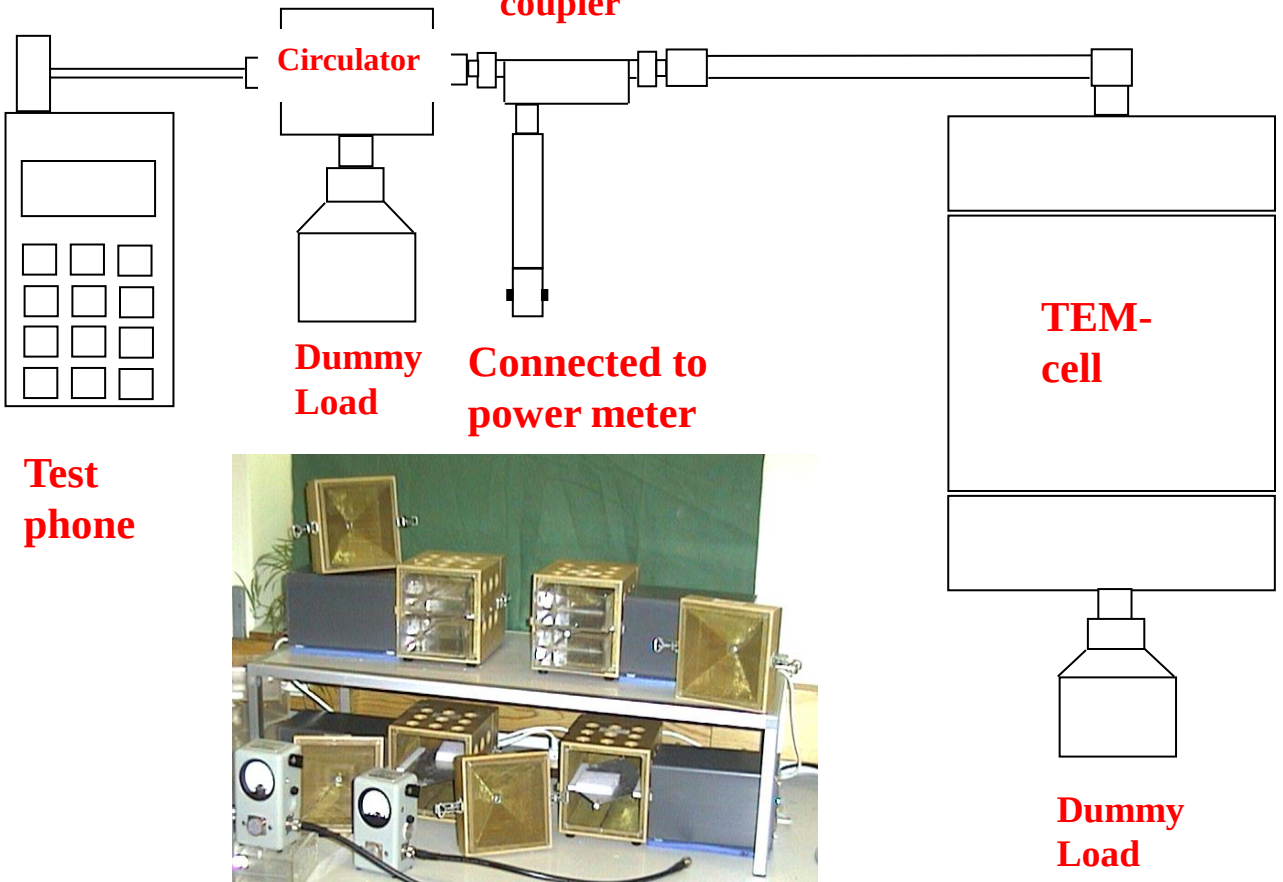
During a single call, GSM users are exposed to microwaves at different frequencies

•There are 124 different channels/frequencies, which are used in GSM900 (Global System for Mobile Communication). They differ by 0.2 MHz in the frequency range between 890 MHz and 915 MHz. Frequency is supplied by base station to a mobile phone user depending on the number of connected users. The frequency can be changed by base station during the same call.

Non-thermal microwave exposure of human differentiated and stem cells in different frequency channels

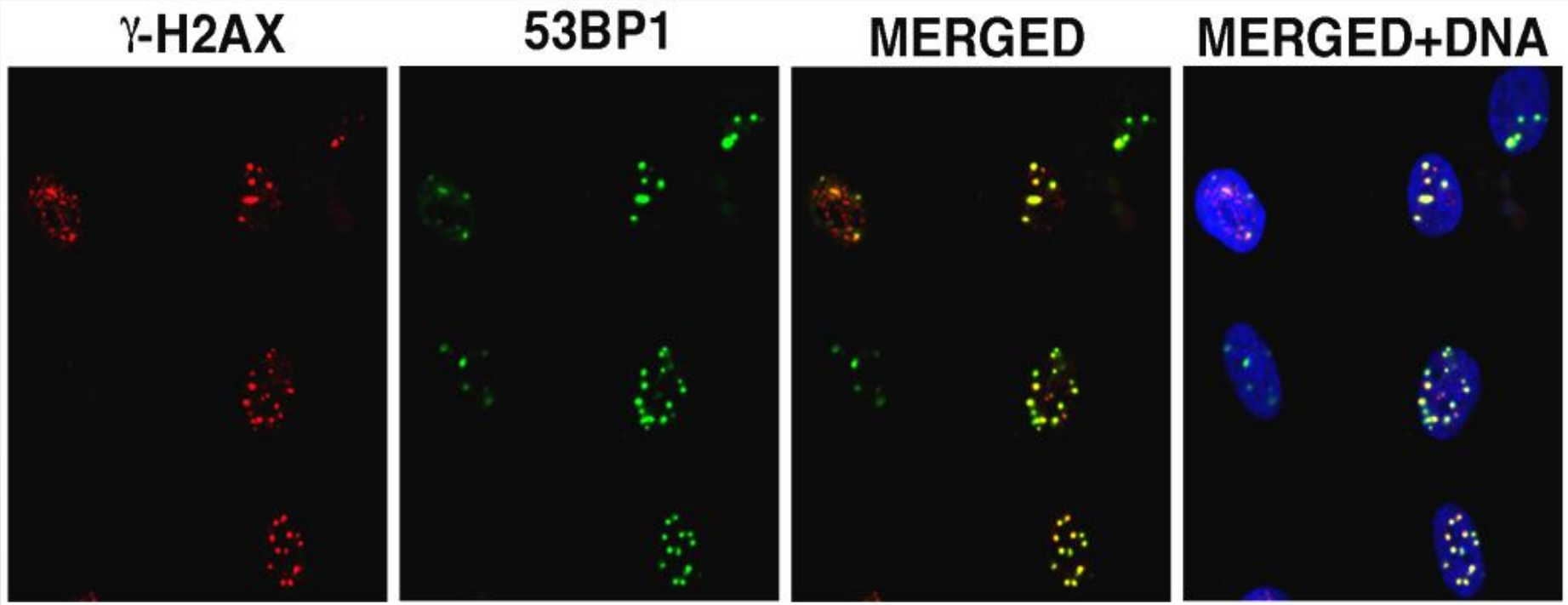
The test-mobile phone is programmed to select a GSM/UMTS frequency channel, and 0.25 W output power.





Distribution of specific absorption rate (FDTD-METHOD)

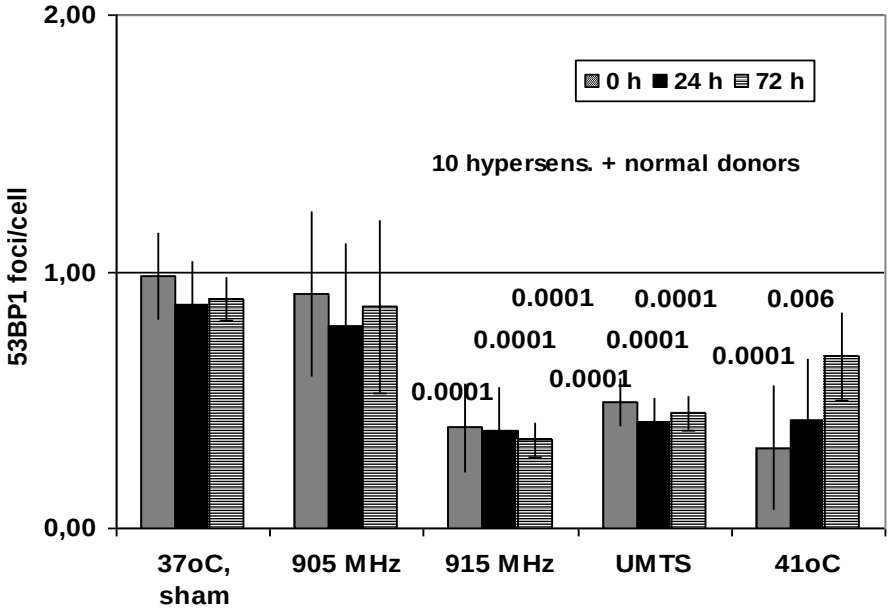
Molecular markers (γ-H2AX, 53BP1) of DNA double-strand breaks (DSB), which are used to visualize and quantify double strand breaks (DSB) by enumeration of DNA repair foci by means confocal laser microscopy and immunofluorescence

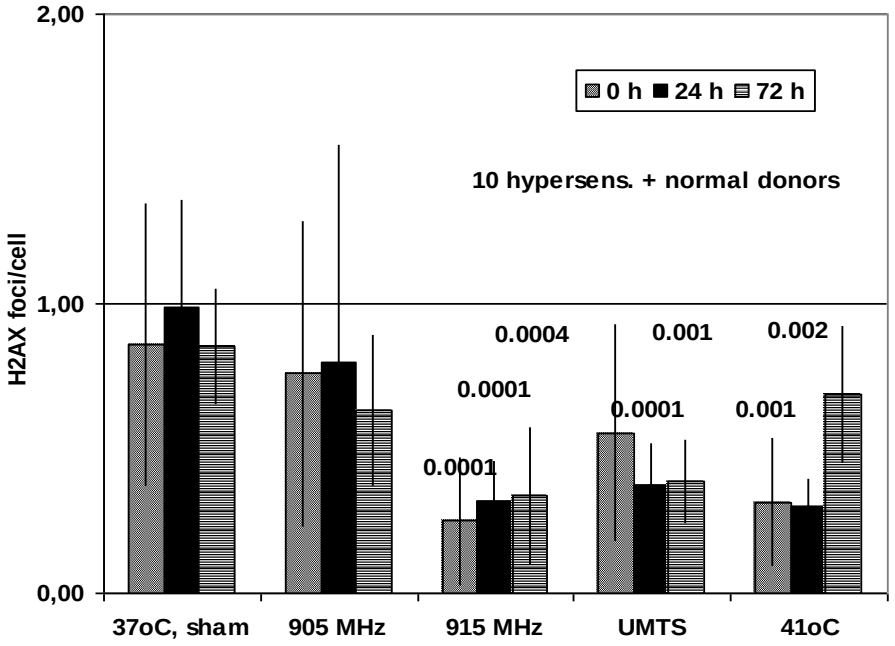


VH-10 cells, 12 h following irradiation with 3 Gy

E. Markova, N. Schultz, and I. Y. Belyaev, *Int J Radiat Biol,* vol. 83, pp. 319-329, May 2007.

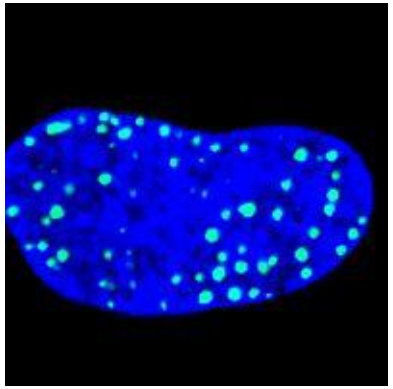
Inhibitory effects of 915 MHz GSM and UMTS on DNA repair foci remain 72 h after exposure of human lymphocytes to MW. No effect at 905 MHz

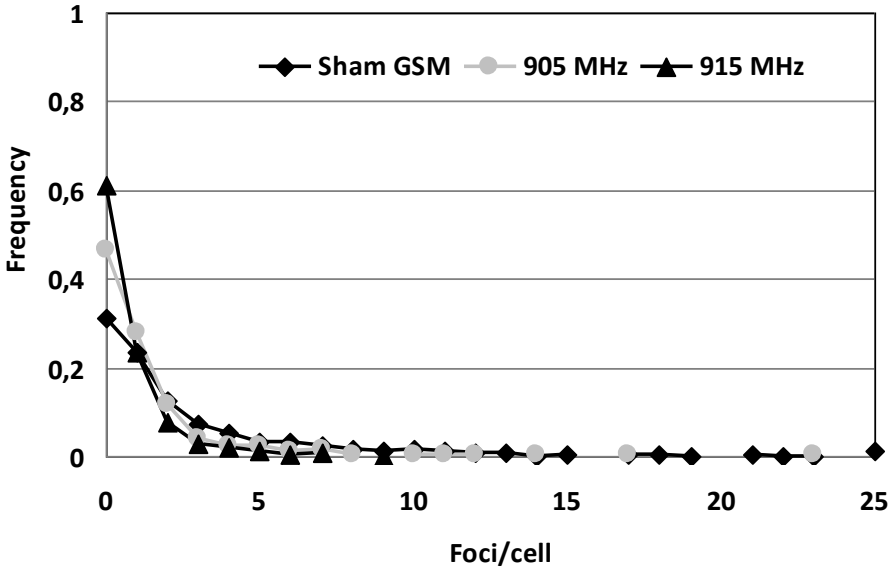


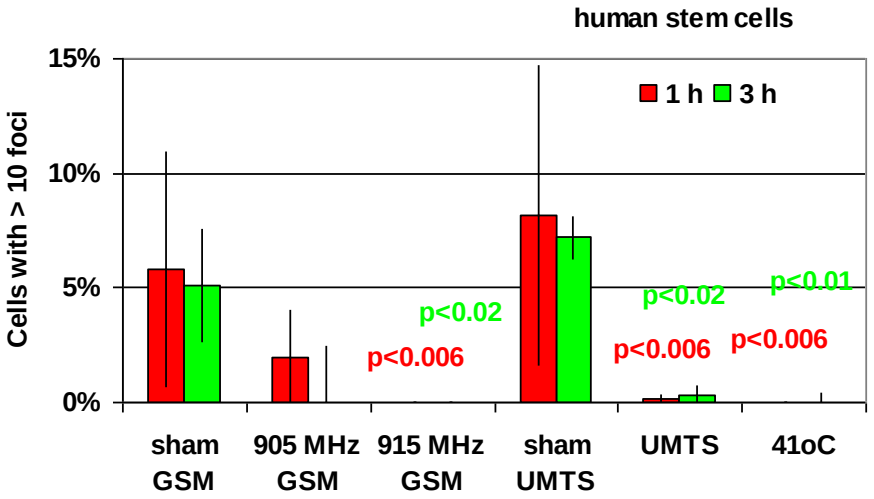


Both molecular markers, γ-H2AX и 53BP1, show the same results

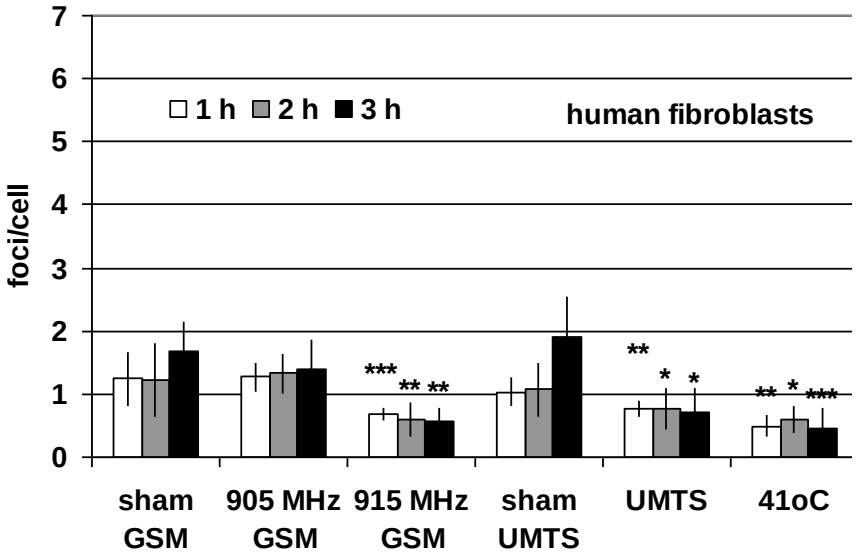
Microwaves completely blocked DNA repair foci in stem cells with multiple DNA damage

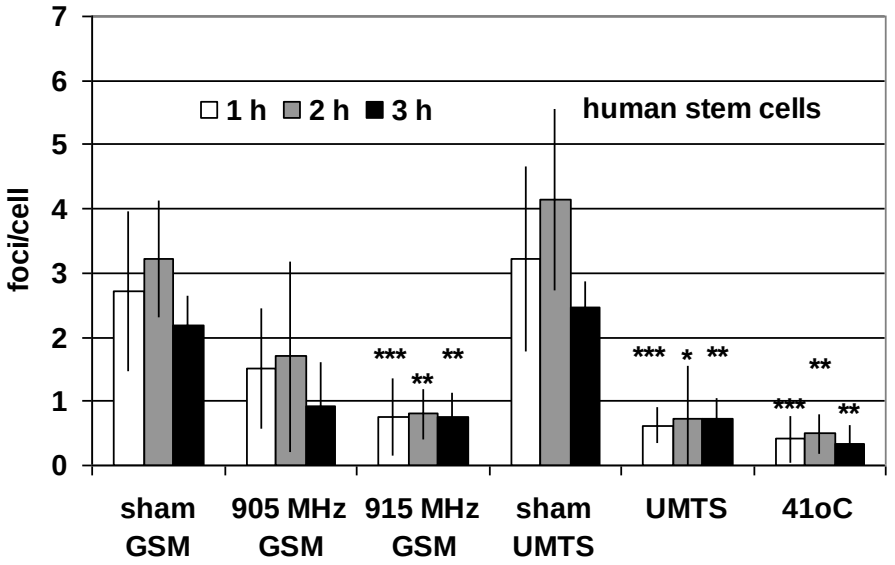






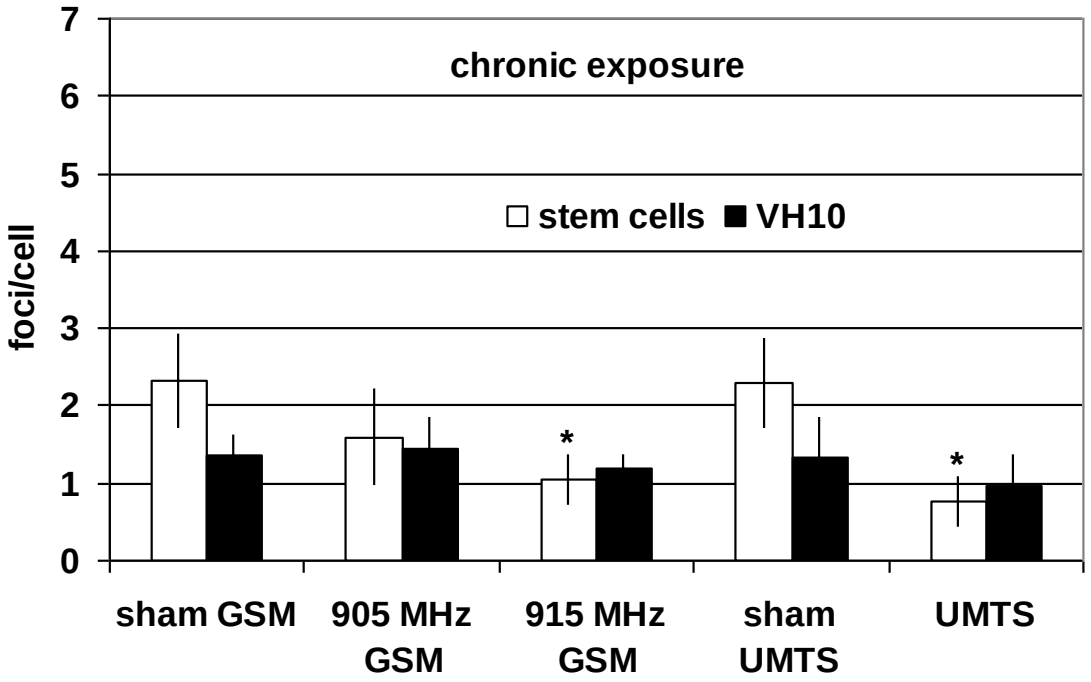
Human stem cells were more sensitive to microwave exposure than differentiated human cells and more responsive to GSM frequency channels



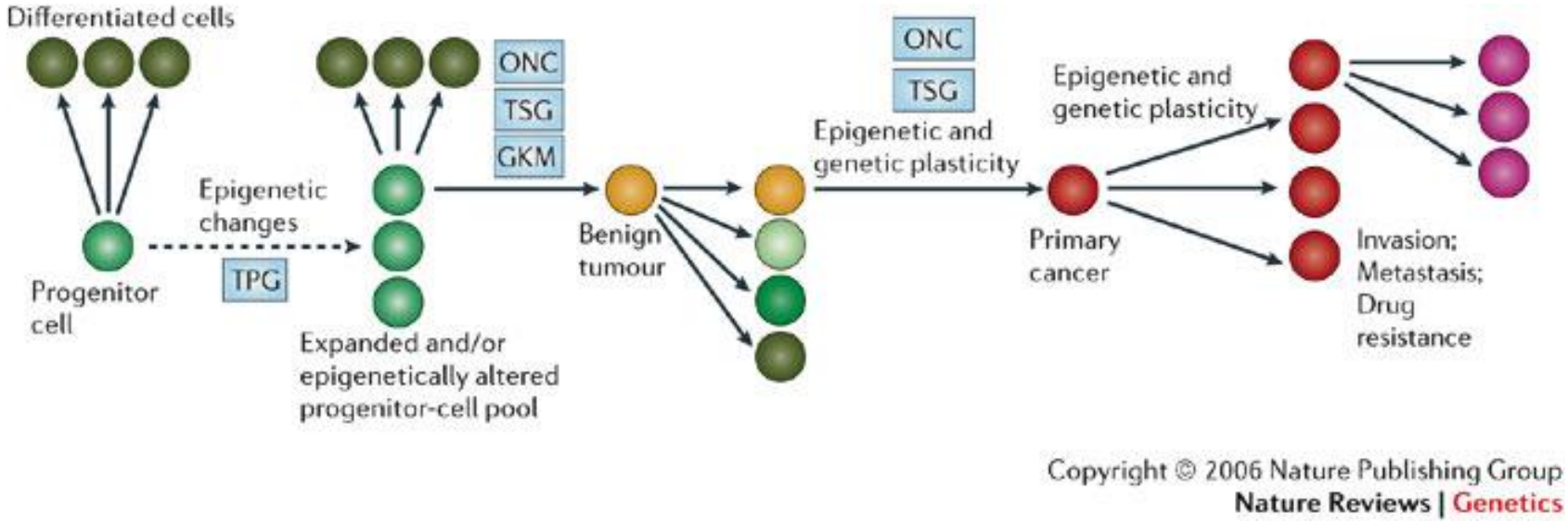


Contrary to differentiated cells, human mesenchymal stem cells did not adapt to effects of MW during chronic exposure

Exposure during 2 weeks, 1 hour daily



Results with stem cells may be especially important because different cancer types (tumors and leukemia) originate from stem cells by well-known genetic and recently suggested epigenetic mechanisms



Feinberg AP *et al.* (2005) The epigenetic progenitor origin of human cancer
Nat Rev gene. **7:** 21–33 doi:10.1038/nri1748

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Conclusions

In dependence on frequency channel, non-thermal microwaves from mobile phones inhibited DNA repair 53BP1/γ-H2AX foci in human cells. These effects indicate severe stress response and disruption of the balance between cellular repair systems and DNA damage.

Importantly, human stem cells were most sensitive to microwaves and did not adapt to chronic exposure, providing mechanistic link to the epidemiologic data on increased brain cancer risk in heavy users of mobile phones

Key References

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Markova, E., L. O. G. Malmgren, et al. (2010). "Microwaves from Mobile Phones Inhibit 53BP1 Focus Formation in Human Stem Cells More Strongly Than in Differentiated Cells: Possible Mechanistic Link to Cancer Risk." Environmental Health Perspectives **118**(3): 394-399.

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