Electromagnetic field therapy: Which system and which can be trusted?

Abstract

Measured against the numerous review summaries, the results of magnetic field therapy applications are often not only presented as contradictory, but their usefulness is even completely disputed. However, a closer look at the latter reveals that even these evaluations, mostly prepared by medical experts, were often done without the scientifically unavoidable consideration of the electromagnetic stimulation, which usually takes place in special pulse forms, i.e. only by means of which frequency and intensity (Pieber K, Schuhfried O, Fialka-Moser V (2007), Quittan M, Schuhfried O, Wiesinger GF, Fialka-Moser V (2000), Wilbacher I (2009)). In the end, it is just as useless, and therefore very regrettable, especially given the confidence placed in medical statements. With correct and interdisciplinary consideration, many of the contradictions presented therein would probably resolve themselves. This controversy, therefore, confronts the potentially interested user with the question „Which system is suitable for me and which can I trust“. This is especially true because of the constantly growing number of magnetic field therapeutic applications that are unaffected by this. Based on the underlying physical and physiological mechanisms of action on the one hand and critical analysis for the scientific evaluation of their effects on the other hand, the following paper is intended to contribute to clarification.

Health as a functional state of complex networked molecular interactions

Health is a state of physical, mental, social, and therefore, also psychological and spiritual well-being. According to the meaning of the word „well-being“, it is a state that can be objectively described by anamnesis, laboratory parameters, genetic, or otherwise, defined markers. Among other things, it is characterized by physical and mental performance corresponding to the age of the patient.

From a Physico-chemical point of view, health is based on regulatory processes that are highly selective and sensitively networked in the organism over time and space. These processes regulate, among other things, the conversion of the energy resting in organic substances into structures, work, and heat according to the laws of nature. The formation and activation of proteins mediated by signaling substances, adhesion molecules, and genetic material play a special role in this process. Health thus reflects the current state of a natural adaptation to internal and external conditions, which is constantly evolving with evolution, and geared towards the preservation of life. Living, working, and environmental conditions - in particular poor nutrition, lack of exercise, and social stress - can, however, overwhelm these regulations, resulting in lasting health disorders often heralded by precursors such as malaise, pain, anxiety, and depression.

It is the common goal of therapeutic measures to compensate for such disorders as comprehensively and gently as possible. Be it the use of medication, physical-therapeutic, psychological, or other measures, they all aim to support and strengthen the self-preservation mechanisms.

Symptom-oriented interventions are problematic

Despite mature diagnostics, for obvious practical and methodological reasons, therapeutic measures are usually geared to the symptoms induced by such overloads, but not to their actual causes. They often occur only within the sequence of disease developments that may have been concealed and prolonged by additional - often cost-intensive - secondary disorders, which are also further promoted by multi-medication.

In contrast, it would be advantageous to take measures that compensate for such disorders as close to their causes as possible, in a gentle and widespread manner, even in their early stages, or - in terms of prevention - not allowing them to arise in the first place.

The concept of (modern) electro-magnetic field therapy and the term „electro-magnetic active ingredient properties“.

Prevention is one of the primary goals of modern electromagnetic field therapy. Complementary to any other type of therapeutic measures, it is geared towards the broadest possible support of the molecular interactions underlying these self-preservation mechanisms: in detail, the activation preceding each physicochemical interaction, which takes place in the energy state of the respective electron configuration (Gray et Riedel 2011). With its electromagnetic field effects, it ultimately aims at influencing - possibly also catalytically - the readiness of the molecular partners involved in the regulations in various ways. Due to the increased reaction probabilities, it can even contribute to the reduction of drug dosages by compensating for too much or too little substance concentration.
Per the above physical-chemical laws, it can be assumed that the desired objectives can only be achieved with suitably coordinated time-intensity curves of the applied electromagnetic fields.

(Fig. 1)

In this respect, one could - similar to the active ingredient properties of a drug that can be characterized by physical and chemical properties - assign „electro-magnetic active ingredient“ properties to the temporal intensity curves of the respective applied fields. These can be quantified by information on the spectral composition of the signal forms used, such as, for example, according to the known formalisms for the mathematical simulation of the functional process through sine and cosine components - suitably superimposed with respect to frequency and amplitude - (Fourier analysis).

It is precisely here that the popularly defined „magnetic field therapy“, which is mainly based on reports from antiquity and was initially limited to the unified effect of permanent magnets but has since been extended to fields that change over time, differs from modern electromagnetic field therapy.

In contrast to a magnetic field that changes over time, permanent magnetic fields exert force effects exclusively on moving charges. Furthermore, it is still largely unclear to what extent the biological reactions to the effects of magnetic fields can be reduced when applying electromagnetic fields. It is conceivable that these only come about as a result of the physical interplay of mutually inducing electric and magnetic field com-

ponents that go hand in hand with changes over time. Thus, the biological effect could come about from the interaction of the magnetic components penetrating the organic tissue largely undamped - initially acting as a kind of carrier - and the electrical components induced during their temporal change. The definition of the term „electromagnetic field therapy“ used here is also to be understood in this sense.

It is undisputed that external electromagnetic fields lead to physiological effects: Depending on their respective changes in intensity over time, electromagnetic fields in the infrared range lead to the perception of heat, in the higher frequency range of visible light to colour recognition, at even higher changes in the UV range to the influencing of chemical bonds (sunburn, UV sterilization) and finally, at extremely high changes overtime - referred to as radiation - in the ranges of X-rays, radioactive (gamma) and cosmic radiation to the ionizing destruction of molecular bonds.

Accordingly, the efficiency of the effect of electromagnetic fields is related to the energy transmitted through different rates of change (somewhat imprecisely through frequencies, see below): the higher their frequency, the more efficient but also riskier is their biological effect. Nevertheless, in the narrow frequency range of visible light from 500-800 nm, even the slightest frequency differences cause significantly different colour sensations.

Static and temporally varying magnetic fields

Static magnetic fields have their origin in uniformly moving charges, such as in permanent magnets or conductors through which direct current flows. They manifest themselves through force effects on magnets, magnetizable bodies, and moving charge carriers.

Variable magnetic fields are created as a result of temporal changes in charge movements, and thus as a result of changes in the electric field caused by these charges.

Independent of this, however, every change in a magnetic field also induces an electric field (Faraday‘s laws). Alternating with each other, they move away from their place of origin as electromagnetic fields (or waves or, in the case of very high rates of change, as rays) at the speed of light.

In contrast to electromagnetic fields, permanent magnetic fields penetrate organic material largely undisturbed - and accordingly transmit only little energy. It is still unclear to what extent the effects induced by alternating electromagnetic fields can be divided into the electric and/or magnetic field components (Meschede 2015).

Electromagnetic field therapy: forms of execution and application

Due to its simple, patient-friendly, non-invasive and painless application, especially independent of age and symptoms, the whole or partial physical application of magnetic and electromagnetic fields as „magnetic field therapy“ has in the meantime secured a firm place in the health care system (Vallbona 1999). Notwithstanding the previously described differentiation between static and variable electromagnetic fields, it is used to maintain and restore performance, well-being, quality of life, and vitality at all stages of life, both in private home use, sports, and in medical and clinical practice (Saliev et al. 2018).

This refers to the physical exposure to low-frequency (i.e. slowly changing) electromagnetic fields that are unchanging (static) over time and intensity. Because the latter is often applied in a pulsed form (with pulse repetition rates in the range of 1 to approx. 1000 Hz), they are also called pulsed electromagnetic fields (PEMF, Pulsed Electro-Magnetic Fields). Conventional systems, still used in therapy today, often work with sinusoidal, arc, sawtooth or trapezoidal pulsed (magnetic) field intensities of up to several milli-Tesla and repetition rates of 0.001 to about 1000 Hz. However, the frequent use of 50 or 60 Hz should not be interpreted as an indication of their particular effectiveness. Rather, these frequencies and forms owe their popularity to their preferred use in electrotechnical laboratories due to their easy technical implementation (Markov 2007).
Depending on their intended purpose, the devices are used either as wellness1 or medical products. The difference is based on legal regulations (Section 3 Medical Products Act, MPG, also see the section on relative contraindications for electromagnetic exposure).

Electrosmog, a colloquial term for the highly controversial daily exposure of humans and the environment to all technically generated (artificial) electric, magnetic, high-frequency, and ionizing electromagnetic fields, currently mostly in the microwave (especially G5) or terahertz (personal scanner) range, is not the subject of this paper.

Stimulation with strong magnetic fields such as those generated by coils of up to 1500 amperes (McClintock SM et al. 2018) is also not included. For example, short-term transcranial stimulation with high magnetic flux densities (200 to 600 µs, up to 3 Tesla) via magnetic coils applied tangentially to the skull leads to changes in electrical potential and thus to the triggering of action potentials in the cerebral cortex near the skull.

(Fig.2)

Depending on the manufacturer of the magnetic field generator, static or pulsating (electromagnetic) fields controlled by different intensity time courses are used (Saliev et al. 2018). Static magnetic fields (permanent magnets) are used in the form of plasters, insoles, bracelets, etc. In a few cases, electromagnetic fields are applied using moving permanent magnets incorporated in various forms of applicators, but mostly by the use of flat coils supplied with currents that change over time.

The field strengths used are usually in the range of up to 1000 microTesla - adapted to the respective valid limit values (NISV, 26th BImSchV, DIN VDE 0100-710, International Commission on Non-Ionizing Radiation Protection 1998). For comparison, the static earth field in Europe is about 50 microTesla.

Irrespective of the similar physical background, the devices are often offered with different names: Magnetic field resonance, frequency, vascular, quantum, pulsating signal therapy, etc. (also see the section on publications and authorship). Although the non-invasive magnetic or electromagnetic form of treatment, like any other medical measure, supports the body‘s maintenance regulations, it is classified as alternative or complementary medicine, a collective term for treatment methods that are seen as an alternative to scientifically based methods of (orthodox) medicine (Köbberling 2017).

Biological effects of electromagnetic fields

The number of publications on the biological effects of static and low-frequency pulsating electromagnetic fields is extensive and continues to grow. Apart from the references in this paper, reference is made to the extensive material in the National Library of Medicine https://pubmed.ncbi.nlm.nih.gov/?db=PubMed&orig_db=PubMed&term=pmf+therapy, the internet information platform EMF-Portal of the RWTH Aachen University and the Federal Office for Radiation Protection https://www.emf-portal.org/de, the Federal Institute for Drugs and Medical Devices (BfArM) https://www.dimdi.de/dynamic/de/das-dimdi/, the Cochrane Library https://www.cochranelibrary.com/cdsr/reviews/topicsa, (Cochrane 1972, Cecchi 2020), and also to the numerous patent applications https://patents.google.com/.

However, it should be pointed out here that the study results, which are particularly requested by the medical sector, are only in a few cases consistent with the individual circumstances due to the exclusion criteria (age, gender, diseases, medication, etc.). It would therefore be advisable to aim for a frequent „trial use“. (See also footnote 2)

Some examples of magnetic field therapeutic applications

(National Library of Medicine)

A small random selection of peer-reviewed2 publications indicate a broad spectrum of magnetic field therapeutic effects:

• Reduction of polyneuropathological pain states as a consequence of oxidative stress after chemotherapy, knee osteoarthritis, and injuries (Mert 2017), (Gabrys 2004), (Hedén and Pilla 2008), (Khooshideh et al. 2017), (Battisti et al. 2004), (Rokyta et al. 2012), (Ryang et al. 2014), in contrast (Menini et al. 2016) and (Beaulieu et al. 2016)

• Strengthening the body‘s defence mechanisms with improved immunity and protection against chemical stress factors (Wojcik-Piotrowicz al. 2017), (Guerriero and Ricevuti 2016).

• Protection against chemical stress factors, in particular, the reduction of chemically (by the teratogen cyclophosphamide) induced malformations in the ontogenesis of warm-blooded vertebrate embryos in the model of chicken eggs (Jelínek et al. 2002)

• Improvement of orthopaedic clinical pictures, especially in the rehabilitation sector with reduction of lumbar-initiated chronic back and movement pain and its consequences: Insomnia, anxiety Depression (Klasen et al. 2006), (Bernatzky et al. 2007)

• Accelerated wound and bone healing, including diabetic wounds (Callaghan et al. 2008, Patruno et al. 2018) and bone healing, back pain (Assiotis et al. 2012), (Furlan et al. 2010), (Krath al. 2017) (Ryaby 1998), (Schmidt-Rohlfing et al. 2011), (Pieber et al. 2007), contradicted by a Cochrane report by Griffin et al (2011)
• Influence on sleep quality is improbable according to Hong et al. (2001) or even disturbing with continuous exposure according to Bagheri et al. (2019)
• Improving well-being and quality of life, particularly in geriatrics and palliative care, multiple sclerosis (Bistolfi 2007), (Guerriero and Ricevuti 2016)
• Increase in performance in top-class sport through the delayed onset of muscle soreness, reduction of fatigue, the formation of energy-rich compounds, in particular, adenosine triphosphate (ATP) and bis-2,3-phosphoglycerate (BPG) in human erythrocytes; Spodaryk K (2001, 2002), Spodaryk and Kafka (2004)
• Improvement of hemoglobin-oxygen affinity in healthy adults (Kafka WA 2003), (Kafka and Spodaryk 2003)
• Increasing cell replication and proliferation rates, and influencing the activity of proteins in defined stem cells of the human bone marrow as an approach to treating bone diseases such as osteoporosis and fractures (Kafka et al. 2005)
• Formation in the form of differential (up- and down-regulated) gene expression of proteins of defined stem cells of human bone and cartilage cells as an approach to treating bone disease (Walther et al. 2007)
• Influencing the activity of different growth factors; epidermal growth factor (EGF), insulin-like growth factor 2 (IGF-2), fibroblast growth factor (FGF), nerve growth factor (NGF), transforming growth factor-beta (TGF-ß), and the bone morphogenesis proteins 2 and 4 (BMP-2, BMP-4) (Ruoff 2008), Sylvester et al (2005)
• Reduced medication - cancer (Moiseeva and Kunin 2018), (Vadalà et al. 2016), (Ruiz-Gómez et al. 2002), (Cheng et al. 2017)
• Functional state of the microcirculation and improved adaptation to the flow of blood cells, blood plasma, and signal substances in the smallest blood vessels, which is dependent on changing metabolic needs, as well as the activation of the Klopp metabolism (2008). Despite the use of identical stimulation systems with partly identical analysis systems, neither Schuhfried et al (2005) nor Gschwandtner et al (2008) was able to confirm such findings.

Concerning the different types of effects induced by the electromagnetic fields, especially the simultaneous up- and down-regulation in gene expression, it can generally be assumed that the electromagnetic signals activate different molecular processes, despite the above limitations on the individuality of the stimulus parameters. Even if some of the findings only become apparent as a result of functional overlaps of primarily differently activated molecular mechanisms, and even if it is still unclear to what extent the biological effects induced can be assigned to the spectral components of the applied stimulation signals, the present findings confirm that the width of the biologically inducible effects in the sense of the concept presented here is associated with the spectral width of the stimulation signals.

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2 A peer review is a procedure for quality assurance of scientific work by independent experts from the same subject area. The authors of the peer-reviewed work must take any criticism seriously and correct any errors discovered or explain why the comments of the reviewers are inaccurate before the study can be published. Disadvantages, apart from fake journals: In the case of cross-border scientific topics (e.g. natural science-medicine), the necessary interdisciplinary competence of the most medical reviewers are often lacking and, because of the great trust placed in their statements, this also has negative consequences for the insured (also see the section on magnetic field therapy: Yes, but which system? Some decision-making aids).

Relative contraindications

The commissioning of magnetic field therapeutic devices, especially when they are classified as medical devices, requires both a safe use (e.g. conformity with equipment technology, CE, GSE, ISO standards, electromagnetic compatibility, compliance with limit values as defined by the International Commission on Non-Ionizing Radiation Protection 1998) and proof of effectiveness (e.g. within the framework of one of the study protocols described below, following Directive 93/42 EEC Annex II Complete Quality Assurance System).

Their use is also subject to certain inclusion and exclusion criteria. For example, persons with electronic implants (pacemakers, cochlear implants, chips, etc.) should only be treated after a competent medical examination.

To avoid rejection reactions after fresh foreign body transplants, it still seems advisable to start electromagnetic treatment only after medically diagnosed normalization of the immunological defence reactions.
However, there is no risk of heat development due to induced currents in metallic implants (they act like antennas), or due to re-magnetizations triggered by the alternating field (implants consist of non-magnetizable material).

If necessary, the individual electromagnetic compatibility between electronic implants and the respective treatment system should be checked.

In principle, magnetic field therapy should never replace professional medical treatment. However, medical advice on magnetic field therapy should only be obtained from medical experts with interdisciplinary competence in this field (see text Fig. 4).

Magnetic field therapy: Yes, but which system? Some decision-making aids

Due to the different system-specific stimulation characteristics mentioned at the beginning, no general therapeutic applicability can be deduced from the findings. For this reason, a thorough and critical examination of the documents provided is necessary, even if the individual‘s therapy wishes are strictly limited. However, given the complexity of the underlying physiological-physical background and a large number of treatment systems currently available on the market, it can be assumed that interested parties not familiar with this field - even members of medical circles - will probably be overburdened.

As a non-judgmental, neutral aid in deciding on one or the other system, the following criteria can be examined to see whether they are fulfilled:

Technical specifications: Is the information on the device technology - in particular on the intensity progression over time - described and sufficiently quantified? Conventional systems, which are still used in therapy today, often work with time-pulsed sinusoidal, arc-shaped, sawtooth, or trapezoidal (magnetic) field intensities of up to several millitesla and repetition rates of 0.001 to 10,0000 Hz. However, the most frequent use of 50 or 60 Hz to date should not be interpreted as an indication of their particular effectiveness.
These frequencies and forms owe their popularity rather than their preferred use in electrotechnical laboratories due to their easy technical implementation. Modern developments are based on the application of complex signal forms with a much broader spectral composition than conventional systems (Fig. 4).
Safety standard: Are the safety regulations, such as conformity to equipment technology (CE, GSE, ISO standards, etc.) specified and documented?

Effect proofs and advertising claims: Are the claimed effects based on studies with the selected treatment system or, as frequently and misleadingly stated, on findings obtained with completely different forms of stimulation?

User manuals, hotlines: Are the contents of user manuals, user instructions, training courses, hotlines, etc. scientifically proven? This applies primarily to information on the duration, frequency, and intensity setting for the treatment of medically clearly defined indications. Often, reference is made to so-called empirical values by scientifically proven facts. Apart from the fact that empirical values are not equivalent to scientific verification (see below), such information is also unsuitable and ultimately absurd because users have been relieved of any other choice of settings from the outset. It can therefore by no means be ruled out that settings other than those proposed in each case would not have led to better therapy results after all. - Even if in such cases a decision against this system would have to be made, it should at least be noted that it is not the suitability of the system that should be criticized here, but rather the advice of „experts“, who are often self-appointed, not very familiar with scientific thinking and/or paid by the manufacturer to spread wishful thinking.

Scientific documentation: Were the studies presented carried out according to scientific standards („studies“), which in particular clearly show that the observed and assessed effects are exclusively due to the stimulus applied in each case? More specifically, this involves testing the research protocol for the most allied, multi-centre studies possible on a sufficiently large population of volunteers randomly distributed among control, placebo, and verum groups, and the results presented in a comparative and quantified manner through significance values (in the range of 0.5 or better 0.01). So-called case reports (case descriptions) - similar to the empirical values mentioned above - do not fulfil the conditions of scientific clarity. At best, they serve as possible working hypotheses for further investigation planning.

A detailed examination of the research parameters and results can be dispensed with to a certain extent (see footnote 2 in the section „Some examples of magnetic field therapeutic applications“) in the case of studies that have been published in a peer-reviewed professional journal, possibly with a high impact number. In these publications, a committee of (internationally) renowned scientists independent of the authorship has already reviewed the material submitted for publication.

Other places of publication, in particular publications in the daily press, self-published brochures, and books, even with ISBNs, are less or not suitable for checking the scientific quality. If, however, only such publications are available, it should be checked by intuition whether the chosen methods of investigation allow the described efficacy. For example, the above-mentioned influences on the functional state of the microcirculation could, because of the investigations carried out in the micrometer range, raise the question of the reliability of the corresponding „before and after“ documentation since the actual recovery in these dimensions requires special technical precautions. This is all the truer when it is described that the follow-up observations were only made after periods of several days or even weeks, during which histological morphological changes are usually to be expected but are not visible in the images of the follow-up observations.

Additional devices or applications: In the product ranges of many manufacturers, there is an increasing number of additional devices with the help of which, individually and optimally tuned stimulation conditions can be determined directly „on-site“, using otherwise determined reference values. These are often sensor systems built into a finger or ear clips, for example, which can be used to measure certain physiological parameters (skin moisture, pulse interval, etc.) by measuring resistance or light absorption. Such a project presupposes that such „reference values“ reflect a scientifically validated state of health which is dependent on electromagnetic treatment, and in particular a health condition corresponding to the person to be treated. Furthermore, unlike the frequent demonstrations of equipment, e.g. at trade fairs or the like, the on-site measurements must be carried out under similar, standardized examination conditions. Without strict adherence to these requirements, such statements are basically to be classified as worthless and dubious. The aim is to convince the interested party of the effect of an applied electromagnetic field, which is usually not perceptible to the senses.

Otherwise, the remarks made in the section „ User manual“ also apply here:

Award ceremonies, winner‘s certificates, patenting, or certification as a medical device do not replace scientific proof of effectiveness. Patents testify to technical innovations, prizes, certificates, medals, etc. Awards are often for sale and are awarded without testing for therapeutically suitable use. The certification primarily confirms the technical fulfilment of medical safety standards. - As practice has shown time and again, such certificates serve rather as an advertisement for interested parties or to convince potential buyers of the effectiveness of a product.

Conclusion and outlook

In summary, it is clear that the interest often proclaimed by manufacturers in promoting medical scientific knowledge is only a marketing strategy to make the documents submitted on the efficacy of their products appear more serious.

It is to be hoped that in the future, scientific institutions independent of manufacturers and distributors will deal with the health effects of electromagnetic fields on a competent interdisciplinary basis more than before. The necessary scientific and technical background for this is given by, Bhavsar 2020), (Cecchi 2020), (Kafka 2009), (Panda 2019), Anonymous Patent Application E2020,0098 AA X (2020).

With these specifications, and precisely because the non-invasive application is a simple, pleasant, and practically side-effect-free therapy option for the doctor and the patient, modern electromagnetic field therapy can be considered a prospective new approach that contributes efficiently and cost-reducing to the improvement of the general health care system, both in private home use and in medical practice.

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Fig. 1-5

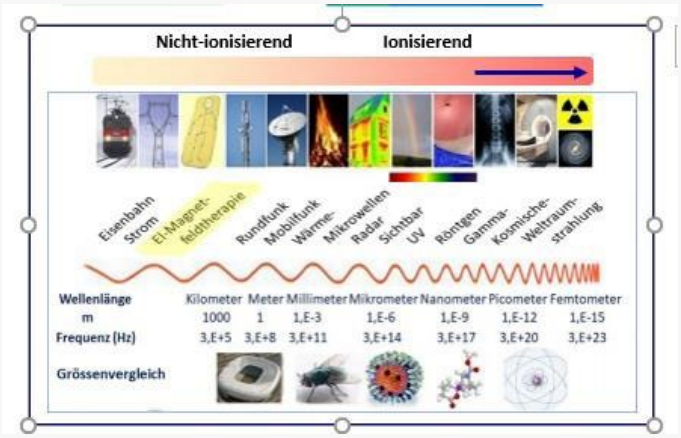

Fig. 1 Electromagnetic spectrum Biological effect and application (see text)

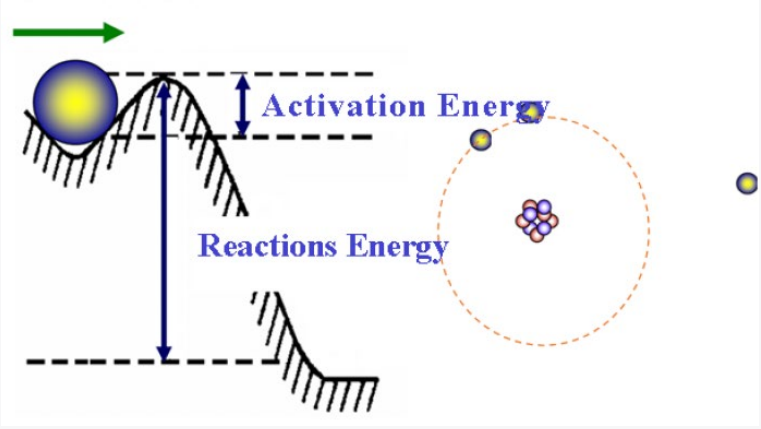

Fig. 2: Activation energy and reaction sequence of physical-chemical interactions.
Activation energy, the energy released during the interaction; the electromagnetic field effect here, therefore, only has a controlling effect.

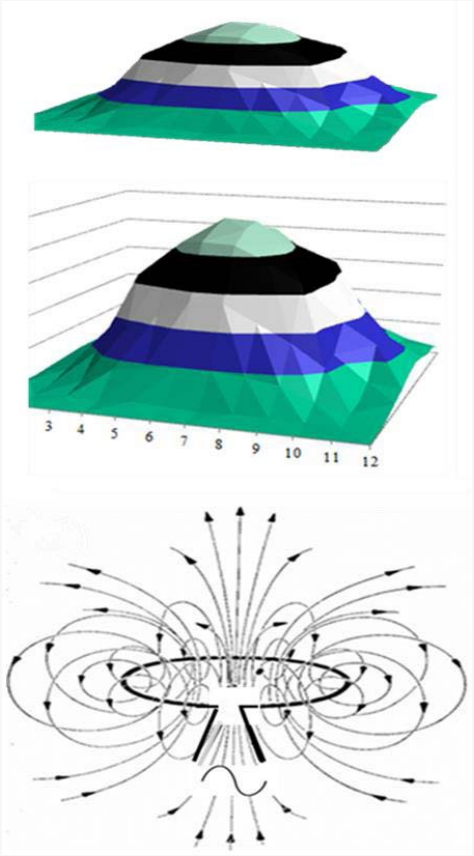

Fig. 3: 3-D field distribution (magnetic flux density) around a ring-shaped air-core coil.
The field intensity is strongly dependent on the distance to the coil surface. In the schematic example, each at a vertical distance of 0 and 15 cm.

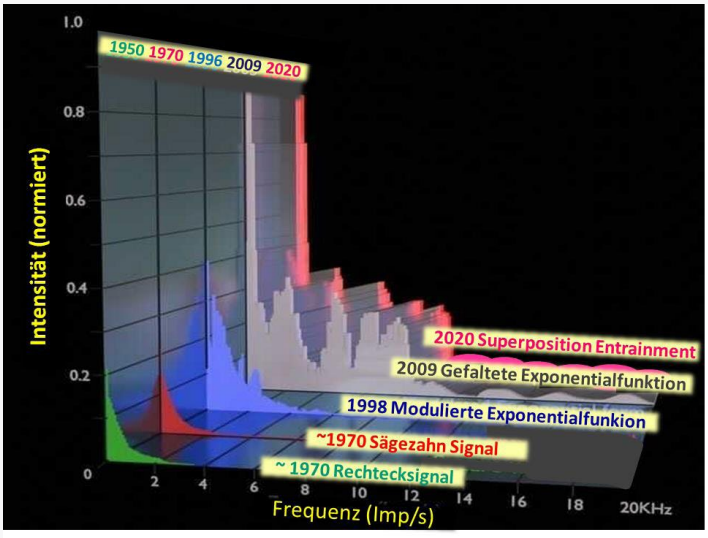

Fig. 4: Spectral composition and effective width.
Measured by the number and size of the components contained in a stimulation signal, a Fourier analysis in the lower part of the figure shows the clear superiority of the folded exponential form (Kafka 2009). The temporal field intensity distribution is of similar importance as the structure-activity relationships of drug substances. Descriptions of effects merely employing information on frequency and intensity - often even in many peer reviews - are thus completely inadequate. Not only do they testify to a lack of expertise, but they may even be the cause of contradictions in magnetic field therapeutic findings that are often presented but do not exist (see text, section Conclusion)