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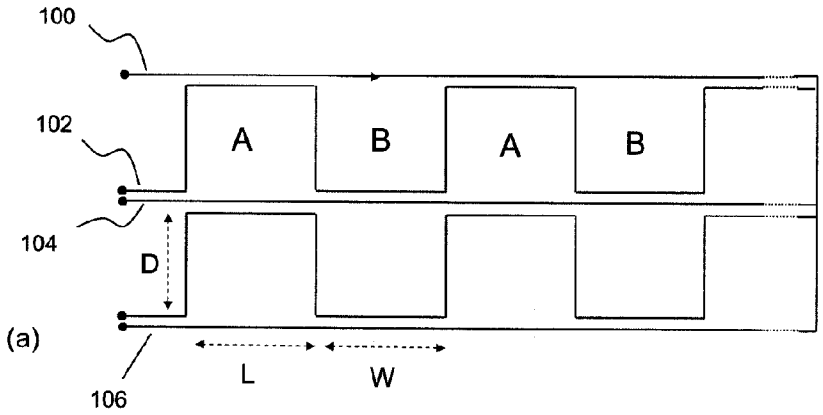
(54) **Title:** COIL STRUCTURE FOR ELECTROMAGNETIC STIMULATION OF A PROCESS WITHIN A LIVING ORGANISM, DEVICE USING SUCH COIL STRUCTURE AND METHOD OF DRIVING



(57) **Abstract:** A distributed electromagnetic coil structure for applying a time varying electromagnetic field to a population of living organisms is described. The coil structure comprises at least a substantially planar first coil sub-structure. The first coil sub-structure comprises at least a first wire of a predetermined shape and a least a second wire of a predetermined shape, wherein said first and second wire are shaped to define one or more of first cells. An electromagnetic field is generated by said first cells when a current runs through said first coil sub-structure.

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Coil structure for electromagnetic stimulation of a process within a living organism, device using such coil structure and method of driving.

Field of the invention

The invention relates to an electromagnetic transducer for stimulating a process within living organisms using electromagnetic fields. In particular, the invention relates to a distributed electromagnetic coil structure for effective stimulation of processes, in particular the immune response, in living organisms in large-area and large-scale applications.

Background of the invention

It is well known that time varying low-energy electric or magnetic fields produce a range of responses in biological systems. Based on these responses various therapeutic or biostimulation treatments using low frequency and low-energy electromagnetic fields have been proposed. For example, US 3,890,953 describes a method for the stimulation of bone growth and other tissues. In US 5,183,456 a method for regulation of the growth of cancer cells is described. In US 5,290,409 a method is described in which the transport of several types of ions can be influenced.

An interesting group of studies have demonstrated that human and murine macrophages can be stimulated to higher activity through low frequency electromagnetic field exposure (see Simkó et al., Eur. J. Cell Biol. Vol. 80, 2001, p. 562-566 and Lupke et al., Free Radic. Res. Vol. 38, 2004, p. 985-993). Several authors have demonstrated that the observed production of cytokines, increased immune parameters and stress effects were initiated by exposure to electromagnetic fields. From these studies it was concluded that low field electromagnetic field exposure causes stress at the cellular level,

leading to production of cytokines and consequently biological response, including immune response (see Blank et al., Bioelectrochem. and Bioenerg., Vol. 33, p. 109-114, 1992 and Mol. Biol. Cell Vol. 6, p. 466a, 1995; Goodman et al., Bioelectrochem. and Bioenerg., Vol. 33 p. 115; Simkó et al., J. Cell. Biochem. Vol. 93, 2004, p. 83-92; Monselise et al., Biochem. & Biophys. Res. Com. Vol. 302(2), p. 427-434, 2004; De Bruyn et al., Environ. Res., Vol. 65(1) p. 149-160, 1994; Markov et al. in Bioelectromagnetics edited by S.N. Ayrapetryan and M.S. Markov (eds.), Springer 2006, p. 213-225).

Proper stimulation of the immune response leads to improved resistance against infectious diseases and thus positively affects the health of the exposed organism. This insight opens new possibilities for (preventive) treatment of large, dense populations wherein infectious diseases are an increasing problem. Such problems are especially prevalent in populations with genetically uniform organisms such as farmed livestock, chicken, shrimp and fish populations. Infectious diseases can be very damaging to such populations and treatments are very costly.

WO 03/035176 describes a device which is particularly effective in stimulation of the immune system of humans and animals. This device is adapted to the application of time dependent electromagnetic fields to a part of the body of a living organism using a pair of Helmholtz coils. The applied signal has a spectrum of frequencies in which some frequencies or frequency areas are more strongly present than others. Such a device can support a therapy in which afflictions involving inflammation and infection can be treated.

The system for electromagnetic stimulation described in WO 03/035176 is a small-scale system only suitable for the treatment of a single organism. Effective electromagnetic stimulation of large populations on a large-scale and the problems related thereto are not addressed in the prior art. For instance, livestock populations are usually kept in large-area buildings or other spaces of large dimensions. Usually stables and sheds for cows, chickens and pigs or ponds for breeding fish have typical dimensions of at least tens to hun-

dreds of meters. Without special measures, controlled electromagnetic stimulation of such large areas is difficult and would require large amounts of energy. Moreover, when using the device in more remote areas a battery fed system with a solar and/or wind energy supply is necessary. In that case reduction in power consumption is a very important aspect.

Moreover, the buildings where livestock is kept vary in size and construction. The transducers installed in such buildings are tailor made. Consequently, the impedance of these electromagnetic transducers will - to a certain extent - vary from building to building. Consequently, these variances and deviations in the load of the driving electronics of the electromagnetic transducers will affect the electromagnetic signal produced. This will negatively influence the effectiveness of the stimulation treatment which is very dependent on the shape of the signal.

Object of the invention

It is an object of the invention to reduce or eliminate at least one of the drawbacks of the prior art and to provide distributed coil structures adapted for producing a electromagnetic field signal which is suitable for effective stimulation of processes, in particular the immune response, in living organisms in large-area and large scale-applications.

Summary of the invention

The invention relates to the observation that the area in which the living organisms are kept and to which the electromagnetic field should be applied is in principle spatially limited to a volume of certain dimensions wherein the horizontal (area) dimensions are much larger than the vertical (height) dimensions. The distributed electromagnetic coil structure of the present invention effectively "divides" this volume in a set of sub-volumes of a predetermined size and allows to expose at least a subset of these sub-volumes to the

electromagnetic field at different points in time. Division over sub-volumes and exposure of sets of mutually non-adjacent sub-volumes to a time varying electromagnetic field at different points in time efficiently reduces and spreads the total energy requirement for complete exposure of all animals present in the volume over a certain time period. It thus allows the use of simple and cheap electronics for driving the transducers.

Furthermore, the use of smaller sub-coil structures in a large-area distributed transducer allows improved control of the characteristic frequency R/L of the transducer. This characteristic frequency determines to a large extent the shape of the time-varying electromagnetic field. Such improved control is advantageous as the electromagnetic stimulation of biological processes in a living organism, depends on the shape of the time-varying electromagnetic field used in the electromagnetic stimulation.

In this way the electromagnetic field can be applied to the living organisms present in this volume (such as livestock, chickens, fish or shrimps) in an (energy) efficient manner.

One aspect of the invention relates to a distributed electromagnetic coil structure for applying a time varying electromagnetic field to population, preferably a large population, of living organisms. The coil structure comprises at least a substantially planar first coil sub-structure. This coil sub-structure comprises at least a first wire and at least a second wire of a predetermined shape. The first and second shaped wires are arranged with respect to each other to define one or more first cells. The electromagnetic field is generated by said first cells if a current runs through said first coil sub-structure.

By defining such cells the electromagnetic field is localized and effectively applied to small sub-volumes of the total volume. The division of the volume is thus effectuated by the particular shape and arrangement of the cells of the distributed coil structure. It is appreciated that in the context of the present invention regarding coil structures distributed

over a large area, the term planar means that the dimensions of the coil structure in two dimensions are substantially larger than the third dimension.

In a further aspect of the invention the coil structure further comprises at least one substantially planar second coil sub-structure defined by said second wire of said first coil sub-structure and at least a third wire of a predetermined shape, wherein said second and third wire are shaped to define one or more of second cells. The electromagnetic field is generated substantially within these second cells if a current runs through said second coil sub-structure. The second coil sub-structure forms a structure which is complementary to the first coil sub-structure. The use of the first and second coil sub-structures allows each sub-volume of the total volume in which the living organisms are kept to be exposed to the electromagnetic field by applying current to the first and second coil sub-structures at different points in time. Such a distributed coil structure thus provides an advantageous and energy efficient way of applying an electromagnetic field to a large area.

Another embodiment of the invention relates to a distributed electromagnetic transducer for applying a time varying electromagnetic field to large population of living organisms. These organisms are kept in a large area S. Typical dimensions of this area correspond to the dimensions of stables for livestock or (breeding) ponds for fish. The distributed transducer comprises at least a first coil structure and a second coil structure, which are - depending on the situation - arranged under or in or above a volume, which is defined by the large area S and a predetermined height of dimensions much smaller than the dimensions defining said large area S. The first coil structure and second coil structure in this embodiment comprise at least a wire with a (spatially) distributed shape.

In one embodiment the (spatially) distributed shape of the wire could be a meandering or a block-wave-shaped or a sawtooth-shaped wire extending under or in or over the volume. Alternatively, the (spatially) distributed shaped wire can be arranged to form a number of loops to form cells. The magnetic

flux generated in these loops will be proportional to the current through the wire. Increasing the number of windings in one loop will increase the magnetic field generated by that loop in a simple way without the need to increase the current through the wire.

The coils can be driven by suitable driving electronics, which produce a time varying drive signal. In use, the distributed coil structure is driven such that in a first time period the first coil exposes a first set of sub-volumes of the total volume to a time varying electromagnetic field and in a second period - different from said first time period - the second coil exposes for a second time period a second set of sub-volumes of the total volume to a time varying electromagnetic field. The first set and second set of sub-volumes cover different sub-volumes in the (total) volume. It is appreciated that one or more sub-volumes of the first and second set may partly overlap. The arrangement of such distributed coils allow simple and effective exposure of large populations of animals which are kept in a volume with a large area.

In another embodiment a first, second and third wire are of a predetermined shape and forms an electromagnetic coil structure which is adapted for applying a time varying electromagnetic field to living organisms over a large area. In such coil structure the first, second and third wire is shaped to define a plurality of first cells and second cells, wherein the electromagnetic field is generated substantially by the first cells when current runs through the first and second wire and the electromagnetic field is generated substantially by the second cells when a current runs through the second and third wire.

The shape of the cells can be adapted by adapting the shape of the wires which define the cells. The shape of one or more of the wires can be e.g. substantially meandering or block-wave-shaped or sawtooth-shaped to define substantially circular-, square- or rectangular shaped, diamond-shaped or triangular shaped cells. One or more wires in the distributed transducer can be shaped to form a number of "loops" wherein each loop has one or more windings. Moreover, distributed

shapes of the wires of the coil structures of the present invention are not limited to planar structures but also include three dimensional coil structures. For example, it is appreciated that the shape of the wires - and thus the shape of the cells - can be adapted to the shape of the support structure of the wires. Such support structure can comprise an existing support frame in the ceiling, floor or subdivisions in a stable, such as the boxes in which livestock is kept or held during feeding.

The area of the cells can be chosen from a range between 0,01 and 1000 m^2, in particular between 0,1 and 100 m^2 so that large areas can be effectively treated.

In one embodiment of the invention the distributed coil structure of the present invention extends over a surface area wherein the plane of said first coil sub-structure is substantially parallel to said surface area. By arranging a plurality of first coil sub-structures in the plane of said first coil sub-structure, the distributed electromagnetic coil structure is positioned over or under the volume which contains the living organisms to be treated. The advantage of such arrangement is that the coil structure allows free movement of the animals and workers within the volume to be subjected to the electromagnetic field.

In another embodiment of the invention the distributed coil structure extends over a surface area wherein the plane of the first coil sub-structure is substantially perpendicular to said surface area. By arranging a plurality of first sub-coil structures or a plurality of first and second sub-coil structures side by side or next to each other, the distributed electromagnetic coil structure is positioned within the volume which contains the living organisms to be treated. This coil structure allows to make use of the existing frames of boxes for the animals as support frames for the distributed electromagnetic coils.

Another aspect of the invention relates to a system adapted to produce electromagnetic stimulation of processes within living organisms when applied to at least a part of a

body of said organisms, which comprises at least one distributed electromagnetic coil structure.

The wires used in the above described embodiments of the invention can be multi-core wires, wherein each wire can be driven by a separate driving amplifier. This way the magnetic field generated by the distributed electromagnetic coil structure can be easily increased without the need to increase the current through the wires.

A further aspect of the invention relates to a system for applying an electromagnetic field to at least part of a body of a living organism. The system comprises at least a distributed electromagnetic coil structure for applying a time varying electromagnetic field to large population of living organisms kept in or spread over a large area S, a generator for applying a time varying signal to the distributed electromagnetic coil structure and attracting means for attracting and/or restricting living animals to the vicinity of the coil structure.

Such attracting means for attracting living animals can be used in systems wherein the living organisms are free to move over a large area and can comprise a fresh water or food supply or a light source or a milking robot or a combination of these features. The attracting means keeps the animals within the vicinity of the electromagnetic coil structure so that these animals can be efficiently exposed to the electromagnetic field. The use of the attracting means thus allows efficient large scale electromagnetic stimulation without the need that the transducer covers the complete area where the living organisms are kept.

Another aspect of the invention relates to a device for applying an electromagnetic field to at least part of a body comprising at least a transducer and a generator for applying a time varying signal to the transducer. The transducer comprises at least one distributed electromagnetic coil structure of the present invention.

Yet another aspect of the invention relates to a method driving at least one distributed electromagnetic coil structure of the present invention. By applying at different

periods in time currents to the sub-structures in the electromagnetic coil structure the large area volume containing the living organisms can be effectively subjected to a time-varying electromagnetic field.

It is appreciated that the invention is not limited to the above described embodiments. For instance, the invention also relates to structures, for instance a building, for keeping living organisms comprising at least one distributed electromagnetic coil structure according to the present invention.

Moreover, the invention also relates to a device for applying an electromagnetic field adapted to produce electromagnetic stimulation of processes within a living organism when coupled to at least part of a body of said organism, comprising:

- driving means for generating a time varying drive signal,
- at least one transducer responsive to said drive signal for generating a time varying signal B(t) comprising said electromagnetic field, and

wherein said signal B(t) contains one periodic signal $b_i(t)$ or a superposition of at least two periodic signals $b_i(t)$ $(i=1,2,3,\ldots)$, each signal $b_i(t)$ being defined as:

$$b_i(t)=a_i*(2\exp(-\omega_o t)-(1+\exp(-\omega_o T_i/2)) \quad \text{for } 0 \leq t \leq T_i/2$$
$$b_i(t)=-b_i(t-T_i/2) \quad \text{for } T_i/2 \leq t \leq T_i$$

wherein T_i is the period of $b_i(t)$, a_i is an amplitude of $b_i(t)$ and ω_o is a characteristic frequency determining the shape of the signal $b_i(t)$, and wherein said transducer further comprises at least one distributed electromagnetic coil structure according to the present invention.

It was experimentally determined that the use of an electromagnetic signal based on the base signals $b_i(t)$ $(i=1,2,3,\ldots)$, which have a special shape, is especially effective in the electromagnetic stimulation of living organisms. The electromagnetic signal B(t) comprises one base signal $b_i(t)$ or,

preferably, a superposition of at least two different base signals $b_i(t)$. Devices generating such signals are further described in a related application with title "Device and method for electromagnetic stimulation of a process within living organisms", which is hereby incorporated by reference in this application.

Typically, the amplitude a_i (i=1,2,3,...) is chosen such that the peak amplitude of B(t) at the treatment positions will be in the range between 1 nT and 1 mT, preferably within the range between 0.03 μT and 30 μT. Due to the effective shape of signal B(t) for electromagnetic stimulation, even small amplitudes signals will be sufficient to generate advantageous stimulation. The use of this signal thus drastically reduces energy consumption in large area and large scale applications.

Brief description of the drawings

The invention will be further explained by means of the description of exemplary embodiments, reference being made to the following figures:

Fig. 1 represents schematic drawings of embodiments of the invention.

Fig. 2 represents a schematic drawing of an embodiment of the invention wherein a distributed coil structure is positioned over a surface area and wherein the plane of the coil sub-structures are in parallel with the surface area.

Fig. 3 represents a schematic drawing of an embodiment of the invention wherein a distributed coil structure is positioned over a surface area and wherein the planes of the coil sub-structures are perpendicular to the surface area.

Fig. 4 illustrates exemplary geometrical wire arrangements forming "cells" used in the coil structures of the invention.

Fig. 5 represents a schematic drawing of another embodiment of the invention.

Fig. 6 illustrates a system for electromagnetic stimulating a process in a living organism.

Fig. 7 illustrates schematic distributed coil arrangements for use in stables according to a first and second embodiment of the invention.

Fig. 8 represents a schematic drawing of the shape of a preferred periodic base signal $b_i(t)$.

Fig. 9 illustrates the results of in vivo experiments on infected fantail goldfish treated with an electromagnetic field signal.

Description of exemplary embodiments

Fig. 1a and **1b** schematically show examples of distributed electromagnetic coil configurations according to the present invention comprising a number of wires of a predetermined shape. In the particular embodiment of **Fig. 1a** the first wire 100 is a substantially straight wire and an the second wire 102 is a meandering wire having a number of blocks characterized by dimensions D,L and W. Wires 100 and 102 are arranged with respect to each other such that parts of wire 2 are arranged over a length W in parallel and in close vicinity to wire 100. Wire 100 and 102 thus form a substantially planar first coil sub-structure comprising a number of substantially closed first areas or cells denoted in **Fig. 1a** by the letter B. In this embodiment the area of the cell is determined by the dimensions of the meandering pattern and can be varied by changing the dimensions D,L and W of the meandering wire 102. By electrically connecting one end of wires 100 and 102 to each other and the other end of the wires to driving circuitry a current I1 can be applied to the first coil sub-structure as depicted in **Fig. 1a**. It is appreciated that - when electrically connected to each other - the first coil-substructure (comprising wire 100 and 102) in **Fig. 1a** can be constructed by the geometrical arrangement of only one wire.

The current will generate a magnetic field around the wires in the coil sub-structure. The main part of the generated field will be localized substantially within and in the

vicinity of the cells B. The distributed arrangement of this coil sub-structure thus allows the application of an electromagnetic field over a large number of cells, thus effectively covering a large area while allowing at the same time control over the characteristic frequency R/L of the transducer.

In a further embodiment a third wire 104 can be arranged to the first and second wire of the first coil-substructure. In the embodiment as illustrated in **Fig. 1a**, wire 104 is a substantially straight wire arranged next to and parallel with the meandering second wire 102. Wire 102 and 104 thus form - in the same way as wire 100 and 102 - a second coil sub-structure which forms a complement structure of the first coil sub-structure. The second coil sub-structure has a number of cells A which are arranged in between cells B of the first coil-substructure. Wire 102 and 104 can be connected to driving circuitry allowing to apply a current I_2 to the second coil sub-structure thereby generating a magnetic field which will be localized substantially within and in the vicinity of the cells A. The distributed coil structure formed by wires 100, 102 and 104 thus forms a coil structure which allows efficient electromagnetic stimulation treatment of the whole area covered by the structure by alternately applying a current to the first coil sub-structure and the second coil sub-structure.

In another embodiment a number of first coil sub-structures can be arranged next to each other effectively forming large area distributed coil structure. This is illustrated in **Fig. 1a** by wires 100 and 102 and wires 104 and 106, which form two first coil sub-structures. By applying currents to pairs of wires (i.e. wires 100 and 102, wires 102 and 104, wires 104 and 106) an electromagnetic field will be generated which will be localized substantially within and in the vicinity of the cells A, B, C or D. In that way the structure in **Fig. 1a** can be extended to distributed coil structures comprising a large number of such coil sub-structures.

In **Fig. 1b** a variant of the coil structure in **Fig. 1a** is schematically shown. In this embodiment wires 108 and 110 are shaped to form a number of "loops" having one or more windings. As shown in **Fig. 1b** the loops of wire 108 and wire 110

are arranged to form an interleaved distributed coil structure forming a plurality of loops or cells similar to the coil structure in **Fig. 1a**. Increasing the number of windings in a loop will increase the magnetic field generated by that loop without increasing the current through the wire. By applying a current to wire 108 and wire 110 at different points in time an electromagnetic field is generated by the loops corresponding to the respective wire. The return paths of wires 1 and 2 can be combined to one wire as shown in Fig. 1b.

In **Fig. 2** the large area distributed coil structure of **Fig. 1** is arranged at a certain height above or below a surface area S of e.g. a stable or a fish pond, thus defining a large area volume V wherein the horizontal (area) dimensions (typically 10 to 500 meter) are much larger than the vertical (height) dimensions (typically 2 to 5 meter) in which the living organisms are kept and to which the electromagnetic field should be applied. The cells of the distributed electromagnetic coil structures of the invention divide the volume in sub-volumes of a predetermined size and allow application of the electromagnetic field to these sub-volumes at different points in time. The distributed coil structure effectively applies electromagnetic field to the living organisms present in this volume, such as livestock, chickens, fish or shrimps in an (energy) efficient manner.

Fig. 3 illustrates another embodiment of an large area distributed coil structure. In this embodiment a number of first coil sub-structures 300,302 as discussed in connection with **Fig. 1** are arranged over a surface area S. The first coil-substructures are arranged side by side with their plane perpendicular to the surface area thus dividing the large area volume V into sub-volumes of a height which is determined by the dimension D of the meandering block-wave shaped wire. Such coil structure allows to make use of the existing frames of boxes in the stables as support frames for the distributed electromagnetic coils.

In the large area coil structures some coil sub-structures can have larger cells than other coil sub-structures. For instance in some applications it is necessary to reduce stray

fields generated at the edge of such large area coil structures. The reduction of stray fields is necessary to reduce unwanted and/or uncontrolled exposure to electromagnetic field of objects or living subjects in the vicinity of the large area coil structure. In that case the shape and the orientation of the coil sub-structure at the edges of the large area distributed coil structure can be optimized in order to reduce these stray fields.

In **Fig. 1a** a substantially planar structure is shown. Here, the term planar should be interpreted in the context of large area distributed coil structures which can cover hundreds of square meters. In such large area structures the wires can deviate from a two dimensional plane, for example by the sagging of the wires under its own weight. Consequently, the term planar structure should be interpreted as a structure having two dimensions which are much larger than the third dimension.

It is appreciated that the geometry of the wire or wires forming the cells can be in various shapes and sizes. In **Fig. 4 a-e** a non-limiting number of cell geometries, such as diamond shaped, triangular shaped, square shaped and circular shaped cells, is shown. It is also possible to form cells by creating a number of "loops" in a wire as illustrated in **Fig. 4e**. Increasing the number of windings in a loop will increase the magnetic field generated by the loop. Consequently, by choosing different numbers of windings in each loop, the magnetic field generated by each loop can be varied along the distributed coil structure. Such arrangement allows the application of different field strengths in one treatment session. The different geometries can be used depending on the requirements of a specific situation.

Fig. 5 schematically shows another example of a distributed electromagnetic coil configuration according to the present invention. In this configuration the distributed coil structure comprises two distributed coils 500,502 wherein each coil is a substantially planar meandering block-wave shaped wire. The first and a second substantially planar meandering block-wave shaped wires 500 and 502 are arranged with respect

to each other, i.e. shifted with respect to each other over half a period of the block-wave of the wires, to form a number of cells E. In this particular arrangement the planes of wires 500 and 502 are oriented under an angle of substantially 90 degrees. Other orientations however are also possible. When applying a current through wires 500 and 502 in a similar way as illustrated in Fig. 1a a magnetic field will be generated wherein the main part of the generated field will be localized substantially within and in the vicinity of the cells E. This structure differs from the coil structure in **Fig. 1a** in that the pair of wires 500 and 502 does not form a planar sub-structure. In the embodiment of **Fig. 5** an additional straight wire 504 can be arranged on the intersecting line of the planes of the meandering wires 500 and 502 thereby forming a three wire distributed coil structure which can be driving in the same way as the structure as discussed in relation to **Fig. 1.**

Typically the area of the cells can be chosen from a range between 0,01 to 1000 m^2, in particular between 0,1 and 100 m^2. Such sizes allow large areas to be effectively treated. Moreover, these area sizes correspond to typical dimensions of structures in buildings in which the living organism are kept, such as ceiling support structure or boxes in which livestock is held during feeding or breeding. These structures can be used as support for the distributed coil structures.

Fig. 6 schematically shows a system for stimulating a process within living organisms using electromagnetic field. The system depicted in **Fig. 6a** comprises electronics 600 for generating a driving signal coupled to one or more distributed electromagnetic coil structures 602,604 of the present invention. If the coil is not a large area distributed coil or if the distributed coil structure does not cover the whole area in which the living organisms are kept, the system can comprise one or more attracting means 606,608 for attracting the animals under or over or at least within the vicinity of the cells. The attracting means can be electronically connected 610 to the driving circuitry of the electromagnetic coils such

that feeding and the electromagnetic stimulation can be synchronized.

In case of fish or shrimps in a large area breeding pond such attracting means can be an automated fresh water supply, an automated blower or another automated local oxygenation means, a food supply, a lamp or a combination of such measurers.

The distributed coil structures may comprise cells having a hexagonal wire arrangement as depicted in **Fig. 6b**. In this embodiment a double wire structure 612,614 is spiraled around a support frame 616. Typically the cell may have a diameter between approximately 1 and 4 meter. The attracting means may be arranged in the center of the hexagonal cell. Activating the attracting means, e.g. the fresh water or food supply, may trigger the driving electronics of the distributed transducer. Upon activation of the driving electronics a time varying current will be applied to the double wire of the transducer thereby subjecting the shrimps and/or fish in the direct neighborhood of the attracting means to a time-varying electromagnetic field.

The frame 616 supporting the hexagonal wire arrangement is formed by six poles arranged in a hexagonal way. In the center 618 the poles are connected to each other by a hinge mechanism which allows the poles to be folded. In the folded position the cells can be easily transported.

In case of livestock in a stable the attracting means can be an automated food or drink supply or a milking robot. The use of the attracting means thus allows efficiently large scale electromagnetic stimulation without the need that the coil structure covers the complete area where the living organisms are kept.

Fig. 7 illustrates a schematic of distributed electromagnetic transducers according to a first, a second embodiment and a third embodiment of the invention. These transducers are optimized for applying a time-varying electromagnetic field to a large population of living organisms kept in or spread over a large area S, such as stables for livestock. The transducer

may be arranged in the floor of the stable or suspended at a certain height above the surface of the floor of the stable.

Fig. 7a depicts a transducer having a coil structure wherein the basic structure of the coil is similar to the one illustrated in **Fig. 1**. The coil structure covers part of the area of two stables 700,702. The meandering wires 704 and 706 and the wires 708,710,712,714 are arranged such that they cover the elongated stable boxes 716a, 716b, 716c, 716d arranged at the opposite sides of the central aisle 718,720 of each stable. In this particular arrangement, the distributed coil structures of each stable are constructed using only three wires 704,708,710 for the first stable 700 and three wires 706,712,714 for the second stable. Further, the arrangement of the wires is chosen such that the wires can be connected at one central point 722 to suitable driving electronics.

Fig. 7b depicts a transducer comprising a number of wires 724,728,732 arranged in parallel along to the length direction of an area S of a stable or the like. At one end-side of the area S the wires are electrically connected to each other by a further wire extending in a direction perpendicular to the length direction of the area S. At the other side of the area s, the wires are connected at a central point to the driving electronics. Adjacent wires thus form elongated coil structures (elongated "cells" 726,730), each covering a predetermined sub-area of the total area S. Typically, the length of the wires is between 10 and 100 meters. The spacing between the wires is between 1 and 5 meters.

In a first phase, the driving electronics apply for a predetermined first time period a time-varying current through the first and second wire 724,728 of the first elongated coil structure. In this way live stock present under or above or in the direct vicinity of the first elongated coil structure is subjected to a time-varying electromagnetic field. Thereafter, the electronics will apply in a second phase a time-varying current through the second and third wire728,732 of the second elongated coil structure. This process will be repeated until

the last coil structure, thereby effectively exposing all live stock present in the area S.

It is submitted that various variations of the above coil structures are possible. For example in one embodiment a number of coil structures as depicted in **Fig.7b** may be arranged next to each other in order to effectively cover very large areas. In a further embodiment, the each wire in the transducer as depicted in **Fig. 7a** may have a distributed shape. The wire for example may meander one or more times along the length of the stable before it is connected via the further wire to the other distributed shaped wires. An example of such embodiment is depicted in **Fig. 7c.**

Effective stimulation of processes in living organisms with low field strength fields produced by distributed coil structures is dependent on the temporal shape of the applied electromagnetic field. One aspect of the invention involves the recognition that a signal comprising a superposition of one or more, but preferably at least two periodic electromagnetic signals of a particular shape is especially effective in the stimulation of biological processes, including stimulation of the immune system. The electromagnetic signal produced by the system preferably comprises a time-varying electromagnetic signal B(t) which comprises a spectrum of frequencies in which some frequencies or frequency areas are more strongly present than others.

In another embodiment B(t) comprises one periodic base signal $b_i(t)$ or a superposition of at least two periodic base signals $b_i(t)$ $(i=1,2,3,\ldots)$, each base signal $b_i(t)$ being defined as:

$$b_i(t)=a_i*(2\exp(-\omega_o t)-(1+\exp(-\omega_o T_i/2)) \quad \text{for } 0 \leq t \leq T_i/2$$
$$b_i(t)=-b_i(t-T_i/2) \quad \text{for } T_i/2 \leq t \leq T_i$$

The periodic base signal $b_i(t)$ is depicted in **Fig. 8.** T_i is the period of the periodic signal $b_i(t)$, a_i is an amplitude and ω_o is a characteristic frequency determining the shape of the signal $b_i(t)$. It was experimentally determined that the use of an electromagnetic signal B(t) based on the signals $b_i(t)$

(i=1,2,3,…), which have a special shape, is especially effective in the electromagnetic stimulation of living organisms. Preferably, the characteristic frequency ω_o substantially matches the R/L ratio of the distributed coil structures, wherein R represents the resistance and L the inductance of the inductive coil(s). Devices generating such signals are further described in a related application with title "Device and method for electromagnetic stimulation of a process within living organisms".

Typically the characteristic frequency ω_o is chosen from a range between 200 and 20,000 $rad.s^{-1}$, more preferably between 500 and 15,000 $rad.s^{-1}$, in particular between 1000 and 10,000 $rad.s^{-1}$. The amplitude a_i (i=1,2,3,…) is chosen such that the peak amplitude of B(t) at the treatment position will be in the range between 1 nT and 1 mT, preferably within the range between 0.01 μT and 10 μT and the periods T_i (i =1,2,3…) are chosen from a range between between 0,01 ms and 1000 ms, preferably between 0,1 ms and 100 ms.

The effectiveness of this signal is shown in a number of in vivo experiments performed on fantail goldfish (Carrassius Auratus spp.). The goldfish were heavily infected with Ecto parasites (Gill parasites) such as Dactylogyrus/Gyrodactylus, Trichodina, Chilodinella and Costia. These types of parasite infections occur frequently at the breeding stage of the fish and increase in frequency during storage and international transport due to the fact that large populations are packaged in one volume. These infections and subsequent secondary bacterial infections cause high mortality if not treated.

Fig. 9 shows typical results from the electromagnetic stimulation treatment for six different field strength ranging from 0.15 μT to 50 μT. Every day the fish were exposed for 30 minutes to a time varying electromagnetic field comprising of at least two periodic signals as described in relation to **Fig. 7**. The results show that the control group suffered a mortality rate up to 52% on day 28. In contrast, the average mortality rate of the treated fish was 15% at day 28. The effectiveness of the treatment reduces slightly when using fields smaller than 0,05 μT. These results were reproducible

and show that the low energy electromagnetic treatment using signals generated by the device of the present invention results in a strong decrease in mortality at all field strength levels used.

The present invention is not limited to large scale electromagnetic stimulation of the immune response in animals, but can also be applied to humans, for instance in the (preventive) treatment against sicknesses such as the bird flue or a biological attack. Moreover, the invention is not limited to the embodiments described above, which may be varied within the scope of the accompanying claims.

CLAIMS

1. A distributed electromagnetic coil structure for applying a time varying electromagnetic field to a population of living organisms, said coil structure comprising at least a substantially planar first coil sub-structure, said first coil sub-structure comprising at least a first wire of a predetermined shape and a least a second wire of a predetermined shape, wherein said first and second wire are shaped to define one or more of first cells, said electromagnetic field being generated by said first cells when a current runs through said first coil sub-structure.

2. A coil structure according to claim 1, wherein said coil structure further comprises at least one substantially planar second coil sub-structure defined by said second wire of said first coil sub-structure and at least a third wire of a predetermined shape, wherein said second and third wire are shaped to define a one or more of second cells, said electromagnetic field being generated by said second cells when a current runs through said second coil sub-structure.

3. A coil structure according to claim 1 or 2, wherein at least one of said first or second wire comprise a substantially meandering or a block-wave-shaped or a sawtooth-shaped wire.

4. A coil structure according to claims 1 or 2, wherein a plurality of said first coil sub-structures are arranged side by side extending over a surface area and wherein the planes of said coil sub-structures all lie within a plane which is substantially parallel to said surface area.

5. A coil structure according to claims 1 or 2, wherein a plurality of said first coil sub-structures are arranged side by side extending over a surface area and wherein

the planes of said coil sub-structures are arranged substantially perpendicular to said surface area.

6. A coil structure according to any of the preceding claims, wherein the area of said cells is chosen from a range between 0,01 to 1000 m^2, in particular between 0,1 and 100 m^2.

7. A distributed electromagnetic transducer for applying a time varying electromagnetic field to population of living organisms kept in or spread over a large area S, said distributed transducer comprising at least a first coil structure and a second coil structure, said first coil structure and second coil structure are arranged under or in or above a volume defined by said large area S and a predetermined height of dimensions much smaller than the dimensions defining said large area S, wherein said first coil structure and second coil structure, each comprises at least a wire having a distributed shape, and wherein when in use said first coil structure exposes for a first time period a first sub-volume of said volume to a time varying electromagnetic field and said second coil structure exposes for a second time period a second sub-volume of said volume to a time varying electromagnetic field, wherein said first time period and first sub-volume are substantially different from said second time period and second sub-volume respectively.

8. An electromagnetic coil structure adapted for applying over a large area a time varying electromagnetic field to living organisms, said coil structure comprising at least a first, second and third wire of a predetermined spatially distributed shape, said first, second and third wire being shaped to define one or more first cells and one or more second cells, wherein when in use said electromagnetic field is generated substantially by said one or more first cells when current runs through said first and second wire and said electromagnetic field is generated substantially by said one or more second cells when a current runs through said second and third wire.

9. System adapted to generate electromagnetic stimulation of processes within living organisms when applied to at least a part of a body of said organisms, comprising at least one distributed electromagnetic coil structure according to any of the preceding claims, said system further comprising attracting means for attracting and/or restricting living animals to the vicinity of at least one of said cells.

10. System for applying a time varying electromagnetic field to a large population of living organisms kept in or spread over a large area, comprising at least a distributed electromagnetic coil structure, and a generator for applying a time varying signal to said coil structure, wherein the system further comprises attracting means for attracting and/or restricting living animals to the vicinity of said coil structure.

11. System according to claim 9 or 10, wherein said attracting means comprises a drink supply or a food supply or a light source or a milking robot or oxygenation means for local oxygen enrichment of water, such as a fresh water supply or an air blower.

12. Device for applying a time varying electromagnetic field to a population of living organisms comprising at least a transducer and a generator for applying a time varying signal to the transducer, wherein the transducer is adapted for applying the electromagnetic field to at least part of the body and wherein the amplitude of said field is time dependent and comprises a spectrum of frequencies in which some frequencies or frequency areas are more strongly present than others, characterized in that said transducer comprises at least one distributed electromagnetic coil structure according to any of claims 1-8.

13. Method of driving a distributed electromagnetic coil structure according to claim 2 or 7 or 8, comprising the steps of:

- applying a first current for a predetermined first time period to said first coil sub-structure such that an electromagnetic field is generated in at least one of said first cells,
- applying a second current for a predetermined second time period to said second coil sub-structure such that an electromagnetic field is generated in at least one of said second cells,

wherein said first and second time period start at different times.

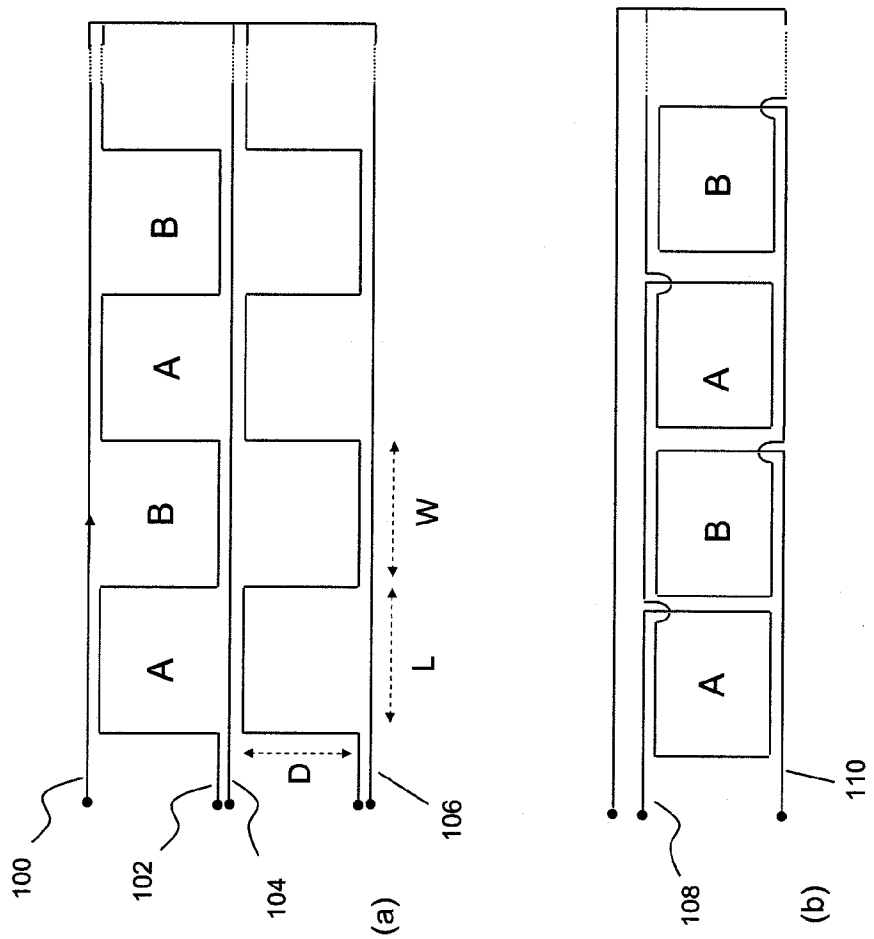


Fig. 1

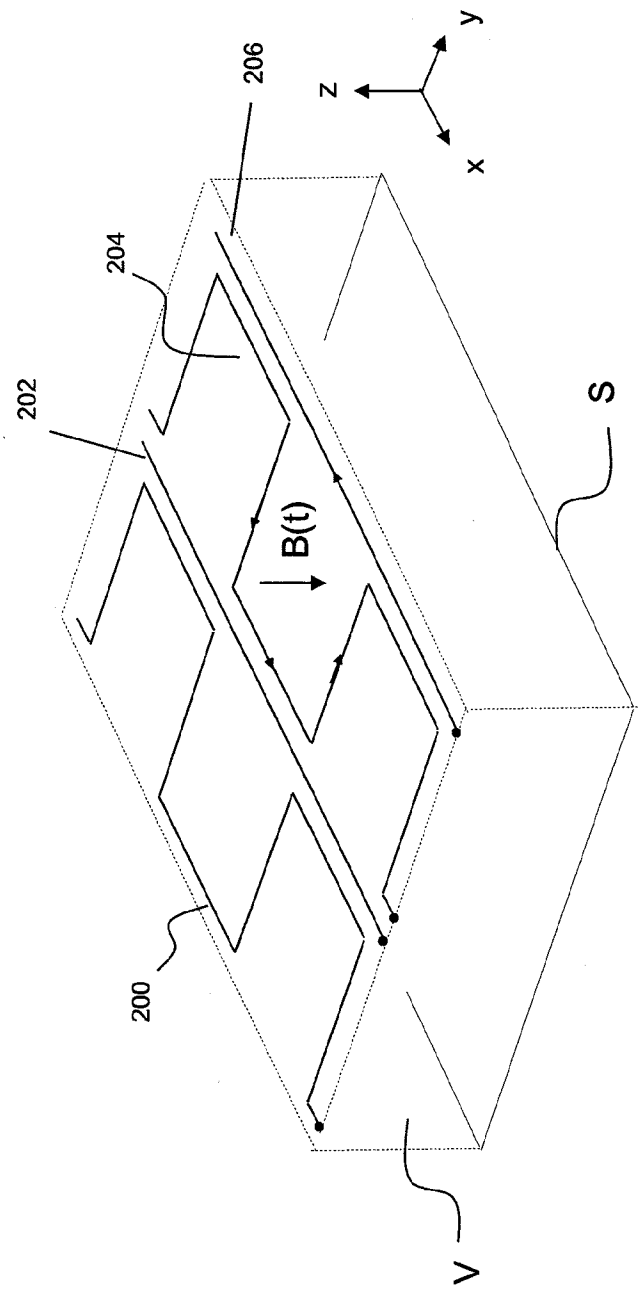


Fig. 2

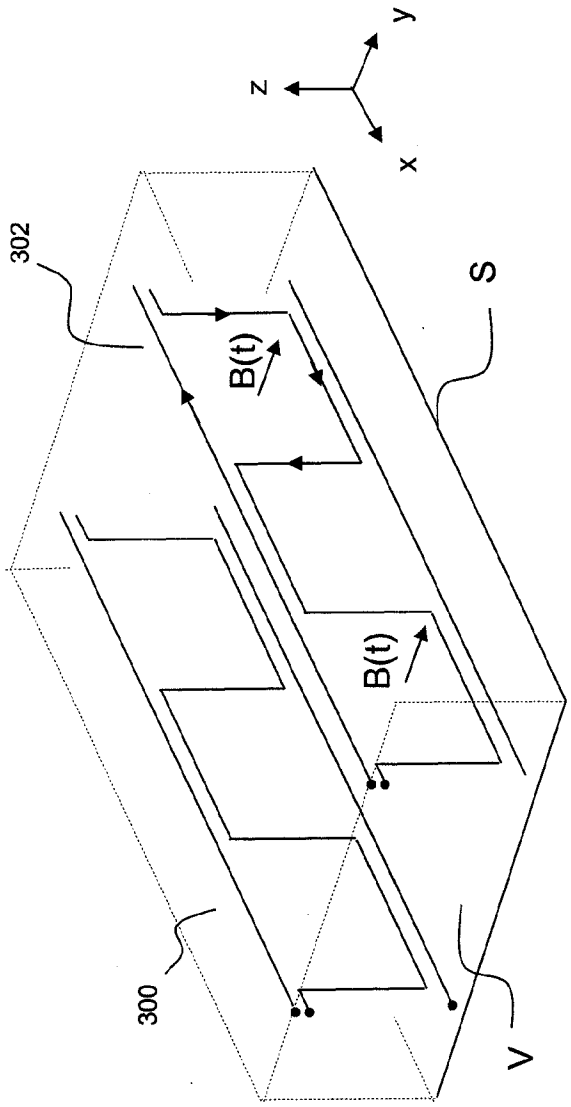
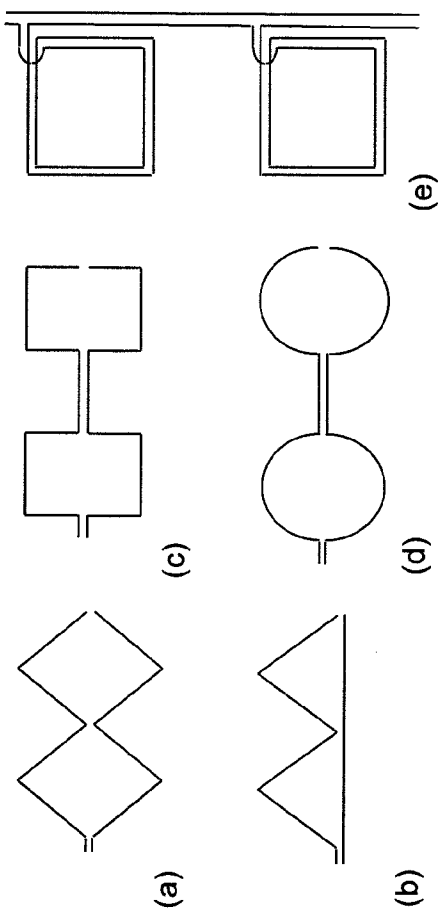


Fig. 3



(a)

Fig. 4

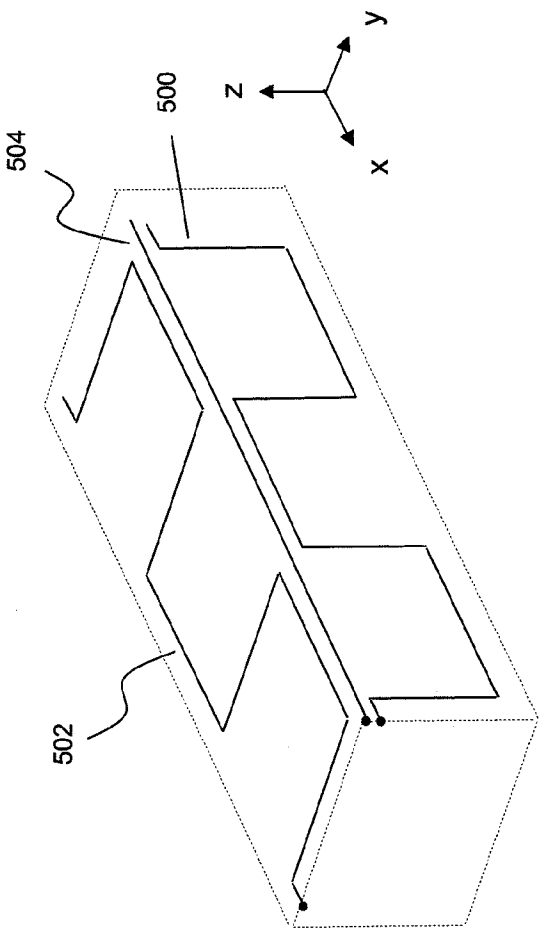


Fig. 5

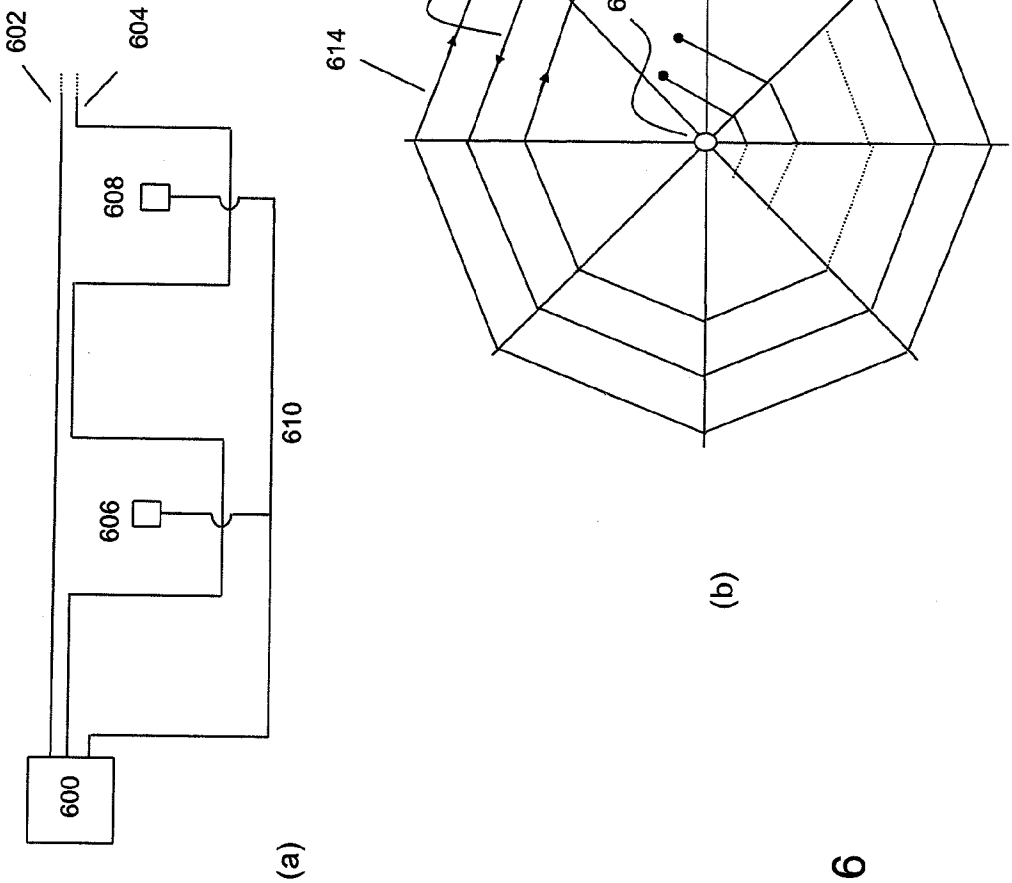


Fig. 6

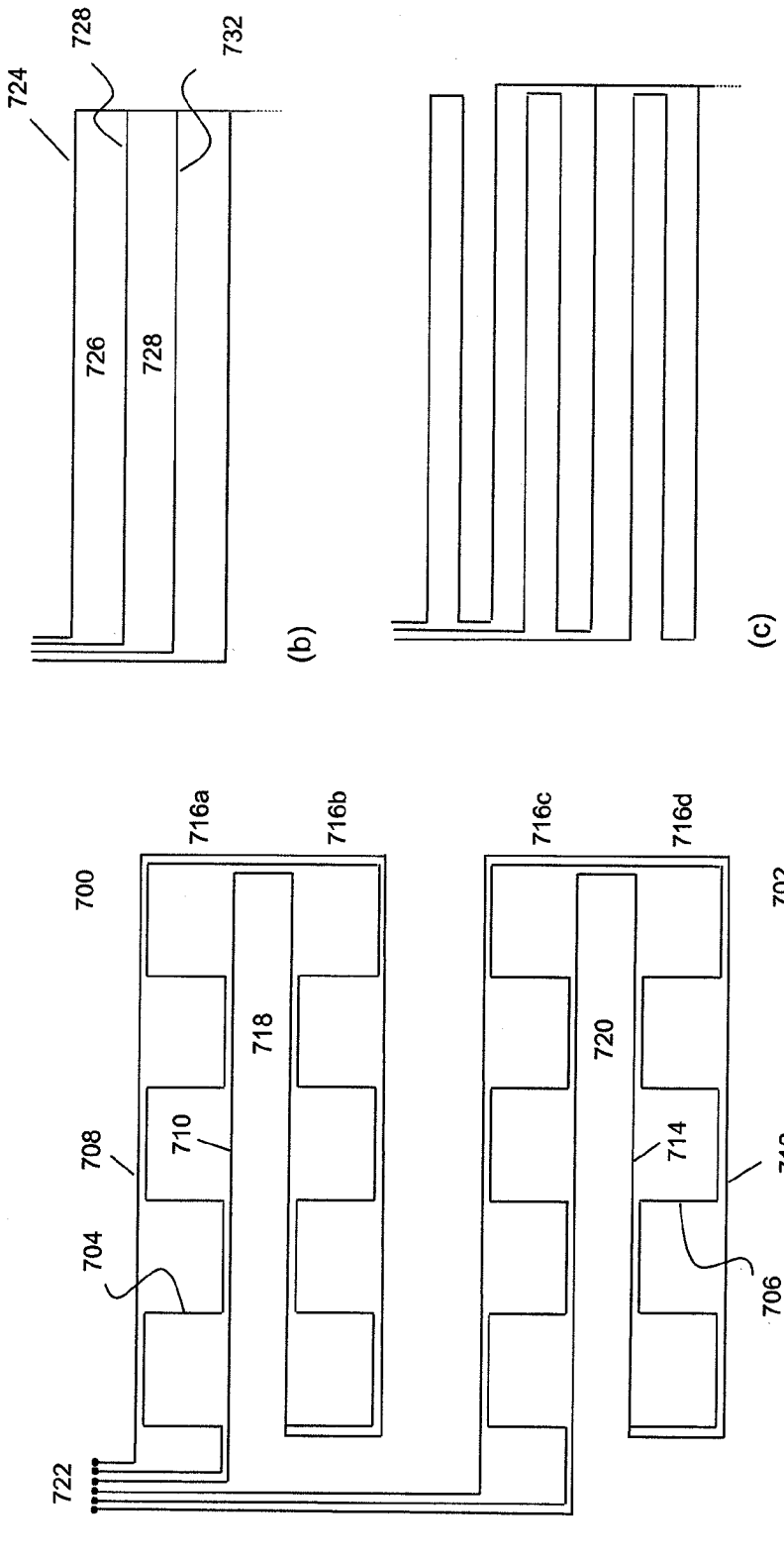

724
728
732
726
728
(b)
(c)
716a
716b
716c
716d
700
702
718
720
708
710
714
712
704
706
722
(a)

Fig. 7

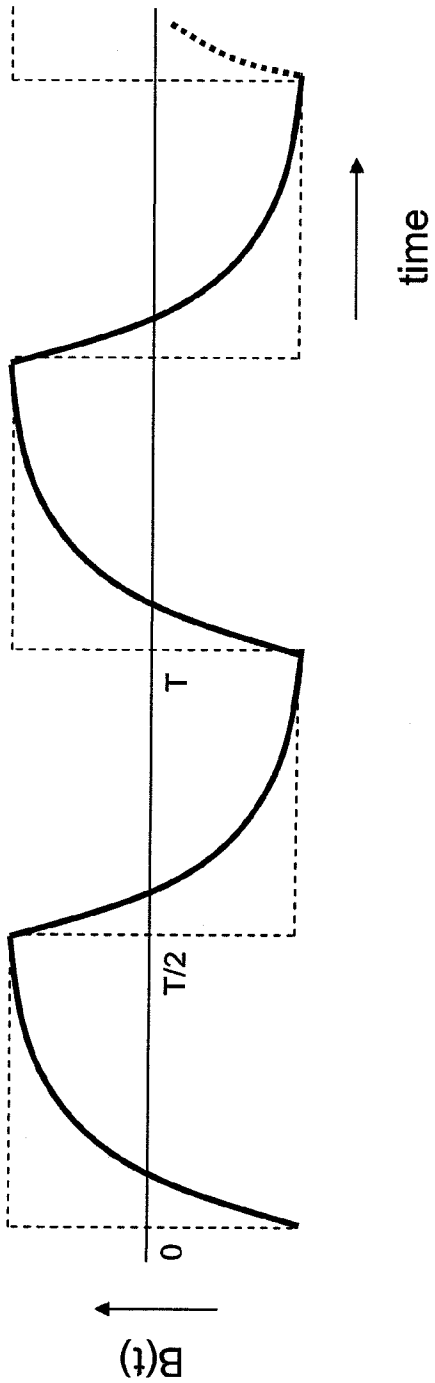
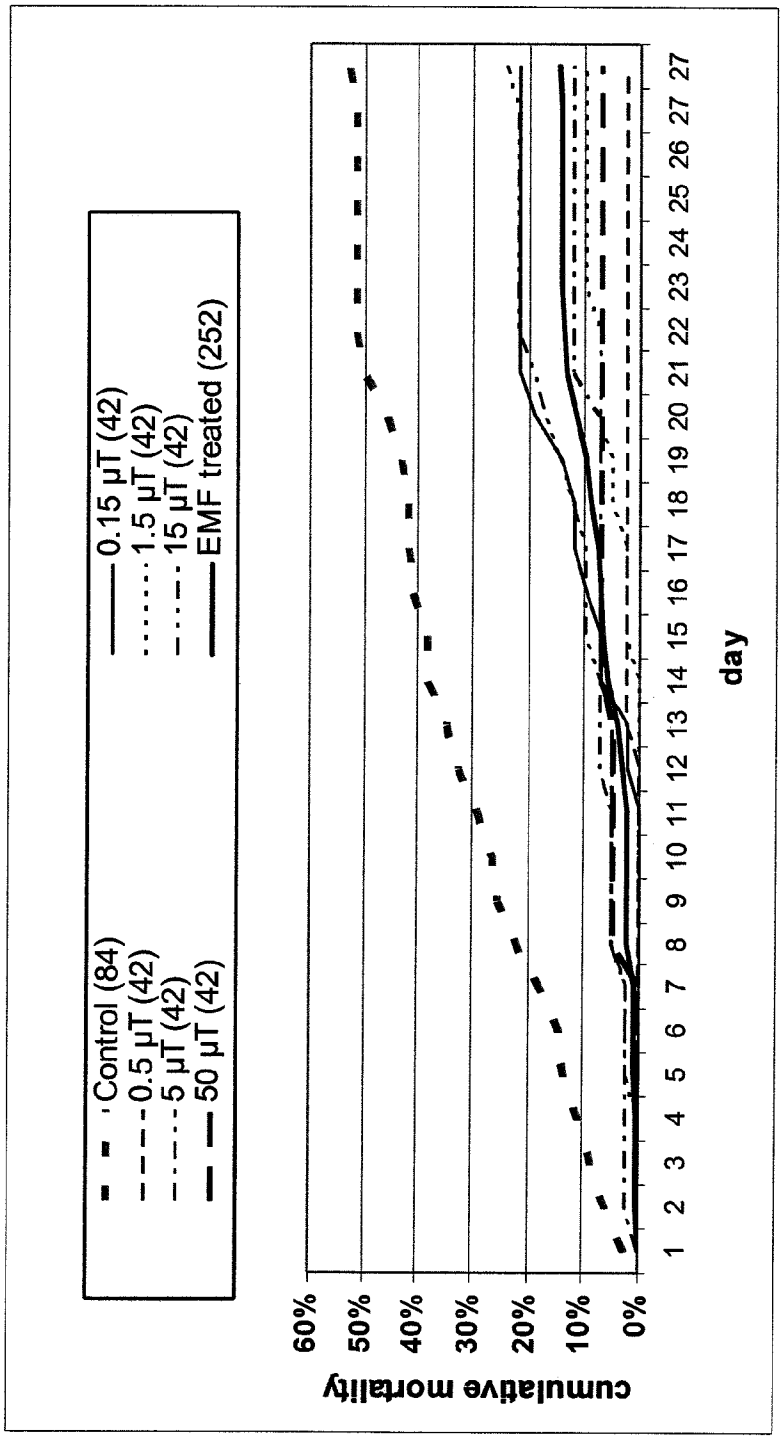


Fig. 8


Control (84)
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5 µT (42)
50 µT (42)
0.15 µT (42)
1.5 µT (42)
15 µT (42)
EMF treated (252)
cumulative mortality
60%
50%
40%
30%
20%
10%
0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
day

Fig. 9