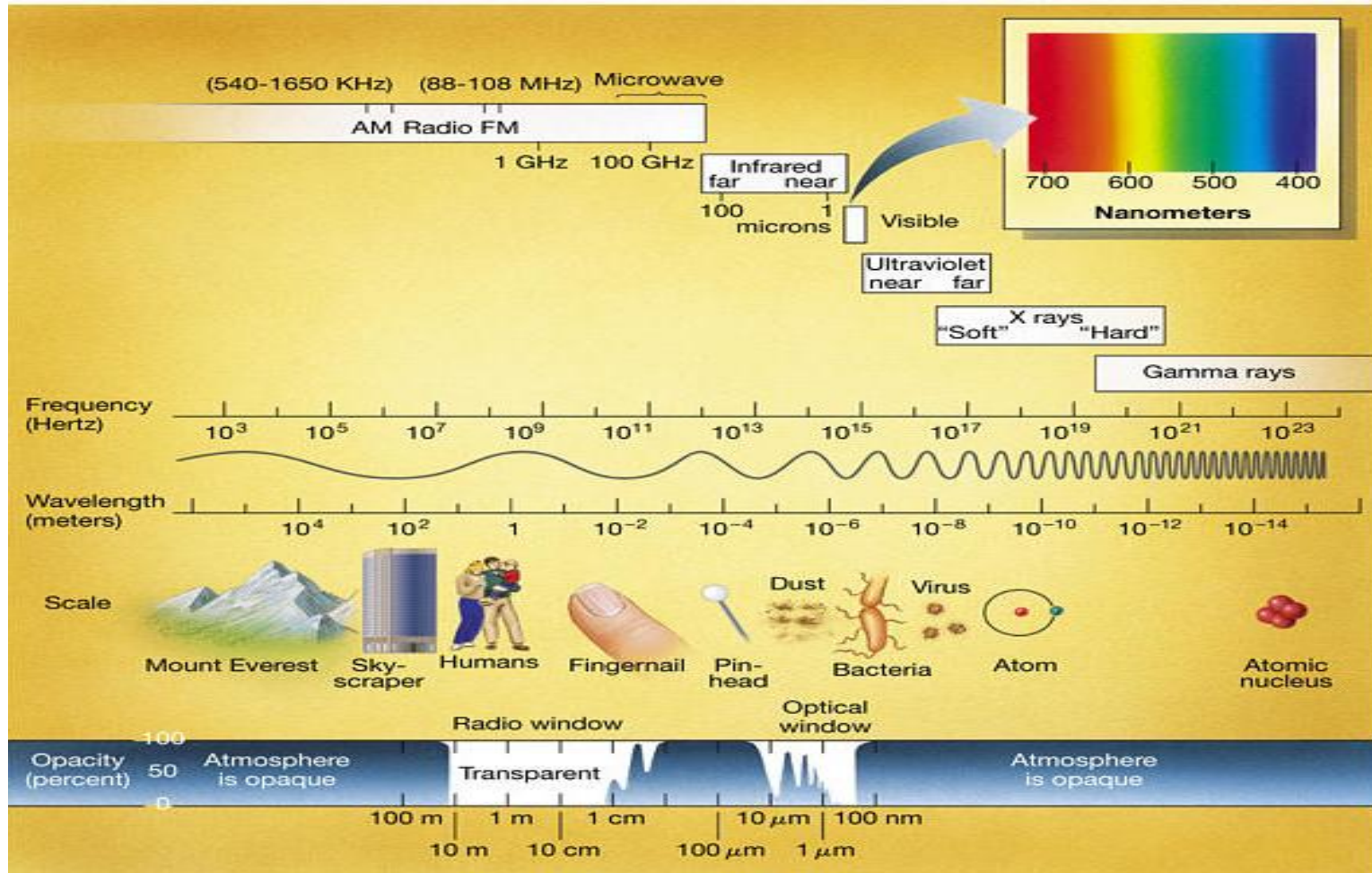# The hypothesis of Fröhlich about intercellular communications in the human body

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Electromagnetic spectrum

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MM wave frequency range

- **Millimetre wave 30-300 GHz and wavelength is 1 cm -1 mm**

- The global polarisation is consisted on five different dielectric mechanisms (electronic, atomic, orientation or dipolar, ionic polarisation and interfacial).

- The energy of rotational transitions corresponds to the microwave region of the electromagnetic spectrum. The typical frequency range of interest is 3 - 300 GHz (0.1 to 10 cm^{-1}).

- Thus polarization and relaxation in MM wave band are connected with excitation of the most small polar molecules or the most large polar groups.

- This is the latest instrumentally mastered range of electromagnetic waves

Polarisation frequency dependence
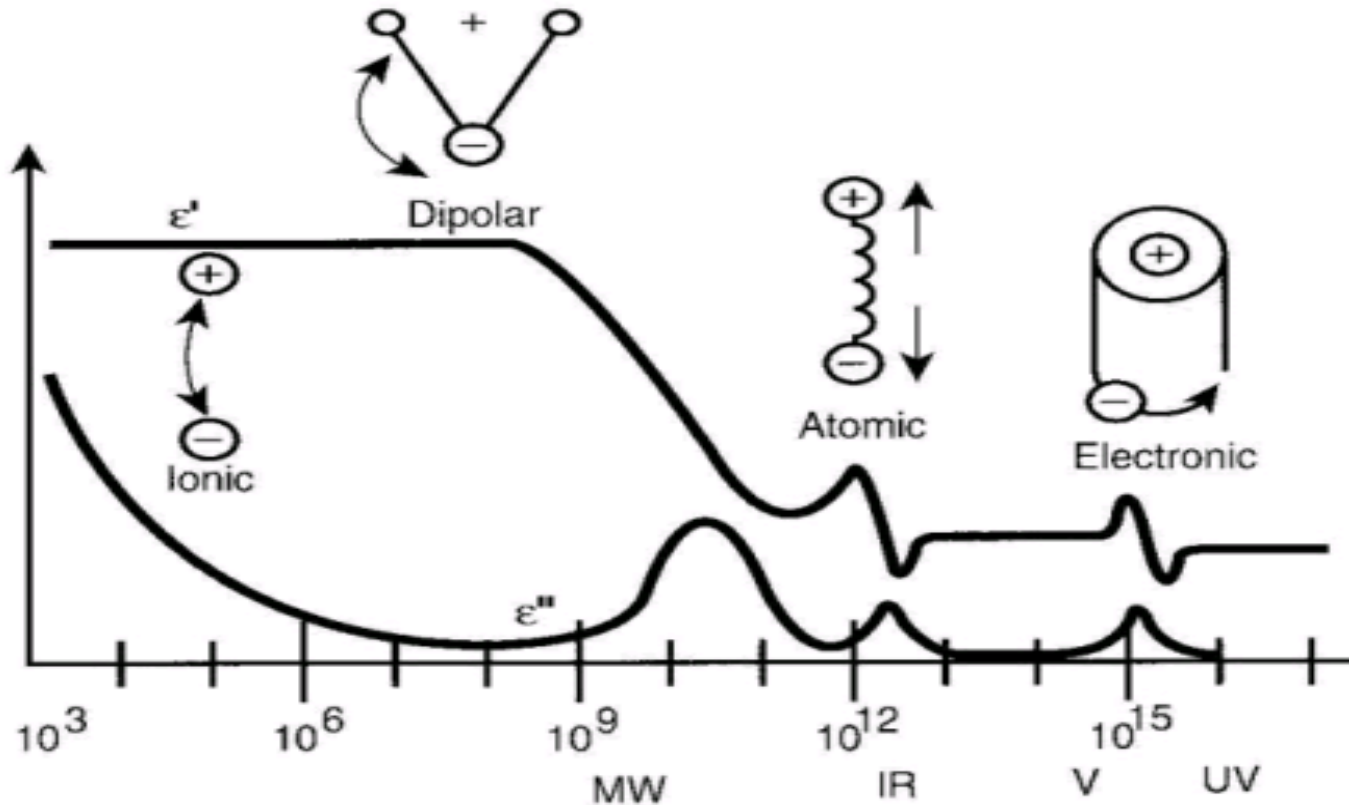
Microwave spectra are a result of two properties

Dielectric constant ($\varepsilon_1(\omega)$) - Reduction in velocity

As the electromagnetic wave passes through the sample it causes an alternating polarization. This polarization and depolarization reduces the *wave velocity* across the chamber during analysis. The response of material under alternating electrical field E results in polarisation. The value of polarisation is connected with the Complex Dielectric Permittivity, that can be measured
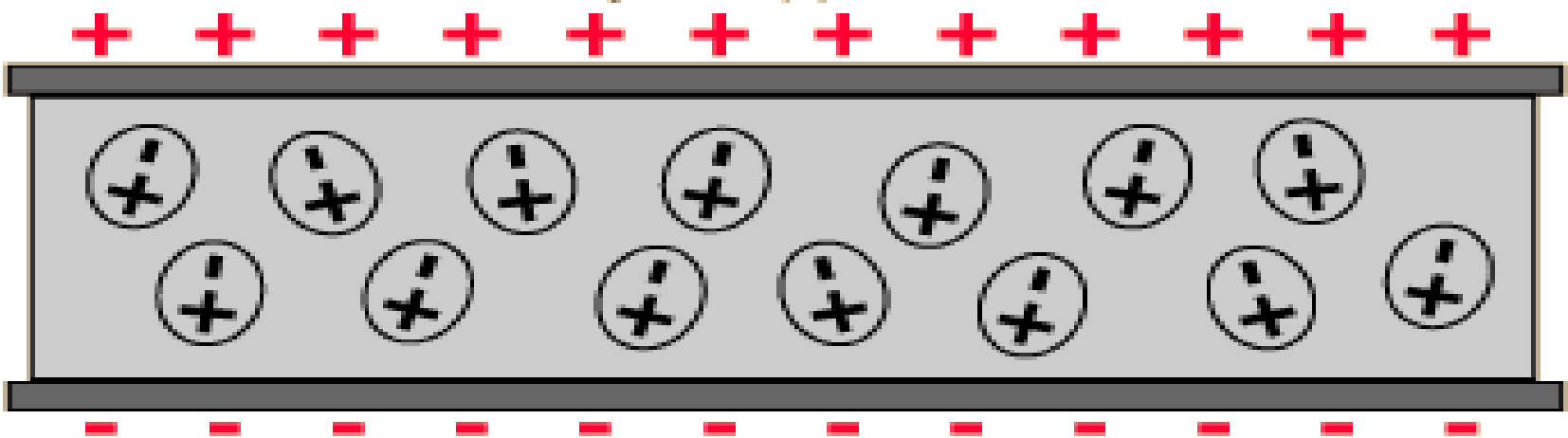
Polarisation
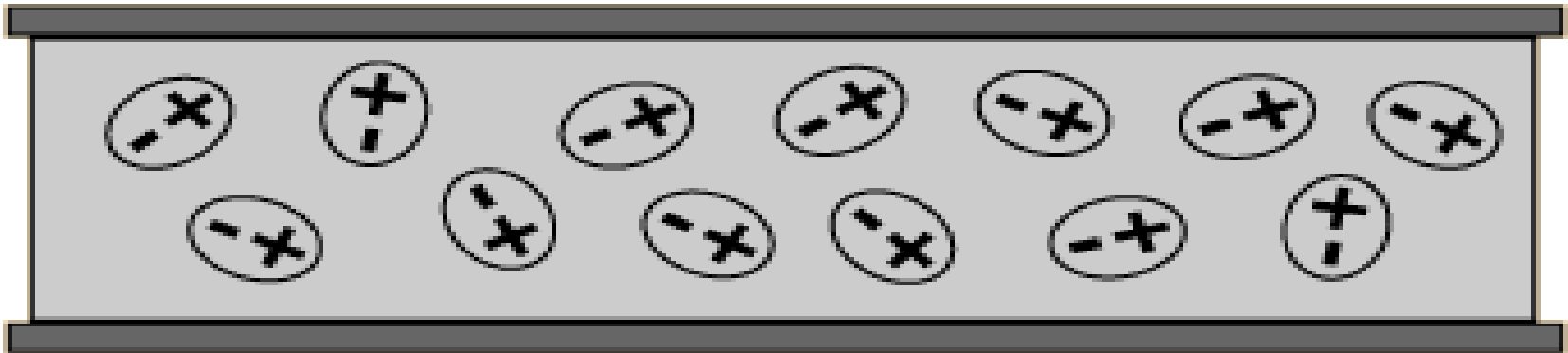
- **Dielectric loss ($\varepsilon_2(\omega)$) - Reduction in magnitude**

- As the molecules orientate in the electric field energy is lost to friction. This causes the waves magnitude to reduce across the sample or **losses.**

- **Complex Dielectric Permittivity** $\varepsilon(\omega)$

- $\varepsilon(\omega) = \varepsilon_1(\omega) + i\varepsilon_2(\omega)$

- $\varepsilon = 1 + 4\pi P(\omega)$

- P is polarisation.

Electromagnetic field

Излучательные процессы	Колебательные и поляризационные процессы

I¶	II¶	III¶	IV¶	V¶
γ-кванты¶	R-кванты¶	фото-ны¶	солитоны¶ (колебания молекуляр-ных цепей)	солитоны¶ (поляризационные взаимодействия водных кластеров и т.д.)

рентген "жёсткий"

рентген "мягкий"

ультрафиолетовое излучение

инфракрасное излучение

$\nu, \text{Гц}$

10^{24} 10^{21} 10^{18} 10^{15} 10^{12} 10^{9} 10^{6} 10^{3} 10^{0}

10^{-16} 10^{-13} 10^{-10} 10^{-7} 10^{-4} 10^{-1} 10^{2} 10^{5} 10^{8}

видимый свет

$\lambda, \text{м}$

$E, \text{эВ}¶$

$4.1 \cdot 10^{9}$ $4.1 \cdot 10^{6}$ $4.1 \cdot 10^{3}$ $4.1 \cdot 10^{0}$ $4.1 \cdot 10^{-3}$ $4.1 \cdot 10^{-6}$ $4.1 \cdot 10^{-9}$ $4.1 \cdot 10^{-12}$ $4.1 \cdot 10^{-15}$

Herbert Fröhlich

War born 9 December 1905 – pass away 23 January 1991). FRS[6] was a German-born British physicist
In 1927, Fröhlich entered Ludwig-Maximilians University in Munich to study physics, and received his doctorate under Arnold Sommerfeld in 1930.[7] His first position was as Privatdozent at the University of Freiburg. Due to rising anti-Semitism and the Deutsche Physik movement under Adolf Hitler, and at the invitation of Yakov Frenkel, Fröhlich went to the Soviet Union.


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Herbert Fröhlich

In 1933, to work at the Ioffe Physico-Technical Institute in Leningrad. He fled to England in 1935. Except for a short visit to the Netherlands and a brief internment during World War II, he worked in Nevill Francis Mott's department, at the University of Bristol, until 1948, rising to the position of Reader. At the invitation of James Chadwick, he took the Chair for Theoretical Physics at the University of Liverpool.
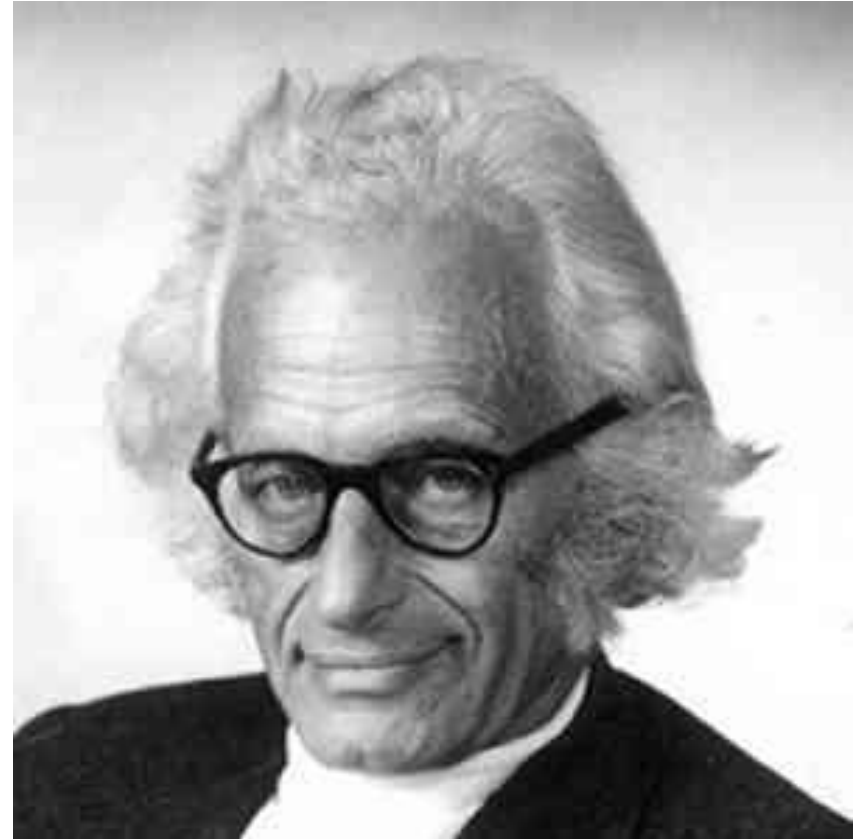
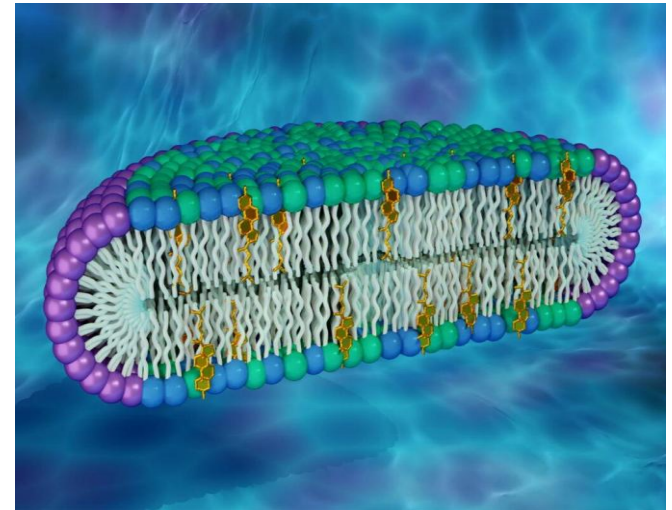# MM wave frequency range: Fröhlich Hypothesis 1968

Biological systems are expected to have a branch of longitudinal electric modes in a frequency region between 10^{11} and 10^{12} sec^{-1}.

They are based on the dipolar properties of cell membranes; of certain bonds recurring in giant molecules (such as H bonds) and possibly on pockets of non-localized electrons. If energy is supplied above a certain mean rate to such a branch, then a steady state will be reached in which a single mode of this branch is very strongly excited. The supplied energy is thus not completely thermalized but stored in a highly ordered fashion. This order expresses itself in long-range phase correlations; the phenomenon has considerable similarity with the low-temperature condensation of a Bose gas.
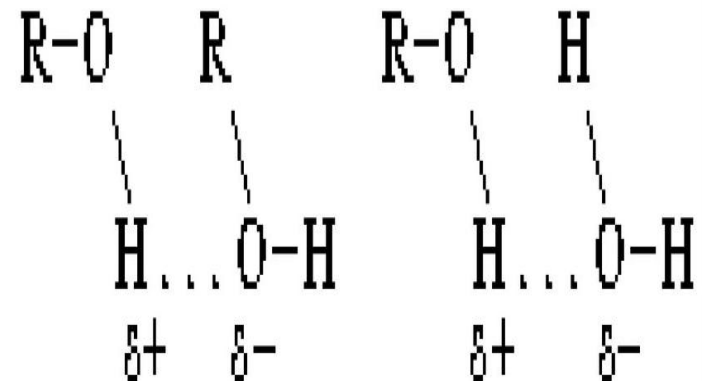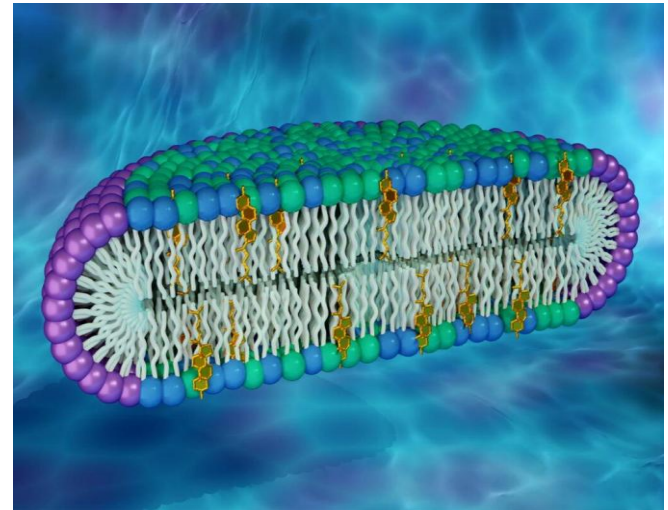
MM wave frequency range: Fröhlich Hypothesis 1968

Cells have a membrane of about some microns. This thickness which maintains a very strong dipolar layer. From the point of view of physics complicated shape of a cell surface, local vibrations of a part of the cell membrane are feasible such that the positive and the negative part of a particular section of the membrane vibrate against each other leading to an oscillating electric dipole. Its frequency is of the order 10^{11}-10^{12} sec^{-1} if a sound velocity in the layer of order 10^5-10^6 cm/sec perpendicular to the surface is assumed.

проводник

(+)(+)(+)(+)(+)(+)(+)(+)(+)(+)(+)(+)(+)(+)(+)(+)(+)

$l = d$ Мембрана – диэлектрик ε

(-)(-)(-)(-)(-)(-)(-)(-)(-)(-)(-)(-)(-)(-)(-)(-)(-)

MM wave frequency range: Fröhlich Hypothesis 1975

In living organisms, due to the presence of metabolic energy,

can be generated coherent vibrations and the energy of chaotic thermal vibrations can be converted into the energy of coherent vibrations.

The existence of coherent electric vibrations in the 10^{10}-10^{12} HZ region has now been established experimentally for biologically active microorganisms.

It is shown that such vibrations might play a decisive role in the control of growth of tissues.
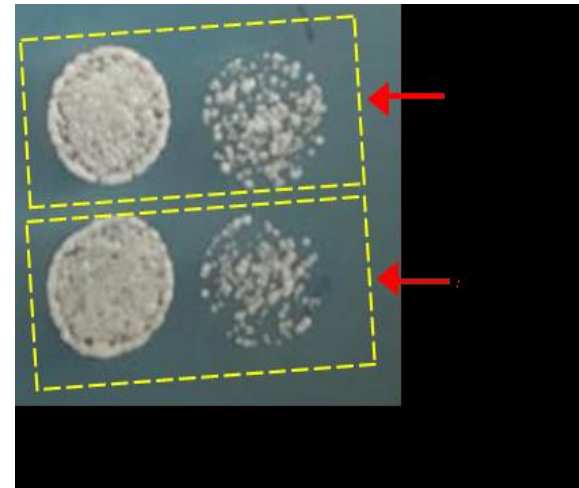
Irradiated wild type (WT) cells. It can be seen from the figure that the colony growth rate of yeast cells the growth rate of WT yeast Saccharomyces cerevisiae could either be decreased (~29%) or increased (~15%) upon MMW exposure within 41.8-42.0 GHz

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MM wave frequency range: Fröhlich Hypothesis 1978

The electric vibrations with frequencies of the order of 10^{11}– 10^{12} Hz should be excited coherently in active biological materials through metabolic processes. The given frequency range is to be considered as a very rough order of magnitude. It thus borders closely on the now accessible microwave range. Excitations of the proposed type could have far-reaching biological consequences, for they would lead to selective long-range interactions which probably are required to control growth in normal tissue and whose absence might lead to cancer.

$$\omega_\pm^2 = \frac{1}{2}\left(\omega_1^2 + \omega_2^2\right)\left[1 \pm \left\{\left(\frac{\omega_1^2 - \omega_2^2}{\omega_1^2 + \omega_2^2}\right)^2 + \frac{M^2}{R^6}\right\}^{1/2}\right]. \quad (1)$$

Here, for given displacements of the oscillators, M/R^3 measures the ratio of the interaction energy between the dipoles and of their individual potential energies. Thus as long as the { } bracket is small compared to unity,

$$\omega_\pm = \left(\frac{\omega_1^2 + \omega_2^2}{2}\right)^{1/2}\left[1 \pm \frac{1}{2}\left\{\left(\frac{\omega_1^2 - \omega_2^2}{\omega_1^2 + \omega_2^2}\right)^2 + \frac{M^2}{R^6}\right\}^{1/2}\right.$$

$$\left. - \frac{1}{8}\left\{\left(\frac{\omega_1^2 - \omega_2^2}{\omega_1^2 + \omega_2^2}\right)^2 + \frac{M^2}{R^6}\right\} + \cdots\right]. \quad (2)$$

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MM wave frequency range:
Fröhlich Hypothesis 1978

- **Frölich hypoteses.**

The absorption length of photons with the frequencies of microwave and MM wave frequencies (10^{12}-10^{13} Hz) corresponds to the intracellular distance at the cell density of $5 \cdot 10^8$ cell/ml. Frölich advanced Hypothesis states that cells are able to recognize each other at a distance and be attracted or repelled. Such photons may be involved in cell-to cell communication according to the electromagnetic mechanism and in agreement with the prediction of Fröhlich that bio-systems support coherent excitations within frequency range of 10^{11}-10^{12} Hz [8,18,23-26]. A second important part of the hypothesis is the vibrational model: trigger action of microwaves causing the excitation of coherent electric vibrations pumped by energy derived from metabolism. [8,18,23,26].

Alexander Sergeevich Davydov -"Davydov's soliton" 1973.

- **Energy along the molecular chain of a protein is carried not by an electron, but by a soliton - a quantum of the electromagnetic field of the terahertz range. The vibrational energy of the molecular chain is converted into a soliton by linear oscillators in the chain - the atomic group AMID - I (C=O) in the peptide group, the energy**

- **vibrations -0.18 eV (absolutely close to the energy transferred by the ATP molecule).**

- **Solitons are transported along the molecular chain without interacting with it, i.e. without loss of energy.**
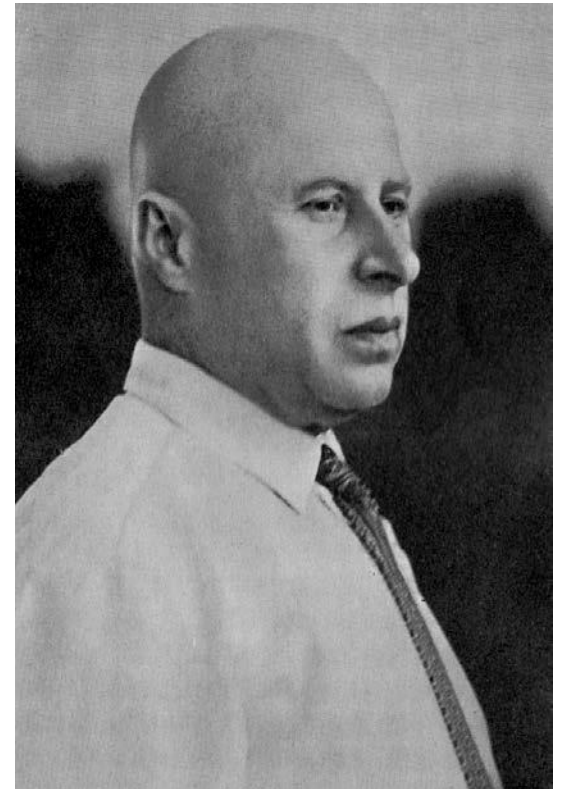
# The hypothesis of Holant Betsky Devyatkov wave range frequency for inter- and intra-cell communication

Natural background electromagnetic field

Natural sources of background electromagnetic field consist mainly of objects of cosmic origin: radio emissions from the sun and planets, relict radiation, and noise from atmospheric events. Background microwave radiation—Relict Radiation—is Cosmic Radiation with a spectrum of the background radiation of the Universe in the shortwave radio band (in cm, MM and sub-MM waves). The main contribution to the energy density is made by radiation with wavelengths from 6 to 0.6 mm), are observed at frequencies of 1.2, 3, 9.5, 35 and 70 GHz, raising the total activity by 30%. But electromagnetic field with Wavelengths less than 3 cm is absorbed by resonance in the atmosphere.

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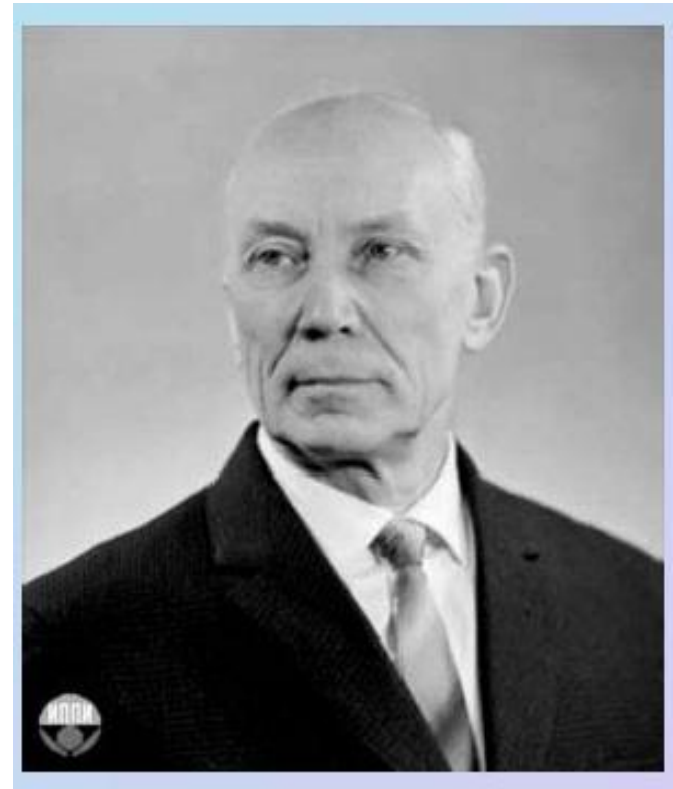
Gurwitsch mitogenic radiation

In 1912, Gurwitsch borrowed the term "field" from physics and applied it to biology in his published theory of embryonic development (Gurwitsch, 1912, 1922). Alexander G. Gurwitsch did experiments with onion roots (Gurwitsch, 1923). He monitored the number of mitoses in a set of chemically isolated onion root cells that were in the vicinity of a group of actively dividing ells (Gurwitsch, 1923, 1924; Gurwitsch and Gurwitsch, 1924). He observed a significant rise in the number of mitoses if detector roots were separated from actively dividing roots by quartz glass but not by normal glass. The fact that UV light can pass through quartz but not regular glass suggested the existence of a form of cellular radiation of an electromagnetic nature which he named "mitogenetic radiation".
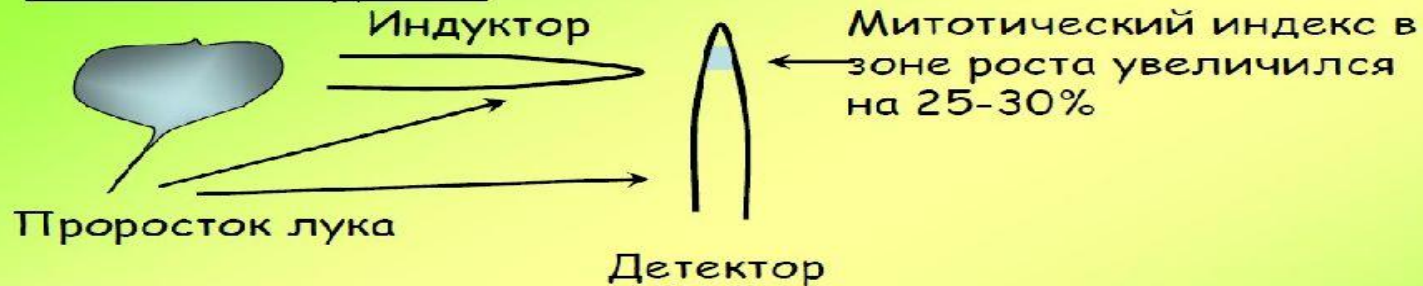

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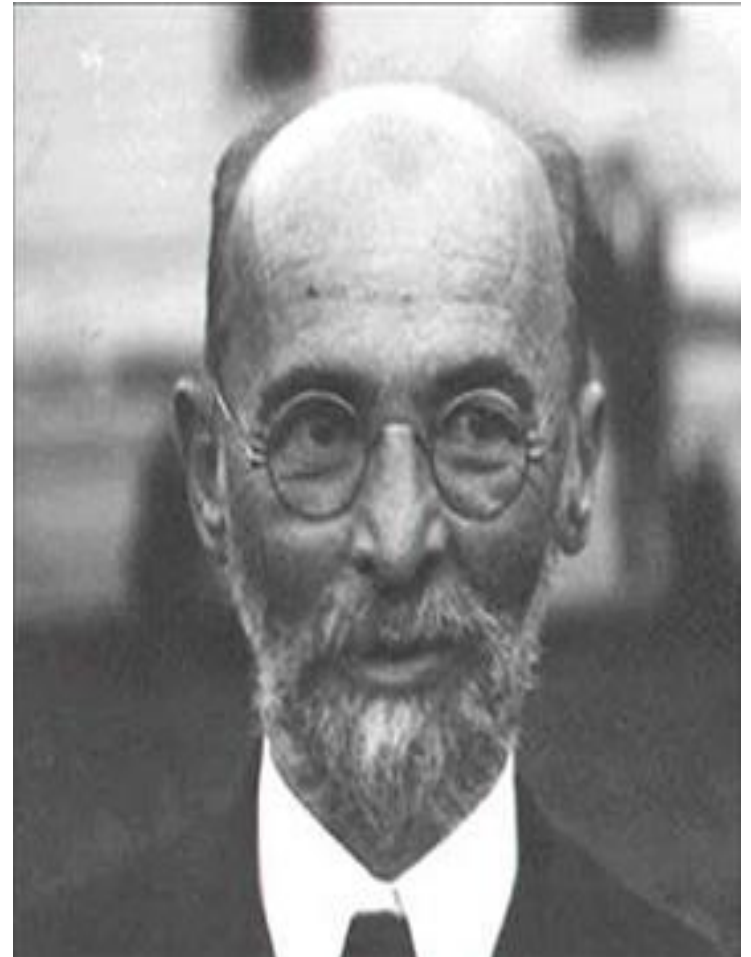
Gurwitsch mitogenic radiation

This study was the first to suggest that the emanation of light is not an incidental property of cells but one that might have relevance to signaling

The hypothesis of Golant Betsky Devyatkov wave range frequency for inter- and intra-cell communication

And radiation in the MM wave band penetrating from space through the windows of transparency can be considered to be the primary radiation. **During the evolution of all living bio-objects in Our Earth Cosmic radiation radiated our Earth with the all frequencies of electromagnetic spectrum, except some frequencies in MM wave range.**

The absence of coherent oscillations in the MM wave range in the natural environment – the absence of noise – would make that frequency band convenient for inter-and intra cell communication [1,4,8,18,23-26].
MM wave range frequency band is the most convenient for inter- and intra-cell communication.

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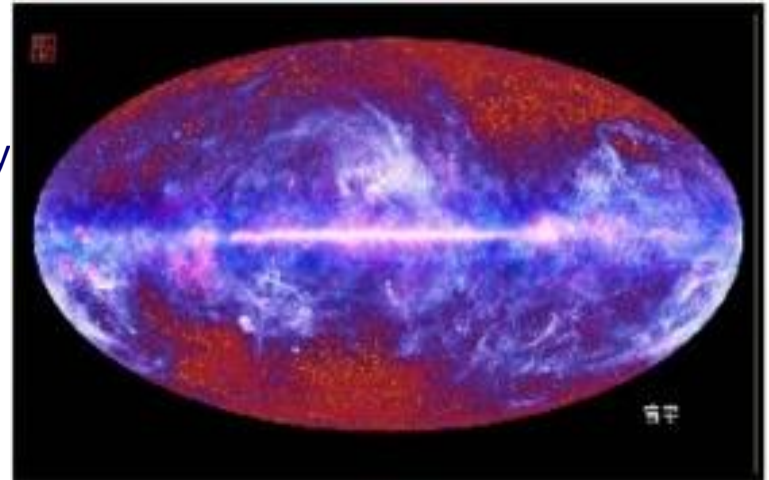
Resonance frequencies of bio-objects in MM and subMM wave frequency ranges

- The approximate resonant frequencies in Hz have been determined experimentally for a few structures in living cells [126-128]:
- somatic cell – 2.39×10^{12};
- somatic cell nucleus – 9.55×10^{12};
- mitochondria from liver cells – 3.18×10^{13};
- human cell genome – 2.5×10^{13};
- interphase chromosome – 7.5×10^{11};
- metaphase chromosome – 1.5×10^{13};
- frequency of vibration of its own membranes, 10^{10}-10^{11} Hz;
- erythrocyte – $(3.5-4.0) \times 10^{10}$,
- cytoplasm and extracellular medium relaxation time 10^{11}-10^{12} Hz.

Water spectrum
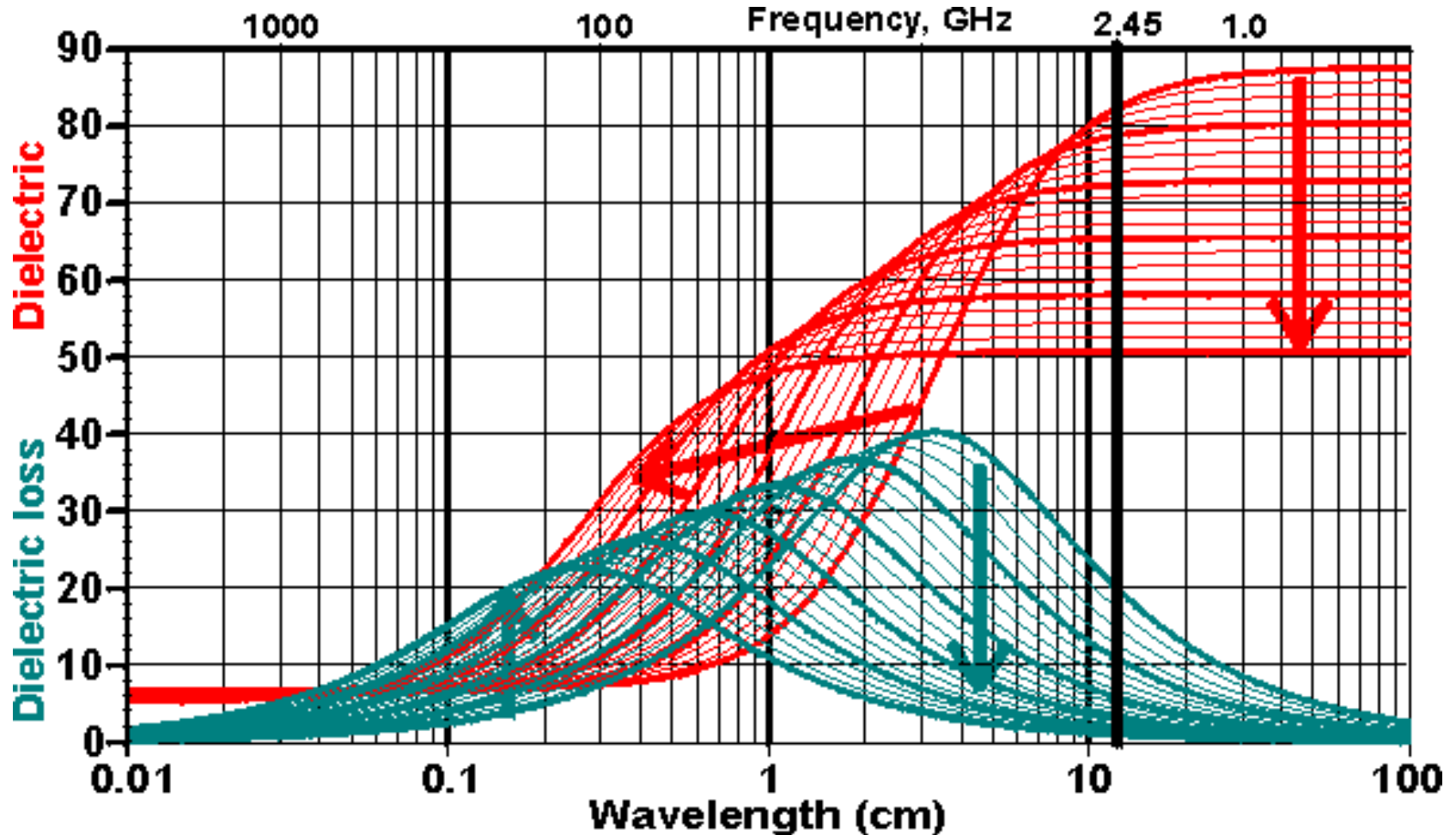
Absorption of water in the MM wave range

- $P(z) = P(0)\exp(-\alpha z)$

- $\alpha[dB/cm) = 4.34\ \alpha[1/cm] = 54.6kc/f$

- $c = 3 \times 10^{10}$ cm/s

- $\alpha[water] = (200 – 400)dB/cm$ at frequencies $(3 – 15) \times 10^{10}$ Hz = (30 -150) GHz (which corresponds to wavelengths of $\lambda = (10 – 2)$ mm)

- Electromagnetic oscillations of low intensity in the millimeter wavelength range have a significant impact on the vital activity of various organisms.

- The primary target for millimeter wave electromagnetic radiation is water molecules (H_2O), which strongly absorb millimeter radiation.

- Indeed, water performs extremely important functions in the vital

- activity of biological objects and the human body.

-

Dielectric properties and absorption of water in the MM wave region
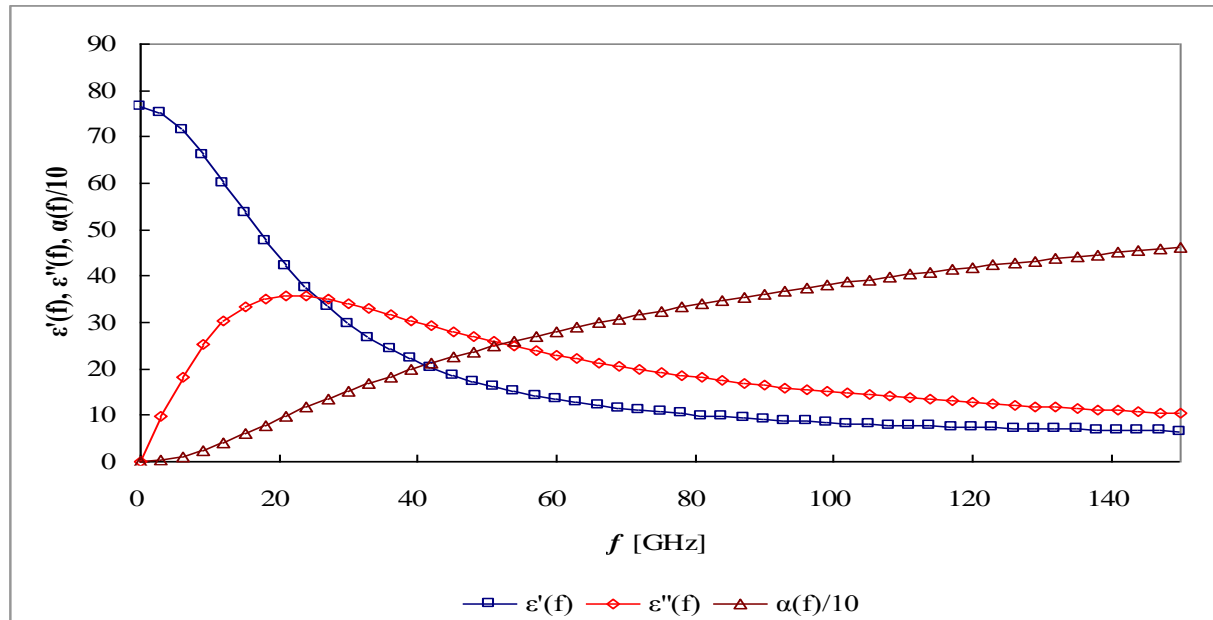
Fig.2 shows frequency dependencies of complex permittivity $\varepsilon = \varepsilon' + i\,\varepsilon''$ and absorption coefficient α= [dB/cm] = 4.34 α [1/cm] of water in the microwave and MM ranges. One can see that in the MM range absorption in water much more than in the microwave range: α =[water] = (200 – 400) dB/cm at frequencies (3 – 15) x 10^{10} Hz = (30 -150) GHz (which corresponds to wavelengths of λ = (10 – 2) mm.

Water and MM waves

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- erythrocyte – $(3.5\text{-}4.0) \times 10^{10}$,
- cytoplasm and extracellular medium relaxation time 10^{11}-10^{12} Hz.

Evidence of those hypothesis

➢ H. Frohlich formulated a hypothesis stating that energy in cells was not thermalized but instead stored in molecular vibration modes.

➢ According to his theory, coherent dipole vibrations generate an electromagnetic field that is used for long-range interactions between cells using water as a medium.

➢ This effect should be visible at normal temperatures and occur in all living things.

➢ Specifically, Frohlich's Hypothesis states that cells are able to recognize each other at a distance and be attracted or repelled.

➢ A second important part of the hypothesis is the vibrational model: trigger action of microwaves causing the excitation of coherent electric vibrations pumped by energy derived from metabolism. [Fro81].

➢ Radiation of many biological effects with millimeter waves in the frequency region of 5×10^{10} Hz show sharp frequency resonances and have nonthermal effects on many biological activities. [Fro75].

Evidence of those hypothesis

➢ It was studied and shown that there are

➢ Physicochemical Effects
➢ Influence at the Subcellular, Cellular and Tissue Levels
➢ Effects on Human Erythrocytes
➢ Effects on Growth Rate
➢ Effects on Proteins, Chromosomes and Genes
➢ Effects on Membranes
➢ Influence at the Organism Level

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MM wave therapy (MMWT)

- Most known and studied is low-intensity (<20 mW/cm^2) MM wave therapy [1-7].

- Most sensitive systems in the human body: nervous, immune, endocrine and reproductive.

- MM wave therapy (MMWT) is a new and effective method for treatment of many diseases: cardiovascular, musculoskeletal system diseases, pathology respiratory and neuro-endocrinological diseases.

- Between neurologic, neuropsychiatric, neuro-endocrinological disease are: diabetic sensorymotor polyneuropathy [10], different pain syndrome [12-16], neuropathy of the facial nerve, trigeminal neuralgia, cerebral palsy [1-14,16,17,19,20], autonomic nervousystem diseases, atopic dermatitis and psoriasis [21, 22] etc.

- **Application of MM wave for therapy many times more effective by application MM wave energy:**

- in **biologically active (acupuncture) points** is than in other parts of the skin [1-7,32,33].

- **within specific frequency windows**: 51.62-51.84 GHz, 41.25-41.50 GHz **that are exactly missing in natural background electromagnetic radiation [1-7, 18-22]**

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Why MM wave therapy can treat?

The medical effect of MMWT is not exactly known, but there are many investigations that show that therapy effect can achieved through some different mechanisms:

- biochemical reception, that is a reception at a cell level, presupposes secreting the inner medicine [1-7].
- a sensory reception, that is a reception at an organism level, in aimed at optimum activity of one's brain [1-7]. .
- absorption of MM wave radiation by water molecules in human skin that result in biochemical reaction and further activation of neural receptors in skin [36].
- resonance absorption of MM wave energy by membranes or nerve ending
- the hypothesis of coherent excitement and interaction [18],
- the informational hypothesis [34],
- the hypothesis on the soliton mechanism of energy transmission [35]

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MM wave provide therapy and diagnostic over skin

- The skin provides a number of vital functions including protection, interaction with the environment, production of hormones, movement of electrical forces, and homeostasis. It keeps the body at a constant temperature and envelopes a volume conductor and resonant cavity.
- Skin appendages include nerves, hair, nails, sebaceous and sweat glands. Skin deforms and reacts neurologically in response to the application of forces and when removed, recoils.
- This helps the body interact with its environment. Therefore, a thorough understanding of both normal and abnormal skin presentations provides necessary support for clinical diagnosis and treatment.
- The human body is full of electrical signals which can be picked up on the skin and analyzed.
- These signals come from metabolic respiration, nerve impulses [GSR], muscle contractions [EKG, EMG], piezoelectric effects of bone and skin; and brain activity [EEG].
- In Traditional Chinese Medicine therapy and diagnostic were provided over skin (acupuncture, acupressure, massage, etc).

- **Interaction of MM wave with skin provides methodological basic for MM wave Therapy and Diagnostic over skin.**

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Evidence of those hypothesis

In many of the studies summarized in the previous chapters, effects markedly different from those caused by heating have been found; in others, the power of **MM wave radiation was too low to cause thermal effects.**

Influence of MM wave on cell and nervous system

Among the possible cellular targets for MM wave in the upper layer of the skin, are keratinocytes, mast cells, melanocytes, Langerhans cells, and free nerve endings. Direct interaction between MW and neurons of various organisms has been shown to result in significant changes of neuronal activity [27-31].

Previously the studies have shown that MW had depressing effect on cell membrane excitability and chemo-sensitivity, which were realized through cell swelling [11]. At the same time it is known that cell pathology is accompanied by cell over hydration [12-14]. The fact that neuronal hydration brings to the increase of its excitation, in the result of increasing of the number of ionic channels functioning in membrane [15], the over hydration induced over-exitation of neurons was suggested as the main mechanism of pain (nococeptive) signal generation [16, 17].

MM wave radiation causes bio-resonant modification of only certain structural units of cells, which are able to absorb the given radiation with the given frequency. By changing the value of the membrane potential in various populations of immuno-competent cells, functional restoration of specific receptors for hormones, neuromediators and neuro peptides is accomplished, which can lead to various changes in neurons and glial cells.

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MM wave diagnostic system at acupuncture points and meridians

- In many investigation [46-52] it were shown that electro-physical properties (GSR, skin electroimpedance/electro-conductance) at acupuncture points and meridians strong differ from its in other skin points.
- In 1950 Nakatani [53] in Japan had found that electrical properties of skin at meridians of patients with some diseases differ from healthy patients.
- Then in Germany Voll [54-56] had elaborate special diagnostic system using measurement of electro-physical properties of skin meridian and acupuncture points. (VEGAtest).
- This diagnostic system was improved during the 1970s, another German practitioner, Dr. Schimmel [57-62] by elaboration of diagnostic systems of many diseases, influence of food, drugs, sport etc on health using measurement of electro-physical properties acupuncture points and meridians.
- These diagnostic are wide studied and used in many countries [63-68].
- All these measurements were provided at ac current or at low frequencies.

MM wave diagnostic system at acupuncture points and meridians

- But ac/ low frequency impedance depends very sensitively on measurement conditions such as the shape, size, material, and contact pressure of the electrodes, the applied current, etc [70,71].

- Non contact measurements give much more accurate results. Thus elaboration of microwave or MM wave measurement methods provide new generation of non-contact diagnostic without parasitic effects on electrodes.

- Besides every frequency range gives own information about human organism. Study human organism in wide frequency range is very important for understanding of origin and ongoing dynamic of diseases. MM wave frequency measurements because of access to moisture content and correlation with neurophysilogical processes is one of the most interesting frequency range for elaboration of such medical diagnostic system .

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