Studies on the Interaction Between Electromagnetic Fields and Living Matter Neoplastic Cellular Culture

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Neoplastic Cell Culture

The study of the interactions between electromagnetic fields and living matter has become a fertile field for research in the last century, even though these phenomena have been empirically observed by various civilisations since ancient times (1, 2). Considerable experimental evidence today points to the possibility of modulating biological functions and structures in a controlled way by applying electromagnetic fields and, vice versa, the possibility of detecting and measuring endogenous electrical currents in living organisms and their components (3, 4).

There are two types of electromagnetic effects on living matter: thermal effects and non-thermal effects (5, 6, and 7). Thermal effects induce an increase of entropic disorder in the target, until at adequate frequencies and power levels, the effects of ionisation develop. The non-thermal effects are not the result of the transfer of erratic movement by means of an increase of kinetic energy, but rather, in line with the theories of the coherence of condensed matter, they can transmit information that would produce order in the bio-structures involved. The information content of the electromagnetic waves would depend strictly and specifically on the waveform, the string of waves, and the time sequence of their modulation. In fact, specific variations in the configuration and temporal exposure patterns of extremely weak electromagnetic fields can produce highly specific biological responses, similar to pharmaceutical products (8, 9). These effects are attracting considerable scientific interest mainly because an electromagnetic wave is easily modulated and thus is an excellent means for the transmission of information. (10) Studies carried out by various writers suggest the possibility of nonthermal effects; they include Gorgun (16, 17, 18), Frohlich (11, 12), and Tsong (13, 23, 24, 25, 26).

Based on these studies, it is reasonable to consider patterns in living matter that take into account the electromagnetic components of biological structures. Every cell, for instance, is made up of biological and chemical components that can be described in simpler and simpler terms down to the cell's elementary molecular constituents. But the cell itself and its internal and external interactions can also be considered in terms of electric and electromagnetic interactions and relationships (1, 3, 6, 27, 28, 29, 30, 84, and 85). Numerous experimental works have shown the possibility of modifying and controlling the selective permeability of the cell membrane by transmitting electromagnetic waves. This leads to the possibility of verifying the specific reactions of healthy cells compared to the reactions of pathological cells and subsequently to select target cells on which to act for clinical purposes. Pathological cells resonate differently from healthy cells due to a different tissue composition.

On these bases, various authors have noted the modulation of some cell functions, from ionic membrane pumps to many cytoplasmic enzyme reactions, including those connected with cell replication (6, 13, 14, 16, 69, 84, 85). From these studies it has been seen that these effects can be obtained from low intensity electromagnetic waves (under 1 watt) and specific frequencies

(within the range of 1 Hz to 50 MHz). Along this line, preliminary observations performed in vitro have shown alterations of the cell morphology, the halt to proliferation, fusion, and necrosis in lymphoblastoid cell lines and some neoplastic lines subjected to specifically modulated electromagnetic radiation.

Reported here are some demonstrative examples to show the biological effects of electromagnetic fields. The electromagnetic waves have a power of 0.25 watts and are in the kilo- and megahertz ranges. They do not produce thermal effects on the bio-structures and have been modulated according to the patterns elaborated by Gorgun. The examples presented here are indicative of significant biological and clinical effects both in vitro and in vivo. The action of these electromagnetic waves on neoplastic cell culture produces fusion and takes place through alteration of the cell potential (Grade 1), whereas cell necrosis takes place with the alteration of the cell structure (Grade 2).

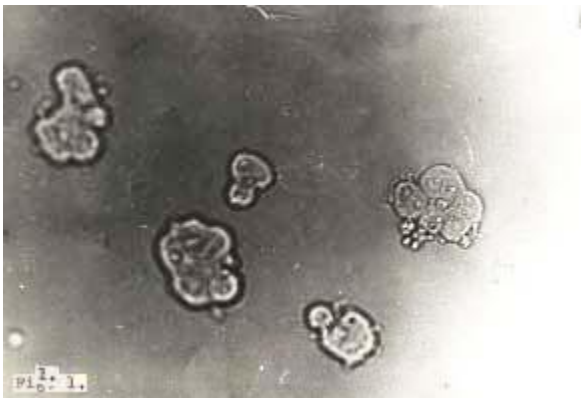
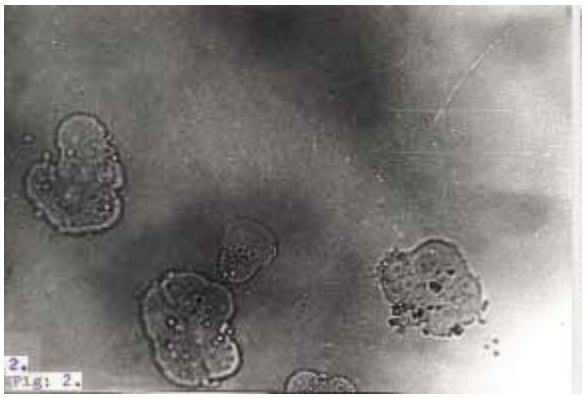


Fig 1



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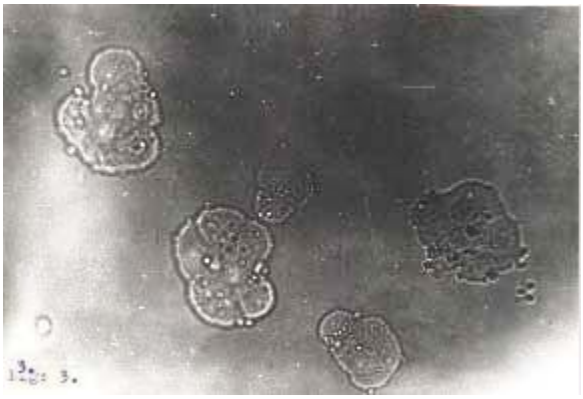

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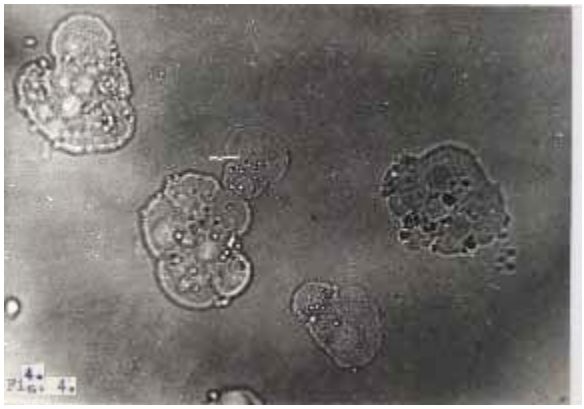


Fig 4

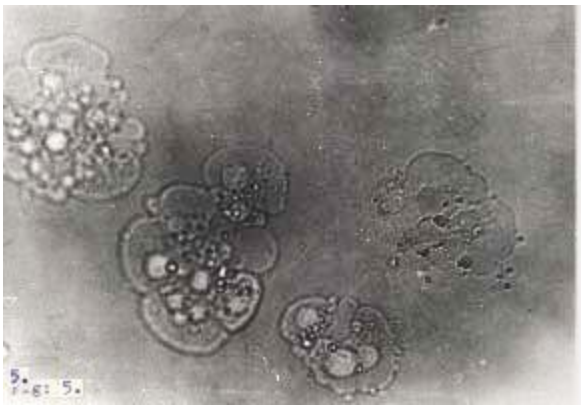


Fig5

Cell Fusion (Grade 1)

In figures 1 through 5 the effects on neoplastic HeLa cells in contrast phase can be seen through the microscope. The culture was exposed to electromagnetic waves with a frequency in the megahertz range and a power of 0.25 watts for a period of about three hours. The electromagnetic energy modulated in this way brings about cytoplasmic cell fusion, which produces up to a maximum of five cells, after which cell necrosis occurs. In these figures the approach of the two cell structures, located in the center of the picture, can be seen until their fusion occurs. In figure 3 the membranes come into contact at which point the potential cell alteration can be noted (Grade 1). The above phenomenon was first noticed in 1970 and has been repeated a number of times; it was also reported at the Balkan International Congress of 1979.

Cell Fusion and Necrosis (Grade 2)

Figures 6 through 9 indicate the progressive fusion and necrosis in vitro of cancer cells of the CC-178 line. These observations were conducted by the Department of Haematology and Oncology at the University of Hannover by subjecting the cells to electromagnetic waves with frequencies in the megahertz range at a power of 0.25 watts for a period of about two hours.

Fig 6

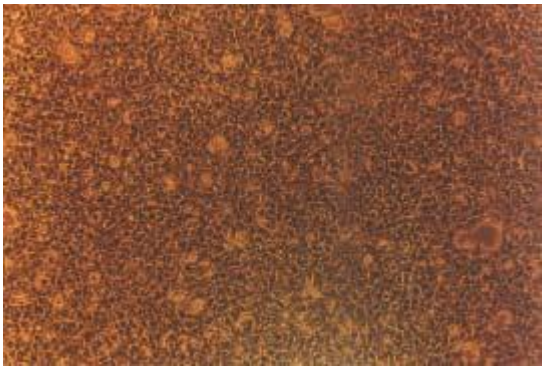


Fig 7

Fig 8

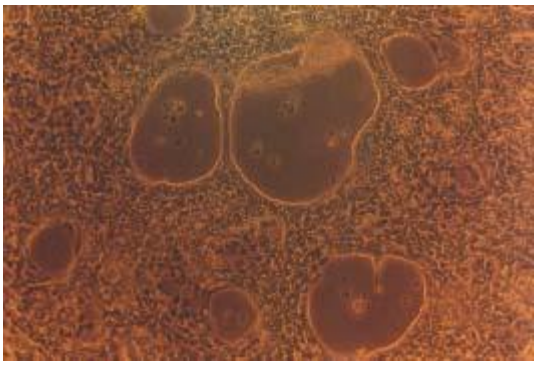


Fig 9

Influence of Electromagnetic Fields on Cell Functions

The preliminary observations conducted in vitro show an alteration of cell morphology, a halt to proliferation, fusion, and necrosis in lymphoblastoid cell lines, and in some neoplastic lines, after treatment with specifically modulated electromagnetic fields (HeLa, mammary carcinoma, CCL-178, colon adenocarcinoma, H 23, H 32, h 12.1, 1411 H, testicle carcinoma, M 5, M51, stomach carcinoma, MCF-7 human Caucasian breast adenocarcinoma ECACC 86012803, normal cell line, and MDBK bovine kidney cells) (16).

It is known that cells communicate with each other by means of direct metabolic exchanges or through the transfer of ions or molecules that act as messengers. Multi-cell signals which originate in the interaction of ligands with membrane receptors can activate a closely connected series of biochemical reactions. The biological membranes represent multi-molecular operative structures, and even a slight alteration in the composition of the membrane can lead to significant changes in its functions. Electromagnetic fields can influence this communication between cells and within the cells themselves due to their ability to activate or change the motion of the electrical charges. In fact, an increasing amount of literature illustrates the possibility of inducing biological effects in cells when appropriate electrical and magnetic fields are applied to have a direct effect on the membranes (94,95,96).

Among the various effects obtained are those on Na+ and K+ dynamics and their role in ATPasi, as well as the effects on the intermembrane exchanges of the Ca++ ion, which, because of its presence in most biomolecular processes, has earned the name of second messenger (94). Moreover, exposure conditions that have led to effects on the membrane permeability of the Ca++ ion have shown a negative influence on the mitotic fuso, and this influence is selectively tied to the characteristic of the magnetic field used.

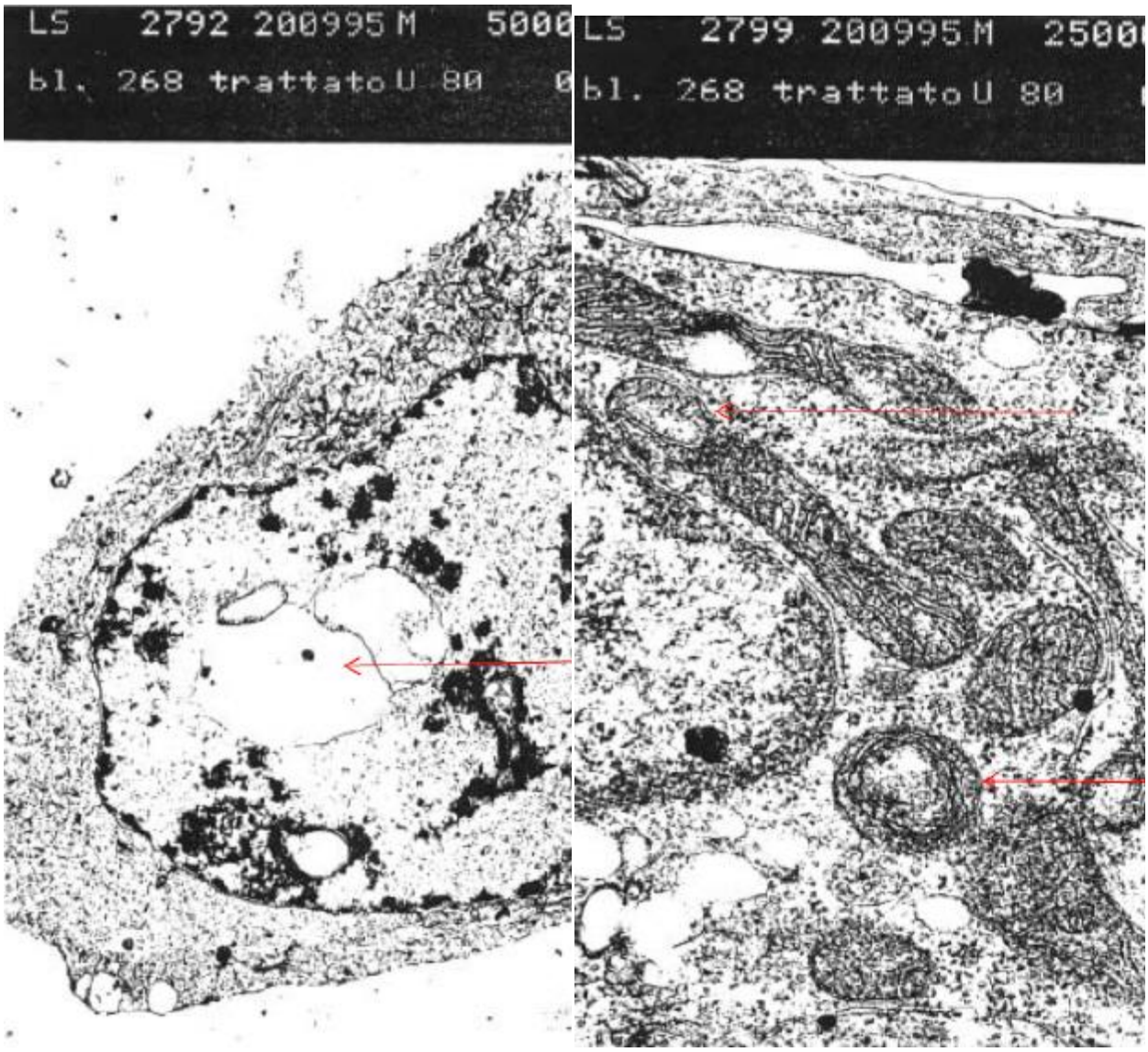
Up to now, the results obtained imply that the membrane receptors (e.g., the gluco-protein complexes), are able to decipher electrical signals at a well defined frequency and amplitude by reacting in a specific way. The energy transformed from the electrical fields is absorbed and directly coupled to guide biochemical reactions. These results have served as the bases for some applications in the therapeutic field, particularly in the reproduction of bone tissue. (98) This is due to the fact that the activation of some cell functions is bound to electrical potentials of the on/off type, that is, not with linear but with rectangular wave shapes.

Cell Fusion and Necrosis (Grade 2)
The possibility that weak electric or magnetic fields can send signals past the strong potential barrier of the cytoplasmic membrane (100 KV/cm) can be explained by the hypothesis of the phenomena of resonance on certain kinds of ions (101), the co-operative gap junction type phenomena (102, 103), and the amplification effects explained by the set up of a field gradient between the inside and outside of a spherical shell made up of three layers of dielectric properties (95). The treated cells were examined with an electron microscope that showed ultrastructural alterations in the following areas:

• Cytoskeleton fiber - at the structure alteration level with an increase in fibers compared to the control and with a more irregular disposition and orientation
• Mitochondrion - a different orientation of the mitochondrion crests and an alteration of the mitochondrion matrix which appears dishomogeneous and pycnotic compared to the control
• Autophages - intra-cytoplasmic bodies in many cells

Moreover, the following can be noted:

• Chromatin degeneration
• Thickening of the chromatin at the nuclear membrane level
• Nucleus vacuolisation
• Mitochondrial degeneration



Electron Microscope Pictures
(Note*: In the original publication these pictures appear at the end*)

These types of alterations, especially at the nuclear level, suggest the hypothesis that an apoptotic type of phenomenon was induced by the treatment. The characteristic of the equipment for these studies was as follows: low power (0.25 watts) electromagnetic waves with frequencies in the kilohertz range and magnetic fields and electrostatic fields specifically modulated according to the Gorgun method (GEMM: Modulated electro-magnetic generator).

Hypothesized Mechanism

It is thought that the chromosomes, following the messages received as a result of the variations of potential in the cytoplasmic membrane, activate through electromechanical effects the

emission of messages by the genes that regulate cell dynamics for normal cell functions or for the mitochondrial activities for ATP production. An electrical circuit composed of a zener diode attached to the base of a bipolar transistor is offered as a model for the operation of the mitochondrion. The zener diode represents the on/off pulse operation of some cell functions, the combined circuit impedance represents the impedance of the glycoproteinic sensors present on the mitochondrial membrane, and the transistor represents the ATP activation process.

It is supposed that the excessive production of ATP is related to an alteration of the glycoproteinic sensors present on the mitochondrion membrane with consequent lowering of the impedance that in turn does not discriminate between the signals in frequency and activates the production of ATP in an almost continual way. The cancer cell would therefore go into mitosis due to the excess of ATP. Static magnetic fields and square wave pulsed electric fields are used to act on the mitochondrial membrane, increasing the impedance of the glycoproteinic sensors through the lengthening of the polyglycidic chain.

A pulsed electromagnetic field in phase with the electrical signal is used to interfere with the communications between the genes and the protoplasmic glycoproteinic complexes involved in the promotion of cell mitosis. It is thought that the impedance of the mitochondrial membrane to the messages coming from the genes increases with the electromagnetic treatment and with increases in the malignancy (the highest impedance for undifferentiated tumours). This is related to a greater alteration of the sensors of the undifferentiated tumours and therefore to their greater predisposition to the bond with polyglycidic chains. The undifferentiated cancer cells, because of the high impedance induced on the mitochondrial membrane by the electromagnetic treatment, stop producing ATP and therefore enter into necrosis. Following the treatment the differentiated cancer cells have impedance which is still sensitive to some messages coming from the chromosomes promoting the normal production of ATP, so these cells change their state of mitosis; however, they continue to live in a quiescent state (vegetative form of life).

The normal cells are not influenced by the electromagnetic treatment as the impedance of their mitochondrial sensors is not modified and remain sensitive to messages that arrive from the chromosomes for the activation of the ATP synthesis.

Clinical Application

Studies recently carried out reinforce the hypothesis that different classes of proteins change in response to electrical field forces induces by oscillating electric and electromagnetic fields at predetermined frequencies and intensities, and suggest that there could be biological effects that might halt the mitosis of neoplastic cells. The use of a static magnetic field of 5 mT for 50 to 60 minutes has changed the lectinici bonds of specific sites on the membrane surface of erythrocytes with a consequent alteration of the ATP content (104). The variation of the lectinici bonds is considered by the changes of the glycoproteinic complex.

Pulsed square wave magnetic fields with a frequency of 10 Hz and an intensity of 10 mT on animals in vivo modified some biochemical blood parameters and produced significant effects on the erythrocyte count and the concentration of haemoglobin, calcium, and plasmatic proteins. The mechanisms of the observed effects are probably tied to the influence of the magnetic fields on the ionic permeability and capacitive reactance of the membrane due to changes in its lipid

component, on the liquid crystalline structure, and on the enzymatic activity of the ionic pumps dependent on ATPasi (105).

Fields of 2 KV/m with frequencies from 1 KHz up to 1 MHz activate the Na+ and K+ pumps in the ATPasi in human erythrocytes. The authors suggest that the interactions that permit the free energetic coupling between the hydrolysis of the ATP and the pumping of the ions are of the coulomb type.

The results obtained indicate that only the ionic modes of transport necessary for the synthesis of the ATP for specific physiological conditions were influenced by the applied electrical field, and some types of reactions are not explicable in chemical terms but only as related to electrogenic effects (106). The use of pulsed square wave electric fields with an amplitude of 1050 volts, an impulse width of 100 microseconds, and a frequency of 1 Hz have strengthened the anti-neoplastic effect of the bleomicina in the growth of fibro-sarcoma SA-1, malignant melanoma B!6, and Ehrlich ascitic tumours (EAT) (107, 108).Electromagnetic fields at a frequency of 7 MHz have been measured concomitant with cell mitosis in culture yeast cells (109). It is known that the ciclines (e.g., P16 and P21) have an important role in the processes of mitosis on cancer cells (110) The ciclines use the terso P. of the ATP.

Classically this second type of interpretation has produced fundamental clinical instruments, such as, for example the electrocardiogram, the electroencephalogram, and more recently the nuclear magnetic resonance (2, 31, 32). The interest in the study of the interactions between electromagnetic fields and living Matter is placed, therefore, on three levels:

• Prevention - the way electromagnetic fields influence the development of illnesses (33, 47)
• Diagnosis - the way endogenous bio-electric signals and weak electrical and magnetic fields, associated with bio-molecules correlate to the state of health (11, 48, 49, 50, 51)
• Treatment - the way biological structures and functions can be modulated by means of electromagnetic fields (16, 17, 18, 19, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75)

The following applications illustrate the therapeutic aspects:

• Illnesses of the locomotor organs - electromagnetic fields are used for accelerating bone regeneration especially in fractures that do not heal spontaneously and for analgesic effects. The results reported in literature relate no side effects to the treatment (62, 65, 71, 76, 77, 78).

Especially noteworthy is the study of cartilage regeneration and osteoporosis.

• Illnesses of the vascular apparatus - excellent results are described in cases of phlebitis and related after-effects; varicose ulcers react positively to the treatment in 90% of the cases with rare recurrences. Also obstructive arterio .pathology of the lower limbs responds well to electromagnetic treatment, showing both subjective and objective improvements (79)
• Dermatological illnesses -both atrophic dermatitis and psoriasis respond to the treatment with satisfactory results in the latter in 60% of the cases. Bedsores can also benefit from electromagnetic treatment (79)

• Surgery - electromagnetic fields promote the healing of surgical wounds (79)
• Inflammatory illnesses - all types of acute and chronic phlogosis that were tested showed benefits from treatment with electromagnetic fields (80, 81)
• Neurological illnesses - positive effects were noted on neuritis irritation and on post-herpetic neuropathologies (82)
• Analgesic treatment - there are numerous observations and applications of the analgesic effects of electromagnetic treatments not only in inflammatory and degenerative pathologies like arthritis, but also in neoplastic pathologies (53, 83)

A growing literature proposes the use of electromagnetic energy with cancer patients. Non-ionising electromagnetic radiation is used in the oncological field with various objectives depending on the frequency range (86, 87). Their use, besides the analgesic effects already described, can make use of the antiblastic action that can be direct or indirect, or they can be applied toward the reduction of the hiatrogenic effects of radio and chemotherapy (16, 17, 69, 87, 88). The therapeutic effects mentioned above often use the thermal effect of the induction of disorder in the target tissue; however, the major interest lies in the non-thermal effects, which, paraphrasing Adey, might allow interventions on cell functions using the language of the cells themselves (89, 90) by means of a highly specific modulation of frequency and intensity.

The characteristics of the equipment were as follows: low-power electromagnetic waves (0.25 watt).With frequencies in the kilohertz range and specifically modulated according to the Gorgun (GEMM: Modulated Electromagnetic Generator).

In Vivo Effects
Modulated electromagnetic fields were applied to mice in 1974. The observations were conducted at the Marburg Universitat Klinik und Poliklinik fur-Nuclearmedizin, Radiologiezentrum der Philippsuniversitat Marburg/Lahn at the Institute for Biophysics and Nuclear Medicine. Before being subjected to electromagnetic fields, the mice were inoculated with three different types of histopathological material:

- Yoshida Solid
- Asditis
- Walker

A regression of the pathology was observed after the application of the electromagnetic fields. Some clinical cases are presented below, which indicate biological effects from modulated electromagnetic fields not only in cells in vitro, but also in organisms in vivo. Histopathological examinations showed that the index of proliferation decreased. Treatments were applied to patients suffering from different types of malignant neoplasia. The treatment applied was highly specific for each patient, based on the type of histopathology, the stage of the illness, and a series of personalized clinical, biophysical and environmental parameters.

The electromagnetic waves used had a frequency in the kilohertz range, a power of 0.25 watts, and were applied daily for a period of time specifically determined for each case. All the studies that follow were carried out under the direction and responsibility of medical personnel.

Case 1
Patient B.G., female, age 49, affected by ductile infiltrating carcinoma of the breast. After surgery and chemotherapy, metastases were noted in the axillary region. A month of treatment was performed in 1989 during which time the metastases regressed. X-ray examinations following the treatment showed no pathological alterations.

Case 2
Patient V. G., female, age 45, affected by a stomach carcinoma (adenocarcinoma slightly differentiated with ring cells and castone). Material was drawn from a voluminous sovrangular gastric ulcer, and the patient underwent a total gastrectomy. Before the therapy, metastases were present in the locoregional lymph glands, and the patient exhibited a compromised general condition. Treatment with electromagnetic energy was applied in 1988 for about forty-five days. The metastases disappeared, and in the following check-ups no recurrence was observed.

Case 3
Patient V.A., female, age 45, affected by leiomiosarcoma retro peritonale that in 1984 showed a diameter of over 40cm. Before the treatment the patient complained of strong abdominal pains and generally poor health, edemas in the lower limbs due to the compression of the lower vena cava, and hydronephrosis due to uretral compression. Chemotherapy had no effect and surgery was impossible because of the adherence of the mass to vital organs, in particular the aorta. After about two months of treatment in 1987 her condition had improved and the mass seemed to have been reduced by more than half. A surgical biopsy showed fibrous muscular type cells of modest density with no cell abnormality or mitosis. In 1991 an echography showed that the volume of the mass had further reduced to about 12 to 13 cm. The mass subsequently reduced further, and in 1993 echography showed a mass diameter under 8 cm.

Case 4
Patient N. M., female, age 41, had undergone a mastectomy in 1988 for infiltrating breast carcinoma followed by chemotherapy. After two years multiple bone metastases were observed in the pelvis and thigh. Figures 10 and 11 show the outcome of the X-ray examinations before and after the treatment with electromagnetic fields in 1990 (lasting about one month). The medical report (referring to Figure 11) stated: “Compared to the last observation there are evident signs of calcifying bone repair at the endosteale and e periosteal levels. The reconstruction is apparent at the level of the right proximate metafisi, at the level of the right ischio, and corresponding to the neck of the left thigh.”

Fig 10

Fig 11

Figure 10 and 11 show the x-rays before and after the treatment.

Case 5

Patient S. M., female, age 64, suffered from infiltrating ductile carcinoma of the breast. Surgery, chemotherapy, and radiotherapy were performed, but the illness progressed to the presence of metastases in the axial area and in the lungs (the chest X-ray showed small round opacities of the secondary type in both lung regions, more numerous in the lower median third right side). The treatment in 1989 with electromagnetic energy lasted two months. The metastases began to regress, although the signs in the lungs remained visible on subsequent X-ray checks. By 1993, the pulmonary lesions had disappeared, and "no infiltrating parenchimali lesions can be observed." A radiological inspection in 1994 confirmed this result.

Case 6

Patient E. P., male, age 59, was diagnosed with pulmonary adenocarcinoma in 1988. The patient had undergone surgery with the removal of the median and lower lobes of the right lung. Subsequently extensive recurrence was observed in the right thoracic cavity and in the mediastinum (Figure 12) He suffered from a generally poor physical condition and intense thoracic pain. The clinical conditions did not permit further surgery, chemotherapy, or radiological treatments. Treatment with electromagnetic fields in 1989, which lasted approximately two months, brought about an improvement in the clinical conditions, disappearance of the pain, and reduction of the neoplastic mass. In figure 13, the thoracic x-ray following treatment can be seen, where it is evident that there was a reduction of the mediastinic volume and expansion of the upper right pulmonary lobe.

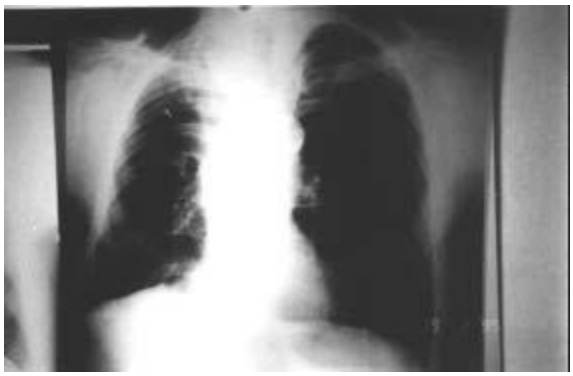


Fig 12 Fig 13

Figure 12 and 13 show the x-ray examinations before and after the treatment.

Case 7
Patient S. A., male, age 44, was diagnosed with peritoneal carcinosis in 1989, having a mass with a maximum diameter of 40 cm. An echograph report in 1990 stated: "...liver... with dishomogeneous structure due to secondary localisations, the largest of which in the left lobe has a diameter of about 4 cm.... Kidneys had moderate dilatation of the calico pieliche structures. Upper and lower abdomen was completely occupied by expansive formation of mixed structure, part liquid, part solid that compresses also the bladder and does not permit a precise evaluation of the bladder walls and the prostate." The patient was inoperable and underwent treatment in 1990 with electromagnetic energy. The echograpy report in 1991 stated: "...the liver is enlarged with diffused dishomogeneous structure. Definite signs of nodular lesions are not identifiable at different acoustic impedances. The pelvis and partially the abdomen are occupied by a voluminous expansive formation with an maximum longitudinal diameter of approximately 20 cm., with an echostructure that is strongly dishomogeneous, referable to discariocinetic lesions. The bladder appears to have conserved regular walls. The dimensions and the echostructure of the prostate are within normal limits."

Case 8
Patient N. M., female, age 56, was diagnosed with lobular carcinoma of the breast in 1988. She underwent a surgical operation and chemotherapy. At the time of the treatment with electromagnetic energy in 1991, she was suffering from a serious decline of general health, a hepatic metastases and a costal metastases. The treatment lasted almost two months during which time the main hepatic localization reduced to a diameter of about 3 cm., and the other metastases disappeared. The upper abdominal echotomograpy report in 1991 stated, "an hypoechogenous area is visible, with irregular margins and a diameter of 3.3 cm. Referable, as first hypothesised, to metastases and numerous other hypoechogenous areas." An echography report described "a delimited hypoechogenous nodular formation, with a diameter of 3 cm, of irregular shape and an endolesional hypereflectant formation." The remaining parenchyma did not show alterations of the echogenous structure. In figure 14, a bone sintigraphy, taken in 1991, shows the examination made in 1992, in which it was pointed out, "the anomalous finding, reported in the previous examination of 28 Jan 1991 is practically no longer recognizable; the other parameters, within normal limits, have not varied."

Fig 14

Fig 15

Figure 14 and 15 show the x-rays before and after the treatment.

Case 9

Patient D. A., female age 69, was diagnosed with papillary cistoadenocarcinoma of the ovary, metastatic and infiltrating in 1987. Chemotherapy was performed, but to no avail. When the patient was subjected to electromagnetic therapy in 1990, she had metastases in the peritoneum, and the echograph showed that the "the parametrium appeared to be occupied by a voluminous mass with a diameter of about 15 cm. and mixed structure, irregular polycystic with vegetating solid formations, that were referred to ovaric adenocarcinoma." Her general condition was seriously compromised. The treatment lasted approximately two months. The progression of the illness stopped and the mass progressively reduced in volume. The echotomograph report of November 1990 stated: ".Posterior to the uterus occupying the Douglas, - an expansive formation with diameter over 12 cm. And mixed structure part liquid and part solid of probable annexial origin."

Case 10

Patent M. M., male, age 20, was diagnosed with plasmocitoma in the tibial region. The patient complained of serious pain in the tibia and was unable to walk. The tibia showed decalcification and serious bone erosion. Conventional chemotherapy and radiotherapy had already been tried and no further therapeutic programs were planned. After the electromagnetic treatment performed in 1988, the pain disappeared; the patient was able to walk again, the bone recalcified and the pathological erosions disappeared. Figure 16 shows the x-Ray before the treatment. The third radiological examination in 1989 was accompanied by the following medical analysis: "The present examination, compared to the preceding one (no. 2061) of 1 December 1988, shows that the large destructive area at the medial diaphisis, is mostly occupied by structural bone growth from bone repair under way with fixed appearance of hardened bone in formation." The treatment consisted of approximately 25 applications.

Fig 16

Fig 17

Fig 18

Figures 16 through 18 show x-rays before, during, and after the treatment.

Case 11

Patient, B. M., female, age 49, was diagnosed with carcinoma of the breast. The patient had had a mammography on May 11, 1994 (Figure 19), which indicated on the right retro-aureolar region a nodular formation with a diameter of about 1 cm with a radiating outline. Excision was recommended. Ago-aspiration confirmed the malignant nature of the lesion and surgery was planned for two weeks later. Waiting for the operation, the patient asked to be subjected to electromagnetic therapy and after eleven sitting the mammography was repeated. The results can be seen in Figure 20. The medical report described granulous breasts of fibromicrocystic type with no evidence of suspicious radiological character nor microcalcifications. Moreover, the cutaneous profile seemed normal.

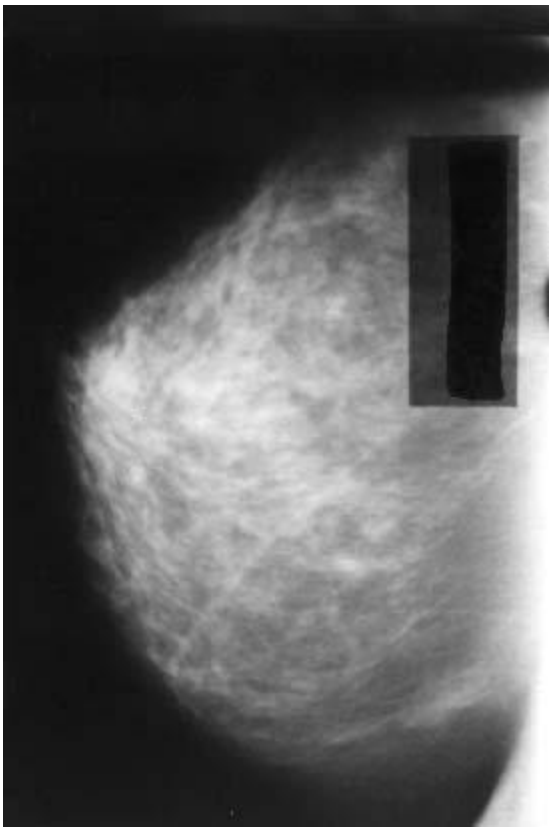


Fig 19

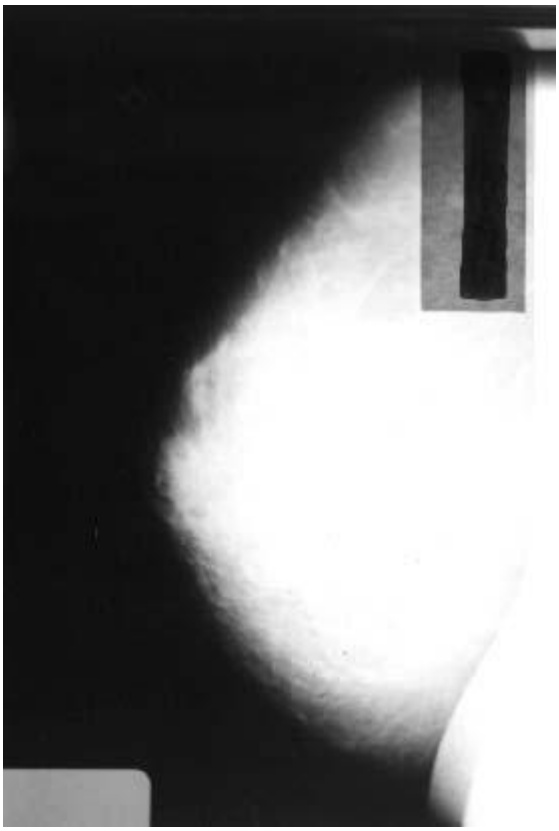


Fig 20

Figure 19 and 20 show the x-rays before and after the treatment.

Properties of the signals Used

Most of the signals used in the clinical field of the rectangular wave shape type (99). This is due to the fact that the activation of some cell functions is bound to on/off type electrical potentials, that is not of the linear type but with waveforms of the rectangular type (100). The electromagnetic treatment last on average about twenty minutes per day with single daily sittings. The duration of the sitting is regulated by the application program and its parameters.

During the first half of the treatment, the static or variable magnetic field at 50 Hz, the pulsed electric field, and the pulse electromagnetic field are all present simultaneously. In the second half, the static or variable magnetic field is not applied. The electromagnetic pulsed field and the electric pulsed field are kept in phase or in counter-phase. The frequency of the electromagnetic field, as well as the temporal width of the square carrier wave, are fixed according to the histological type of tumour, grade of differentiation, mass, and location.

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