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Extremely low, wide frequency range pulsed electromagnetic fields for therapeutical use (WFR-ELF-PEMS)

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INTERNATIONAL RESEARCH ASSOCIATION ON THE PHYSIOLOGICAL EFFECTS OF ELECTROMAGNETIC FIELDS UNDER NORMAL AND EXTREME (SPACE) CONDITIONS (EMPHYSPACE)

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Keywords: *Electromagnetic Pulses, (BEMER-) Therapy, Extremely low frequencies (ELF), micro-Tesla*

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Abstract:
Wide frequency range pulsed electromagnetic fields applied through coils introduce a new era in electromagnetic therapy equipment. They set the standards for a promising health related application with measurable physiological effects. They secure a well-deserved place for electromagnetic field therapy in the reputable medical and clinical scientific environment. The underlying action mechanisms can be traced back to the mathematical formalisms of Maxwell's equations, which have been given insufficient consideration in the past. Analysis of these equations leads to an understanding of the physical or physico-chemical processes involved in the biological effect, which occur at submicroscopic, i.e. atomic or molecular levels. Supported by the discrete spectral Fourier analysis of the time sequences, which are narrowly limited in frequency during conventional treatments with the various sinusoidal, sawtooth or trapezoidal fields applied, it could be expected and has been verified through the experiments presented here for the first time, that wide frequency range applied fields will provide optimized therapy.

Electromagnetic field therapy

Terminology

It is basically the aim of electrotherapy or magnetic field therapy to influence the organic state of the body through appropriate electric and/or magnetic field effects, so the body may be classified as „healthier" after treatment than prior to. In this context we disregard the extremely problematic quantification of the state of health, which, at best could be only partially correlated to age- and sex dependent standard values. In the following, the healthier state should be understood in simplified terms, for example, as an obvious improvement in the healing process of a wound or fracture, or an improvement in a chronic disease, that is related to the use of therapy. It could als be a stabilization of potential diseases or general wellness. Both electric and magnetic forms of therapy are based on the same physical action mechanisms, and the differentiation made until now eventually depends on whether the emphasis of the treatment is placed on the electric or the magnetic field. Since in practice mainly time variable fields are applied, and because both field forms are mutually dependent, as described in detail below, the general term **Electromagnetic Field Therapy** should be utilized instead of the terms *Electrotherapy* and/or *Magnetic field therapy* (see below).

Problems

Too many speculations

Measured by the various success stories ascribed to electromagnetic field therapy, especially with applications of extremely low time-varying fields with sinusoidal sequence in the frequency range of > 0-3.000 Hz (**e**xtremely-**l**ow-**f**requency or ***ELF*** range), not much confidence is placed in these forms of therapy. There are numerous reasons for this. It is of considerable importance that the introduction of this form of therapy did not originate, as is usual, in the scientific exploration of the underlying mechanisms, but was stated by laymen, more or less based on information that was scientifically inadequate and not very reliable. This information often includes unedited articles in the daily press, simple journals and books, often disregarding any scientific foundation and reliable proof, as well as the uncontrolled distribution of therapy successes praised too generously in advertising material.

Poor description of the experiments

Considering the increasing number of sometimes excellent publications, currently about 2000 per annum, the problem, however, is not due to a lack of scientific activity in the field of analysis of the influences of electromagnetic fields on biological systems. The problem rather arises from the apparent contradiction between different presentations and the relevant interpretations. There is also the fact that interpretation of the results is based on far too generous speculations. Especially in the cases lacking an exact description of the stimulus situation, i.e. the experimental setup, the performance of the experiment, like forms, durations and intensities of the applied fields and the evaluation of the results. This applies in particular to the debate on the very controversial results of epidemiological studies.

Fundamental knowledge

In conjunction with the complexity and the difficulty of the subject matter, the reluctancy in the scientific medical application of electromagnetic field therapy may mainly be based on the fact that those who would actually be entitled to actively study the problem of electromagnetic field therapy prefer to avoid it due to their profession. This is expressed without any reproach, because they lack the necessary basic physical knowledge on electromagnetism in their basic medical training. This far a detailed knowledge on the focal subject of *Physical Therapy* is merely asked from physicians obtaining specialized degrees. (Drexel et al 1998; Carpenter and Ayrapetyan 1994; Polk and Postow 1996).

Purpose

The purpose of this scientific paper is to make the basic physico-chemical and physico-physiological action mechanisms more accessible to those interested in the use of the electromagnetic field therapy in a simplified form. By, at great extent,excluding the presentation of highly complex mathematical relationships, it is rather intended to give an understanding of the underlying mechanisms of the electromagnetically induced biological effects. Emphasis is therefore placed on the model. The mathematical formalisms (?), in particular *Maxwell's equations*, are kept in the background, and merely used to explain and create a connection to additional literature (e.g. Kafka 1999, *Biological effect of electromagnetic fields* (*Biologische Wirkung elektromagnetischer Felder);* literature database with more than 1,000 references including around 700 abstracts or full texts and/or comments in original language).

The physical laws will first be introduced, then applied to the atomic, molecular and ionic physico-chemical interaction and reaction mechanisms of free and condensed matter. They will then be discussed in relation to their effects on the physiological reactions occurring in the submicroscopic area, which in the end determine the complex interplay of physiological body functions.

Taking into account the factors that decisively influence physiological chemistry on one side, and the consequences deriving from the time dependence of Maxwell's equations on the other, it is found that for positive therapy outcomes it is generally better to influence the physiological mechanisms through applying a spectral stimulation which contains as wide a range of frequencies as possible. This is far better than stimulation through, for example, the sinusoidal, rectangular, sawtooth or exponentially formed variations of magnetic flux used previously, as these signals have highly restricted frequency response. Using discrete (spectral) Fourier analysis (***DFT***), different signal patterns are compared with regard to their spectral components, and effects induced through broad band frequency stimulation supported by physiological measurements. For a detailed presentation of the appropriate measurement methods (infrared thermography, non-invasive infrared plethysmography of the heart circulatory system, non-invasive spectral white light reflection analysis in the micro-capillary area, neuronal electro-physiological recordings) and their results, other sources should be consulted.

The demand for an appropriate extended definition of dosage, which is important for the legal standardization of medical tolerances, arises as an important side result - not just through the analysis of the undesired and sadly often undocumented, but actually existing spurious frequency ranges caused by the electric-electronic configurations of the relevant medical products. - According to Maxwell's equations, the definition should contain - instead of mere data on frequencies and field intensities - also parameters on the time courses of the applied electromagnetic fields, e.g. on the spectra of frequencies as they could likewise be determined by discrete Fourier analysis.

Physical Background

Maxwell's equations as a basis for the description of electromagnetic processes

Maxwell's equations describe observable interactions between electrically charged and/or magnetic matter in physical space, which are traced back to field effects. The equations generate a formal connection between the interaction of electric and magnetic forces, between uniform – i.e. also static – and accelerated moving charges or currents under the influence of electromagnetic fields **(*cf. K1*).**

Maxwell's equations are mathematical formulations of observed physical processes, so called phenomenological functions, which cannot be mathematically derived. Their validity is more or less limited to the non-relativistic case, where the moving charge is slow compared to the speed of light.

Their contents can be summarized as follows: Each charge is bound to a mass (The references in brackets relate to the appropriate content of the equations **(1 - 6**) in **K1**): There are positive and negative charges[1]. A force exists between the charges. Equal (of equal polarity) charges repel, opposite charges attract each other. The forces and fields can be defined by their vector quantities, i.e. their magnitude in contrast to scalar quantities. A vector is additionally characterized by a (vector) direction at any physical location. Electric fields end perpendicularly at the charge surface (except for example with electric dipole radiation) **(1)**. Magnetic fields are closed – magnetic monopoles corresponding to an electric charge do not exist **(2).** Each variation in time of an electric field creates a magnetic field **(3)** and each variation in time of a magnetic field creates an electric field **(4).** The respective speed of change is crucial. The directions of the reciprocally inducing fields are perpendicular to each other and propagate in empty physical space at the speed of light $\mathbf{c_0}$ = 300,000,000 (m/s).

The penetration properties of empty physical space are defined by the permittivity (di-electric constants) **(ε_0)** for electric fields resp. the permeability constants **(μ_0)** for magnetic fields (**5, 6**). In the case of space filled with matter these values should be multiplied by non-dimensional factors (ε_r relative permittivity *(*dielectric coefficient*)* for electric fields and/or μ_r relative permeability coefficient for magnetic fields).

The description summarized in Maxwell's equations not only refers to the mobility of free electrons and ions, but also to the velocity of bound electrons in atoms, molecules, ionic and molecular structures as well as to the atoms and molecules themselves through caused or already existing polarization. This is very important for the following investigation into atomic and molecular interactions.

The effects of electric and magnetic forces

Due to the fact the charges are always bound to a mass, their velocity are subject to the laws of motion: Each mass remains in a state of uniform motion and opposes any change of motion (= acceleration **b**) with a force **(F)**, which is proportional to the mass **(*m*)** [kg] of the body **(8)** (***cf. K2***).

According to the Maxwell's equations the force **(F)** acting on a cloud ρ of charges comprising of **(n)** single charges **(*e*)** moving at a defined velocity **(*v*)** within an external electromagnetic field consists of an electric (**Coulomb force**) and a magnetic component (**Lorentz force**) **(9)**. During the process the charges are deflected parabolically by the electric field ***E*** and aligned with the electric field; while they are deflected circularly by the magnetic field ***B*** and aligned in perpendicular direction to the magnetic field (***fig. 1** and **3***).

[1]) According to a general convention the states of charge *positive* and *negative* are also associated to spatial charge accumulations: a charge accumulation of negative charges is for example positive compared with one that contains a higher concentration of negative charges.

K1 Maxwell's *equations*

Based on the physical quantities **mass (m)** [kg], **charge (Q)** [Coulomb C, ampere/second, A/s], **displacement (D)** [= charge/area (A), C/A], **electric field (*E*)** [volt/m, V/m, kgm²/s³A²], **magnetic field (*H*)** [*ampere/m, A/m*], **magnetic induction (*B*)** [Tesla = Vs/m²] and **time (t)** [*s*], Maxwell's equations describe the observable interactions (field effects) of electrically charged and/or magnetized matter within a physical space.

For a given charge **(0)** $\mathbf{Q} = \int \rho \, \mathbf{d}\tau$ with ρ as charge density within space element $\mathbf{d}\tau$ and with changes of charge accumulations occurring during small periods of time **dt**, which according to **(0a)** $\mathbf{I = dQ/dt = \int jda}$ add up to a total current **I** incorporating single currents **j** moving through small area elements **da**, the correlation can be illustrated by integral or (in brackets) differential vector forms as follows:

(1)	$\iint \boldsymbol{D}da = \mathbf{Q}$	**(div *D* = ρ)**	(Electric charges are the sources of electric fields)
(2)	$\iint \boldsymbol{B}da = \mathbf{0}$	**(div *B* = 0)**	(Magnetic fields are closed)
(3)	$\int \boldsymbol{H}dr = \boldsymbol{I} + d/dt \int \boldsymbol{D}da$	**(rot *H* = *j*+*dD/dt*)**	(Moving charges and changes of charge density create magnetic fields)
(4)	$\int \boldsymbol{E}dr = d/dt \int \boldsymbol{B}da$	**(rot *E* = *dB/dt*)**	(Law of induction, changes of the magnetic field induce electric fields)

The penetration properties of space are described by values which depend on the relevant material (the permittivity (ε_0) [s⁴A²/kgm³] for electric fields and the permeability (μ_0) [Vs/Am = kgm/ s²A²] for magnetic fields) as follows

(5a) $\boldsymbol{D} = \varepsilon_0 \mathbf{E}$ or **(5b)** $\mathbf{B} = \mu_0 \mathbf{H}$

Considering not only the macroscopic charges but also the submicroscopical ones deriving from the atomar or molecular structures these values have to be either multiplied by the non-dimensional factors ε_τ relative permittivity coefficient and μ_τ relative permeability coefficient or expanded with the corresponding values of the electric and magnetic polarizations ***P*** or ***M*** respectively.

(6a) $\boldsymbol{D} = \varepsilon_\tau \varepsilon_0 \boldsymbol{E} = \varepsilon_0 \boldsymbol{E} + \boldsymbol{P}$ or **(6b)** $\mathbf{B} = \mu_\tau \mu_0 \boldsymbol{H} = \mu_0 \boldsymbol{H} + \boldsymbol{M}$

Material with μ_τ >> 1 (iron, cobalt, nickel) are named ferromagnetic. They strengthen the field by causing a concentration of the field in the matter. Material with μ_τ > 1, for example platinum, aluminium, air, are named paramagnetic, those with μ_τ <1 (copper, glass) are named diamagnetic. Both strengthen or weaken the outer field only slightly; compare equation (5). The relative permittivity values (relative permeability values in brackets) are
$\varepsilon_{r\,=}$ 80 ($\mu_{r\,=}$1) for water, $\varepsilon_{r\,=}$ 3-4 ($\mu_{r=}$1) for wood and approx. $\varepsilon_{r\,=}$ 60 ($\mu_{r=}$1) for human or animal tissue. Accordingly human and animal tissue virtually does not impede (influence) magnetic fields. On the other hand, electric fields are weakened by a factor of about 60. Additionally, the fact that the relative dielectricity values of individual tissue structures differ, and – referring to textbooks on pure physics - that the penetration of electric fields consequently depends on the size and orientation of these areas. In many cases therapeutic applications should try to obtainto non-homogeneous field distributions in (***fig. 9***).

The values $\boldsymbol{\varepsilon_{0\,=}}$ **8.885* 10^{-12}** [As/Vm] and $\boldsymbol{\mu_0}$ **= 1.256*10^{-6}** [Vm/As] are connected through the speed of light $\mathbf{c_0}$ in the following interesting way: **(7) $\mathbf{c_0}$ $(\mathbf{I}/\varepsilon_{0*}\ \mu_0)$.**

K2 Electric and magnetic force

Every mass remains in a state of constant velocity **(*v*)** and opposes any change of motion (= acceleration ***a***) [m/s²] with a force **(*F*)** [Newton N, kgm/s²], which is proportional to the mass (***m***) [kg] of the body.

(8) $F = m\, a$

In connection to Maxwell's equations it can be derived for the non-relativistic case **($v << c_0$)** that the force ***F*** on a charge cloud $\rho = e\, n$ of **(n)** single charges **(*e*)** moving with a given velocity **(*v*)**, within an electromagnetic field composed of an electric field (***E***) and a magnetic field (***B***) consists of an electric **(Coulomb force)** and a magnetic component **(Lorentz force)**:

(9) $F = d\tau\, \rho\, [E + v\mathrm{x}B]$

The contents of this function displayed in vector form show that the charges are deviated in alignment with an electric field ***E*** and in a magnetic field $H = B/\mu_0$, charges are placed in a circular path perpendicular to the magnetic field lines according to equation (**6**) in **K1** (***figs. 1 and 3***).

With the equations (**0, 0a, 2**) in **K1** and the scalar description in (**9**) for magnetic force

(10) $F_{magn} = Q\, B\, v$ **(Lorentz force),**

the centrifugal force

(11) $F_{centri} = m\, v^2/r$

and from the condition **Lorentz force = centrifugal force**, the radius (**r**) results from

(12) $r = (m\, v)/(e\, B)$

depending on the charge, velocity, field intensity and mass.

With given charge, velocity and magnetic induction, the radii are larger for larger masses (***figs. 1 and 3***).

In the special case of an undisturbed motion, the respective radius of curvature depends on field intensity, charge, mass and path velocity. According to (**10, 11, 12**) larger but identical charged masses moving with a given speed are less deflected by a given field than smaller masses at else same conditions. ***(figs. 1** *and* **3).***

Practical significance
For the analysis of the molecular mechanisms occurring in actual physiological tissue, the relations described in **K1** and **K2** have to be adapted to the physicochemical conditions of the

Moving charges in an electric field and in a magnetic field

Under the influence of an electric field the charges move on parabolic paths parallel aligned to the field. The curvature depends on field intensity, velocity, charge and mass. With given charge and velocity, larger masses are less deflected.

Under the influence of a magnetic field the charge carriers move on circular paths perpendicular to the field. The radius depends on field intensity, charge and mass. With given charge an velocity, the radii are larger for larger masses.

Fig. 1*:* The movement of free charges (+ and -) under the influence of electric **(*E*)** and magnetic **(*B*)** fields

physiological reaction medium. This would especially concern as well the velocity distribution (temperature) and steric dimensions (volumes) of the involved masses and charges as their mutual interactions on one side and the time variations and densities of the applied electromagnetic fields on the other. It is obvious that any attempt to analyze such a complicated system in detail will a priori be doomed to failure. The study and analysis of the mechanisms of physiological reactions occurring under the influence of electromagnetic fields is mainly left to an evaluative discussion of the presented equations.

Field types: Continuous field – Alternating field – Pulsed field symmetrical to the reference line and asymmetrical to the reference line

Zeit = time, field type, magnetic induction

Fig. 2: **Examples of conventionally applied electromagnetic field patterns during Electromagnetic Field Therapies.** From front to back: Continuous field (for example permanent magnets); alternating fields: symmetrical to the reference line sinusoidal; asymmetrical to the reference line (=*na*) sinusoidal pulsed; *na*-rectangular or *na*-trapezoidal pulsed; *na*-sawtooth pulsed alternating field.

The application of ELF fields

The selection of the time course of conventionally applied therapeutical field intensities.
Concerning the electromagnetic therapies as they are normally applied at extreme low frequencies (**ELF**), the relevant fields are either created by permanent magnets (static field) or by current-carrying coils (static and/or alternating field). Depending on the interference with some given static fields, we have to discriminate between more or less asymmetrical field distributions in reference to a given zero-field baseline (***fig. 2***). The above mentioned term *Magnetic field therapy* can be seen to originate from such static magnetic fields. [2)] [3)]

As far as can be understood, the hitherto utilized time courses of therapeutical applications of electro-magnetic fields can mainly be traced back to the time courses of internal bodyfunctions or external physical influences.

Among the intra-corporeal functions there are for instance the electric potential variations in the magnitude of 30-100 mV which derive from individual body, nerve and muscle cells at time intervals of milliseconds to seconds (e.g. the generator and action potentials of nerve cells, or the evoked potentials of the central nervous system known as α, β, χ (Gamma?), δ waves), as well as those, which partly arise from individual oscillations, pulsation, motion rhythms or endocrinologically conditioned activities and reaction processes. Among the extra-corporeal fields there are, for example, the circadian fluctuations of the terrestrial magnetic field and gravitation, the voltage fluctuations linked to climatic changes as well as the activities of solar and cosmic radiation (spherics).

[2)] Due to the almost loss-free penetration of magnetic fields through biological objects as described above and thus due to the lower energy transfer to the penetrated biological material in comparison to electric fields, even the term *Electrotherapy* would be justified (*see above „Terminology*“).
[3)] Furthermore, these terms should not be mixed up with the terms of *electromagnetic* and/or *non-ionizing radiation* since radiation interactions take place only if the wavelength of the radiation is at least in the geometrical order of the receiver. In the given cases, however, even in the upper end of the ELF-spectrum with alternations of the magnetic flux at f = 3,000 cycles per second the resulting wavelength λ ranges far above body dimensions at a length of 100 km according to $\lambda = c_0 / f$ 300,000/3,000 [s*km/s] and c_0 = 300,000 km/s!

Based on thus electromagnetic fluctuations - irrespective of their real functions - the conventional therapy tries to influence the above mentioned „*physical disharmonies*“ by applying sinusoidal, sawtooth resp. trapezoidal pulsed fields, in order to restore or to maintain a so-called *physical energy required for controlled body functions*. In addition to the missing relevance to body functions the applied signals are often additionally disturbed by inadequate technical completions of the stimulus systems with high-frequency spurious components, which, if they refer for instance to the range of microwaves, should definitely not be ignored. Anyhow, it remains open in such cases wether an achieved success is based on the expectation placed on the form of stimulation.

The resultant biological effect

The ideal case: Free undisturbed motions of differently coupled charge carriers

If the affected system is independent of the actual conditions considered as an accumulation of free moving charge carriers, the charges would move in the applied sinusoidal magnetic field on segments of circles perpendicular to the field according to the above discussed Maxwell equations. With a given field direction the positive charge carriers move opposite to the negative charge carriers thus, depending on the mass and velocity of the charge carriers (***equation 9-12*** and ***fig. 3***), leading to a variation of the respective distances. The distances are additionally influenced by the electric fields according to equation (**4**), which guide the charges on an additionally parabolic path component. Under the influence of periodically alternating electromagnetic fields the charges thus move evenly on sections of a kind of spiral path. During the alternating periods the distance between the charge carriers can accordingly increase or decrease, thus leading, at appropriate periods of the applied fields, to certain resonance phenomena (cyclotron resonance, ***fig. 3***).

A similar situation applies within fields which are pulsed asymmetrically to a given reference intensity. Here, the charge carriers are subject to an additional drift motion depending on the degree of asymmetry. Under the influence of such asymmetrically pulsed fields this drift can create electrical potential differences which (see below), once again depending on mass, charge and mobility of the charge carriers, might influence membrane potentials and membrane potential activities. In agreement with practical experiences, however, the electric activity of nerve cells will only be influenced by magnetic inductions in the order of some 10,000 μ-Tesla (Kafka 1999, *Biologische Wirkung elektromagnetischer Felder/Biological effect of electromagnetic fields;* literature database). A direct influence of biological sensory membrane potentials (for example through facilitation) through the normal therapeutically applied field intensities is therefore not to be expected.

If, however, the charge carriers are not individually free moving, but connected to each other by any kind of binding forces, as for example in polar molecules with asymmetrically distributed – e.g. lipophilic or hydrophilic – electron cloud structures, the electromagnetic forces described above may act on the binding system as a whole. Under the influence of the electromagnetic field, side motions occur around a center of motion lying between the charge accumulations, which depends on the respective mass and charge ratio. Depending on the inner flexibility of the charge carrier system, the structural geometry (conformation) of the coupled system may also be affected according to the explanations given before leading to the different types of electromagnetic polarizations (as for example subatomic and submolecular dispersions, as well as the effects of *electroporation* = perforating of membranes under the influence of high local electrical fields).

Fig. 3: **Side motions and conformation changes of coupled charge configurations in alternating electromagnetic field.**
The combination of parabolic and circular deflections may cause molecular conformation changes through extension or compression of the charge configuration along the dotted line (***cf. fig. 6***).

Here, similarly to the situation described above, resonances may also occur at appropriately selected periods of the applied fields (including the material which is bound to the charge carriers as for instance hydration shells).

The physical case: Disturbed free movements

Transposing the above considerations onto the case at hand, i.e. a biological system filled with matter and, particularly, with structured space, the inevitable interactions due to the movement of additionally available ions, molecules and molecular combinations must furthermore be considered. To these belong the mechanical processes of temperature and volume dependent momentum transfer through molecular collision (under normal conditions depending on density, e.g. $>10^{10}$ - 10^{19} collision/s) and the closely associated processes, which, depending on the respective electron configurations, lead to physical and chemical binding interactions or which can at least influence them.

(Anzal von Kollisionen pro cm3, Liter oder m3? Gunnar)

Electromagnetic field effects and physical-chemical interaction: reaction mechanisms and activation energy.

Chemical or physical reactions (= weak interatomic or intermolecular interactions) are basically determined by the energy level of the electrons of the outer electron shell of the interactive partners. These are initiated by increasing the energy levels (activation) upon collision. If the energy thus transferred exceeds a certain value (activation energy) then, through the creation of a new electron configuration, a common lower energy status may be attained for both collision partners ***(fig. 4)***. Both interacting partners may enter a new bonding state time-dependent upon the addition of more energy.

Selective interaction
Key-lock

Fig. 5: **Selective interaction (Molecular fitting).** The selectivity of bonding mechanisms is very much dependent upon the precise joint (cooperative) convergence of sub-molecular bonding locations in space and time. The analysis of the structural activity relationships of physiologically important enzyme and signal agents is a focal point of pharmaceutical research.

Activation energy is accordingly also described as the driving force for physical-chemical reactions.

Activation, that is the triggering or acceleration of bonding reactions, can be effected by increasing the collision rate – i.e. by supplying heat – and also by catalysts, i.e. through defined, mostly highly selective reactive chemical substances, which themselves do not appear to participate in the reaction. This especially includes enzymes, which are distinguished by their high selectivity and sensitivity, as well as molecular signals and hormones which are highly effective in low molecular quantities. Numerous investigations on the pharmacologically and physiologically important structure-activity relationship have shown the decisive importance (f***igs. 5, 6, 7)*** of an appropriate functional (geometrical and electronic), as well as a timely well coordinated (cooperation) fitting at defined reciprocal submolecular active sites (key-lock principle).

Fig. 4: **Activation energy ↑**. Bonding as a result of activation and subsequent generation of an electron configuration that is energetically more favorable for both interacting partners.

Sterically hindered *Sterically unhindered*

Fig. 6: **Influence on the reactivity due to conformational change.** The *molecular fit* discussed in ***fig. 5***, here for example, associated with the release of a molecular signal, is often the result of previous conformational changes. (cf. length and direction of arrows).

The activation described leads to an increased rate of turnover but not to a displacement of the reaction equilibrium. The reaction processes are therefore only assisted, i.e. the likelihood of bonding reactions is increased.

Corresponding to the discussed effects on molecular structures, it should be possible to influence the likelihood of reciprocal molecular fitting through suitable electromagnetic field activities, and in the end help to raise reaction readiness. This is particularly relevant for reactions in membrane regions, in which free motion is in any case limited due to intermolecular binding mechanisms [4)]. Purely thermal activation could thus be supported by suitable periods of electromotively governed intramolecular conformation and side motions. Depending upon the periodicity of the influencing fields and charge, mass, volume as well as inner flexibility and/or electron configuration, the reactionary readiness of the various interactive systems might consequently be increased through excitation of various molecular resonance states.

Spectral bandwidths
Discrete Fourier Analysis
The above remarks suggest that successful therapy attained with conventional systems can actually be traced back to stimulations with empirically chosen periods specifically tuned to activate a variety of molecular interactions.

Measured against the conceivably large number of different molecular interactive systems regulating physical body functions, only a relatively small number of molecules can be activated by individual frequencies. Stimulations with signal waveforms characterized by a wide spectrum of frequencies should therefore extend and improve the success of the therapy.

Since with sinusoidal stimulations apparently only the individual instantaneously active repetition rate contributes to the effect, and with saw-tooth and trapezoidal shaped stimulations mainly the frequency components of the rise and fall phases (***see below, and K3***), correspondingly a form of stimulation should be found which, compared with the different forms of conventional treatments, is characterized by a wide spectrum of frequency components. Referring to the molecular mechanisms during the processes of stimulation, especially those frequency components have here to be considered which result from the mutual rise and fall of the electric and/or magnetic fields according to the Maxwell equations **(3, *4*)** .

[4)] In this context it might be worth mentioning that membranes can be seen as the preferred loci for the biologically important, highly selective and sensitive receptors (!).

Such comparisons may likewise be based on the fact that any given repeated functional sequence, e.g. the time-variation of an electric or magnetic field ***f(x),*** can be quantified by combining (summing up) sinusoidal (so-called harmonic) components with suitably selected amplitude and frequency, as so-called Fourier series ***F(x)*** **(equation(*13*) K3).**

(Gunnar hat eine eigene versuch gemacht):
This comparison is based on the following mathematical description of the different signal sequences according to content of frequencies: They all depend on the principle that every signal has some kind of repetitive time-function, e. g. change of electric or magnetic fields *f* (x) through superpositioning of the sinusoidal (harmonics) amplitudes and frequencies selected from the Fourierserie F(x) (Equation (13) in K3)

Narrow band waveforms of conventional applications
As shown by the example in ***fig. 7***, the saw tooth (or exponential) and trapezoidal (or rectangular) signals applied as conventional stimulations can be simulated even by a small number (<10) of such sinusoidal harmonic components corresponding to a spectral composition of a narrow frequency bandwidth. These do not, therefore, meet our demands.

Wideband signal waveforms
An example of a function which, as desired, is composed out of a considerably higher number of harmonic components is shown in the equation:

(14) $y=x^{a}\, k(x)\, e^{\sin(b)}/c+d$

The corresponding graph and its spectral compositions analyzed by discrete Fourier Analysis referring to the following parameters is depicted in ***fig. 8*** according to the following parameters:

$(k(x)=\sim\sin(x^{f})$, here $k(x)=1$; $a=3$; $b=3$; $c=50$; $d=0{,}5$.

a

b

K3 *Fig. 7:* Discrete Fourier Spectral Time - Frequency - Analysis

Any repetitive, in short periodic, functional sequence of signals, e.g. the time variation of an electric or magnetic field ***f(x),*** can be demonstrated by a combination (sum) of sinusoidal (harmonic) components with suitably selected amplitudes and frequencies by means of a Fourier series like: **(13)** $\boldsymbol{F(x)=a_0 + a_1 \cos x + a_2 \cos 2x + \ldots + a_q \cos qx + \ldots + b_1 \sin x + b_2 \sin 2x + \ldots + b_m \sin mx}$. The individual coefficients $\boldsymbol{a_0}$, $\boldsymbol{a_q}$, and $\boldsymbol{b_m}$ (with q and m =1, 2, .., n) depend and result from the required agreement between the given function ***f(x)*** and the sum function ***F(x)***. As verified by the graphs in **a, b,** trapezoidal and sawtooth shaped signals can be fairly simulated (synthesized) by combining just a few (ca. 7) sinusoidal harmonics **(a, b)**. In analogy with the synthesis, given functional sequences of signals can vice versa be analyzed by mathematical methods like the Discrete Fourier Spectral Time-Frequency-Analysis (DTF) and hence show the vast number of frequencies. Such analyses carried out at discrete time intervals using 30 Hz **(c, d** and **e)** further confirm that the different exponential-, sawtooth-, rectangular- or trapezoidal- shaped signals, as they are used during conventional therapeutic stimulations, are merely composed from a small number of harmonic components only. (Their numbers remain usually below 10 even at a frequency of 1000 Hz). This is independent of the form and function of the signal. The intensity of higher frequencies has very little influence on the actual signal.

e

signal sequence (exponential) max = exp(2)

Time in seconds

Frequency in Hertz

signal sequence (rectangular)

Time in seconds

Frequency in Hertz

d

signal sequence (exponential)

Time in seconds

Frequency in Hertz

e

a

b

signal sequence

Frequency in Hertz

c

signal sequence discharge

Time in seconds

Frequency in Hertz

Wide band pulsed electromagnetic fields in the ELF range. Compared with the functional sequences depicted in ***fig. 7*** **(K3)** the special expression **(14)** $y=x^{a}$ **k(x)** $x^{\sin(b)}$**/ c+d** renders the desired broad band stimulations as depicted in **b** and, for its time derivative according to equations ***(3 and/or 4)***, in **c**. The graph refers to a signal realized in the ***BEMER 3000,*** with values of t>0 and k(x)=1; a=b=3; c=50; d=0.5, (functions related to abscissa). In this case as a contrast to conventional stimulations, the corresponding numbers of harmonic components range between 750 **(b)** and 2000 (!) **(c)**

Methods and results of therapeutic applications

The stimulation

Depending upon the field intensity and size of the chosen type of coil applicator, the electromagnetic stimulations take place through a very distance dependent and inhomogeneous distribution of the field intensity according to ***fig. 9***. The highest intensity is close to the body.

Fig.9: **Strongly inhomogeneous distributed magnetic field from the BEMER 3000 coil applicator mat containing thee pairs of coils. Measuements are made at the intensity level 10.** The field of ***the BEMER 3000 intensive applicator (cf. text)*** is shaped similar to one of the cones displayed in the graphs to the left, but at intensity of 100 µTesla.

According to ***(6a)*** and ***(6b)*** the field distribution and field effect can be influenced locally by material having high dielectric constant ***(ε)*** (like electrically conductive material (e.g. metal, electrolyte)) or high permeability ***(µ)*** (ferrous or ferrimagnetic materials, e.g. iron, nickel, special ceramics). In practice such material which is placed extracorporeal mainly causes a weakening of the field effect, intracorporeally placed, however, its effect can only be roughly estimated due to extremely complex geometric and specific dielectric condition of the organs.

Fig. 10: **Thermographs before and during local stimulation with an Intensive Applicator (*BEMER 3000*, Level 10 on horse and human).** The test person had already been at rest for 20 minutes prior to commencement of the experiment; color is an indication of radiation temperature. Temperature variation from approx. 33ºC (blue) to 36 ºC (red). Noticeable is the increase in temperature across a wide surface of the body despite local stimulation (***cf.*** text *Molecular signals). Left, above: Stimulus equipment* ***BEMER 3000***.

Larger amounts of incorporated magnetized or magnetizable (e.g. ferromagnetic) material or inserted electronics could lead to a disturbance due to distortion of the electromagnetic field. By maintaining the legal authorized regulations (***MedGVtreshold value 5000 microT***), as they are especially validated for the BEMER 3000 Systems, interferences with electronic inserted material (e.g. heart pacemakers of older models) can be practically excluded ***(cf. fig. 9).***

The permissible field intensities in the ***ELF***–range in Europe (in agreement with an upper limit proposed by the WHO) is fixed at a continuous charge rate of 100 -tesla. In comparison: the field strength of the earth is approx. 50 -tesla. Despite of it, in the opinion of the author, the permission of fieldintensities is sofar not sufficiently substantiated by way of biologically relevant facts.

For the experiments described below – these were all carried out using ***BEMER 3000*** signal configurations - intensities up to a maximum of 100 Tesla were applied for one-minute segments, up to several weeks.

Operationen = operations
Funktionen = functions
Frequenz-Bild waehlen = Select frequency image
Spektrum auswählen = Select spectrum
Interferogramm = Interferogramm
Hauptauswahl = Main selection

Fig. 11**: Spectral reflection (Fast Fourier Analysis).** Under the influence of the applied electromagnetic fields (BEMER 3000 Intensive Applicator, Level 4, ca. 40 -tesla) obvious changes are clearly shown to the spectral reflection properties of a human lower lip exposed with a white Xenon light as a result of possible variations in arterial blood composition.

The physical measurement of physiological field effects.

In the scope of the ***EMPHYSPACE*** research objectives, i.e. the comparative compilation of as many physiological independent parameters as possible under normal and extreme (outer space) conditions, the effects of broad band applied fields were sofar investigated in relation to their effects on thermal infrared radiation, on the characteristics of blood circulation within the micro-capillary systems (by infrared and white light spectroscopy), on heart and respiratory activity, blood oxygen and erythrocyte activity (by dark field microscopy). Even if the results are not based on extensive placebo – randomized double blind studies, the data which are presented here for the first time leave no doubt about reproducibility even under the strictest rules necessary for statistical safety. We refer to a wide spectrum of ongoing or already completed and to be published case studies of this kind with other scientific Institutes, particularly to the cooperation with the Euroinstitute for Bioenergetic Medicine of Dornbirn (Austria).

Thermal reactions

Fig. 10 shows the increase in thermal radiation of both an animal and a human body initiated by a partial body treatment with the ***BEMER 3000*** intensive applicator, at the intensity level 10 (100 Tesla) (recorded by *IRTIS Sony*, a nitrogen-cooled infrared camera system). What is noticeable is that the increase in temperature radiation indicated by the red coloration appeared after just three minutes of stimulation, and – particularly important and informative for the analysis of the underlying physiological mechanisms (*cf.* molecular signals, enzymes, hormones) – that the increase in temperature does not spread out from the point of application. The animal-human comparison is important in sofar that with humans, even after the simple process of lying down, temperature radiation strongly influenced by air movements often increases. To avoid this (placebo) effect the test series were always commenced 20 minutes after the test person has taken up the respective rest positions.

Spectral reflection analysis according to Michelson

Fig. 11 shows measurements of the spectral reflection properties of a human lower lip after a two minute lasting ***BEMER 3000*** Intensive Applicator stimulation (level 4, approx. 40 -tesla) performed firstly using a Michelson Interferometer and a subsequent Fast Fourier Analysis. The physiological mechanism of the resultant changes in the wavelength range from 300 to 1200 nm are not known. From comparing with results from other spectral reflection analyses, the effect could be related to the chemical transformation of blood composition through oxygenation. Concerning the reproducibility of data recording it appears promising to implement this recording system (originally developed for optical investigations of flies' eyes) for further studies.

Non invasive infra red photoplethysmography

Fig. 12 shows the time sequence of blood flows in the microcapillary system of a finger pad. From the area between baseline and the recorded pulses the relative blood volume can be determined, from the amplitude variation the breathing rate and from the time intervals between the pulses, the variability of the heart rhythm (as a measure of the adaptability of the circulatory system to physiologically changed physical body functions). Upon measuring and appropriately

Non invasive photoplethysmographic measurement (finger pad)

Example: Components of volume pulses (white light units)

T_P Pulse duration f = 60/T = Herz frequency

Fig. 12: **Photoplethysmographic measurement** of the pad of a finger of a 35 year old patient under the influence of BEMER 3000 coil mat applicator, level 3. (The patient had already been in a resting position for 30 minutes prior to commencement of the trial). The breathing rate can be clearly recognized by the waves envelopping the pulse registration in a). b) shows an enlargement of the pulse sequence from a).

Changes in arterial oxygen saturation in comparison to a reference value

Results report

Readings

Fig. 13: **Photoplethysmographic measurement of oxygen saturation**. (Experiment conditions as in ***figs. 10, 12).*** Oxygen saturation increased from 8 to 19% just 5 minutes after 1 min partial stimulation with the ***BEMER 3000 Intensive Applicator***. The subsequent pulse sequence is presumably caused by self regulatory mechanisms of the circulatory system. The oxygen saturation continues to increase even after completion of the stimulation (cf. Text).

calculating the reflection values of two light sources working at different color ranges, one for oxygenated (IR1) the other for deoxygenated hemoglobin (IR2), the oxygen saturation of the blood under different conditions can then be determined. ***Fig. 13*** shows the changes in blood oxygen content after a five minutes lasting ***BEMER 3000*** stimulation calculated in this way as a percentage of the value at the beginning of the photoplethysmographic recording.

Fig. 4: **Dark Field Microscopy**

Human blood before and after three minute lasting stimulations with the ***BEMER 3000***, coil mat applicator level 7, approx. 23 -tesla. Separation of the erythrocytes can be clearly recognized. (For oxygen exchange, flow speed and transportation characteristics of the blood, the immune system, the pharmacology and the impact on the heart *cf*. text).

Dark field microscopy

Fig. 14 shows dark field microscopy photographs of blood immediately prior to, and after a 3 minute session using the ***BEMER 3000*** mat applicator. An 'unpacking' of the partly thrombotic blood can be clearly observed. These findings correspond with the increased flow rate of the blood observed by the photoplethysmographically determined relative blood volumes (Kafka 1998).

Electrophysiology of the brain of a bird

Ongoing electrophysiological studies of specialized areas within the brain of birds used for the ontogenetic development of singing patterns indicate that spontaneous neuron activity will only be marginally reduced as a result of the stimulation with broad band electromagnetic fields **(according to equation (14)).** Supported by our own extensive investigations on the electrical activity of peripheral olfactory nerve cells, this is not necessarily to be seen as a result of a direct electromagnetic influence of the electrical nerve or neuron potentials, but rather due to a locally altered chemistry which is extremely sensitively registered by the neurons (cf. The above mentioned *Resultant biological effects*).

Summary and debate

In relation to sensory awareness the phylogenetic development of life has apparently only made minimal use of the numerous electromagnetic processes surrounding and influencing everything. The discovery of magnetized particles (magnetite) in birds and their potential importance for homing ability, the occurrence of bacteria containing magnetite at special geomagnetic locations, the possibility of influencing the orientation ability of insects through influence of electromagnetic fields, the investigations into weather sensitivity, represents only some of many examples, but they indicate that apart from light sensing organs or the lateral line organs found in fish, electromagnetism might be an important factor for the space-time coordination of living beings. This is a fact that has hitherto been given very limited importance. It is however noticeable that such electromagnetic processes, which are said to induce negative health effects, do not arise from the ELF-range but from the range of rapidly time-varying fields (>>10^8 cycles/s, equation (**1**)). That is, they arise from the wavelength range of microwaves, UV and gamma rays (*cf.* Federal Emissions Regulation 26, BimSch dated 20.12.1996). (Between microwaves an UV-radiation we have a wast wavelength-area containing infrared and visible light. Comment by Gunnar S) Nevertheless, studies on reporting on negative health effects caused by the influence of high current and high voltage systems operated at the ELF-range are existent. However, they are commonly strongly disputed, and must –

also in the opinion of the writer - be seen as in no way proven, due to methodological reasons. This is particularly true in view of the fact that even field intensities in the Tesla range, which since the end of the 80's have routinely been used in nuclear spin resonance tomography for periods of approx. 10 to 30 minutes, have not led to any detrimental health-related consequences. Furthermore, there are no reports of proven negative effects of the millions of electromagnetic therapy applications .

Electromagnetic fields – electromagnetic radiation

Fig 15: **Spectral Distribution of electromagnetic fields**

In this connection the successes hitherto attained using various therapy devices can be considered safe, independently of their many times inadequate, or even incorrect and speculative interpretations. Despite of the latter, most of these therapies support the underlying physical and physiological mechanisms here introduced: Broad band electromagnetic stimulations may raise the readiness to activate and start certain physiochemical processes. Similar to an increase in temperature the mentioned electromagnetic stimulation does not shift the stoichiometric reaction equilibrium – the forward and reverse reactions are affected in a similar manner – but due to greater likelihood of adjusted molecular fittings a higher rate of interactions may occur. Contrary to the temperature effect, the above mentioned electromagnetic fields might – aside their electrophoretic shift effects – influence the mutual orientations and by thus means additionally support the intermolecular fitting of highly selective and sensitive interactions. In accordance with the spectral frequency range of the influencing electromagnetic field, here, in contrast to the conventional narrow band stimulations with sinusoidal, rectangular, trapezoidal or sawtooth signal sequences, **wide band pulsed electromagnetic fields will consequently activate a considerably wider group of molecular interaction partners.**

The immediate variation of the infrared radiation of large body areas after local stimulation as demonstrated in ***fig. 10*** could arise from the widening of the vascular system of the skin or, in agreement with the results of non-invasive photoplethysmography, the microcapillary system. The widening of the vascular system of the skin, which normally facilitates heat radiation from increased body or skin temperature, is however - as easily to be verified by a comprehensible calculation comparing the necessary energy amounts emitted from the device and from the warming of the body area – presumably not to be seen as caused by the electromagnetic field energy transferred to the body or the heat producing (ATP-) metabolism, it should rather be seen as governing an amplification process via neurons and/or molecular signals. It is conceivable that there could be, for example, a thermogenic influence by hormones, for example by thyroxin produced in the thyroid glands. Particularly in connection with the increase in temperature on wide body areas, despite selective local stimulation, the raised temperature radiation could also be caused by the stimulation of cell metabolism (fats, carbohydrates, proteins, sodium and potassium) and an increase of oxygen consumption in the whole body through nitric oxide or the hormones epinephrine and Norepinephrin produced by the suprarenal glands. Analysis of the relations between the photoplethysmographically proven extensions of the microcapillary system (***cf. figs.*** *12 and **13***) and the velocity of the blood could considerably contribute to clarify the electromagnetically induced physiological mechanisms.

In case the measured temperature increase is not only to be considered as a mere result of increased radiation from the body core (core temperature) due to vascular extension, but a result of an actual increase in body temperature, the latter would be equivalent to an external, electromagnetically controlled defense mechanism (*pyrexia, fever*), which the body normally uses to protect itself against bacterial and viral infections (fever).

Independent of this, the increased temperature radiation from large areas of the body initiated by a very limited local stimulation, contradicts the general hitherto accepted hypothesis, according to which biological effects basically results from direct interactions of the electromagnetic field with membranes, cell and vascular walls. This is relevant for the concept according to which, for example, the membrane permeability of blood vessels depends on electromechanically stimulated resonance vibrations (on account of the strongly varying thickness of different blood vessels, but still very questionable) (Warnke 1992). Similarly, the results presented here contradict the hypothesis, according to which deoxygenation of the blood (***cf. fig. 13***) can be directly attributed to the paramagnetism of oxygen and accordingly described by pure physical formalisms (Stemme 1992).

Despite strong arguments for the fact that electromagnetic effects can be indirectly related to, for example, effects controlled by molecular signals, the experimental findings do not however give evidence as to whether the applied fields are associated with additional, direct physicochemical effects. Indications of this can be found in the observed ‘unpacking’ of erythrocytes. It would be conceivable that here, under the influence of the electromagnetic field, a movement, depending on volume, mass and charge, leads to a separation of the molecular and/or ionic charge carriers. These kinds of charge separations could contribute to the creation of potentials through selectively permeable membranes. In the examples of dark field microscopy depicted here ***(fig. 14)*** the disrupted and hence thrombotic accumulation of normally positive charges on the outer region of the erythrocytes could be recreated under the direct influence of an electromagnetic field. The rejection caused thereby leads to an increase in the surface area and resultant improvement in gas exchange connected with an increased release of oxygen and better blood flow characteristics. The existence of such kinds of processes are reinforced by the ongoing physiological effects initiated by just one minute electromagnetic stimulations but extending over many hours.

An occasionally observed change of portions of bound and unbound body-water with so-called fat weighing-machines (not described here) might likewise be associated with a direct result of electromagnetically (simulated weight change) field effects. (The measuring basis for this is the change of the dielectric constant obtained by determining the capacity related change of body AC- resistances (impedance).

Independent of the implementation of the biological effect, whether direct or indirect, the advantage of an electromagnetic stimulation lies in the clearly separated bandwidth. It facilitates activation and associated adjustment of a wide spectrum of potentially disturbed chemical equilibria, which in the end always have to be considered a cause for health related complaints and illnesses.

Comparable to a temperature increase or the effect of a catalyst, the different, mostly highly selective and highly sensitive physiological – physicochemical interactions can be activated by well adapted electromagnetic forces. Consequently and advantageous over systems stimulating with spectral narrowbanded electromagnetic fields, wideband electromagnetic pulse stimulation, as described,might facilitate a wider range of reaction mechanisms or expressed in simple terms: the ***BEMER-3000*** pulse boosts a wide range of body functions.

A potential objection that such reactions may possibly trigger disharmonies and potential illnesses, can be countered by observing that with the spectral width of activation, the likelihood also increases that exactly those chemical events are activated which the body has held ready for the prevention of negative processes.

Stimulation using an electromagnetic signal spread over as wide a spectrum as possible can therefore not only restructure a disturbed condition of health but, in the sense of a precautionary therapy, also maintain a healthy condition.

As an addition to the electrophysiological investigations into the above described chemical events in the brains of birds, further trials for the potential use of special electromagnetic fields are in progress, as is work on the analytical kinetics of highly sensitive and highly selective biological interactions.

Summary

As a result of appropriate electromagnetic stimulations, the reactivity of highly differentiated and selective reaction mechanisms can be influenced through submolecular charge displacements and the activation of atoms, ions and molecules in conjunction with potential membrane polarizations. Wide frequency range pulsed electromagnetic fields applied therapeutically can thus contribute to the vitally important communication between the various organic system components to stabilize, to regenerate and to immunize against disturbances as a precautionary measure.

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