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(54) **Multi-axial magneto-electric transducer, for variable magnetic fields**

(57) A multi-axial (X,Y,Z) magneto-electric transducer, for variable magnetic fields, propagating into space. The transducer comprises a directional antenna system (W1,W2) capable of picking up the fluxes of the components of the magnetic field, in which the core members

(15, 16) of the antennas (W1, W2) are disposed in magnetic continuity with one another, contributing to provide a reciprocal drainage and thickening or concentration of the flux (Φ_X); the windings of the antennas (W1, W2) comprise one or more winding sections (W1; W2.1, W2.2, W2.3, W2.4) connected in series to one another.

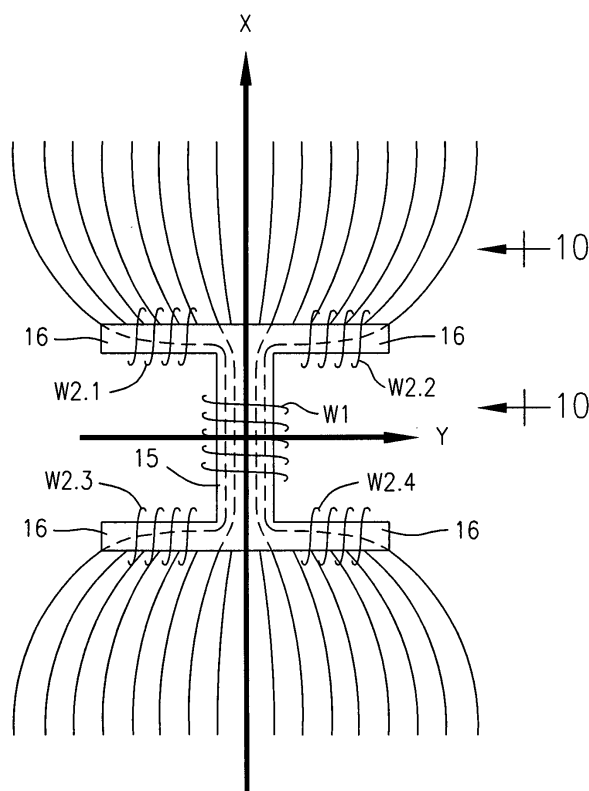


Fig. 9

Description

BACKGROUND OF THE INVENTION

[0001] This invention concerns a multi-axial magneto-electric transducer suitable to convert, into electrical voltages, the value of the components of a variable magnetic field, propagating into air space, for example an alternate magnetic field of variable intensity over time with a sinusoidal pattern.

[0002] The aforesaid transducer is suitable for use in all electronic apparatus where the values of the intensity and direction of a magnetic field must be detected, with high sensitivity and reliability, especially whenever there are restrictions and limitations in terms of overall dimensions, weights and costs.

[0003] An apparatus belonging to this type of equipment is the one known as ARVA (avalanche victim finding beacon) which essentially consists of a transmitter for emitting, by ON-OFF modulation, a sinusoidal magnetic wave, for example of 457 kHz, a transducer for detecting signals having such characteristics emitted by other similar apparatus, and a system for processing the detected signals.

STATE OF THE ART

[0004] A classical mono-axial magneto-electric transducer for alternate magnetic fields, usually is composed of a solenoid having several dozen turns, in which the flux of an alternate magnetic field, directed according to the axis of the solenoid, induces in the latter an electromotive force depending upon the linked magnetic flux.

[0005] Similarly classical are the following expedients aimed to improve the sensitivity and selectivity of a transducer:

- Concentration of the magnetic flux, achieved by a core of magnetic material having high permeability, for example ferrite; for sake of clarity, the word "ferrite" means any other magnetic material suitable for the purpose. Fig. 1 shows, in a single Cartesian quadrant X, Y, how the magnetic flux " Φ ", which in the space outside the solenoid S is contained in an imaginary tube of radius R, goes to thickening or concentrate in a tube of radius $r < R$, represented by the core of a ferrite bar 10. Fig. 2, compared to fig. 1, shows how the concentration of the a flux Φ in the core of a ferrite bar 10' decreases as the length of the bar decreases. In fig. 2, "r" is once again the radius of the core 10' identical to the radius "r" of the core 10 of fig. 1, while R' is the radius of the tube of flux collected by the core 10' in which $r < R'$
- Creation of a resonant circuit, obtained by connecting in series with the winding of the solenoid, which constitutes the inductive component, a capacitor of sufficient capacity to cause resonance at the frequency of the magnetic field. The resonant circuit

selectively intensifies the useful frequency and consequently also takes on the function of an analog filter.

[0006] The transducer described, which was used in the first-generation ARVA apparatuses, is schematically shown by reference T1 in fig. 4; it constitutes a selective antenna capable of detecting the VCM_X component only, and namely the component in the X direction of the Magnetic Field Vector VCM, it being decided to adopt a spatial reference system consisting of the three Cartesian axes X, Y, Z, referred to with the outer casing 11 of the ARVA, as shown in fig. 3. The operator engaged in searching for a people buried under the snow, is entrusted with the task of systematically pointing the instrument in all the directions of the air space to search the strongest signal, which represents VCM in intensity and direction.

[0007] Fig. 5 shows the embodiment of a second-generation of ARVA, in which two mono-axial transducers T1 and T2 have a typical L-shaped disposition according to X and Y axes of the triad of reference axes of fig. 3.

[0008] Conversely, fig. 6 shows a cross-shaped disposition of the two mono-axial transducers T1 and T2, also of a second-generation of ARVA, whose cores are distinct and separate from each other, likewise to the previous embodiments.

[0009] Lastly, fig. 7 shows the disposition of three mono-axial transducers T1, T2 and T3 existing in third-generation types of ARVA. The addition of a third mono-axial transducer T3, parallel to the axis Z, enables the calculation of the vector VCM of the magnetic field as a product of VCM_X, VCM_Y and VCM_Z vectors; consequently in this case the operator is relieved of the difficult and time-wasting task of finding the strongest signal by trials and errors.

DRAWBACKS OF THE CONVENTIONAL TRANSDUCERS

[0010] The conventional transducers of the bi-axial and tri-axial type, obtained by simply combining two or three mono-axial transducers, suffer by at least two rather serious drawbacks.

[0011] The first comes from the need to limit the size of the apparatus within reasonable dimensions, and to consequently reduce the length of the ferrite bar of the mono-axial transducer T2 oriented according to the Y axis and, even more drastically, the length of the transducer T3 oriented according to the Z axis. By comparing fig. 2 with fig. 1, as previously mentioned, it can be seen that the effect of concentration of the flux, in the short bar 10' of fig. 2, is decisively smaller than the long bar 10 of fig. 1. Using FAF value (Flux Aggregation Factor) to indicate the ratio between the areas of the cross sections of the tube of flux outside and inside the winding (R^2/r^2), the analysis backed up by experience reveals an FAF value of approximately 45 for a cylindrical bar of 10mm in diameter and 120mm in length, but only approximately

10 for a bar of the same diameter and material, but of half the length.

[0012] The second drawback comes from the lack of symmetry, with respect to the XZ and YZ planes, of the L-shaped disposition of the mono-axial transducers T1, T2 oriented according the X and Y axes of figures 5 and 7. If the distance which separates the magnetic bars of the two transducers T1 and T2 is not wide enough (in practice, so as not to increase the overall dimensions, it is generally not more than 10-15mm), the following operative anomalies occur:

- A magnetic flux lying in the XY plane, slanted with respect to the X axis, tends to follow the path having the lowest reluctance, represented by the succession of the two bars.
- Consequently, whilst the direction of the VCM_XY vector, of VCM_X and VCM_Y components, varies within quite a wide angle, astride the two bisectors of the angles formed by the X and Y axes, the intensities of the fluxes inside the two bars tend to remain practically identical and constant. Using VCM_X' and VCM_Y' to indicate the inaccurate measurements of VCM_X and VCM_Y which are obtained under such conditions, fig. 8 shows the distortion of the function $Tg(VCM_XY'^X) = VCM_Y' / VCM_X'$ (F1 value detected), where VCM_XY'^X represents the angle formed by VCM_XY' with the X axis, compared to the correct function $Tg(VCM_XY'^X) = VCM_Y / VCM_X$ (F2 actual value) which represents the tangent of the angle that the direction of VCM_XY forms with the X axis, in a very wide critical angular field α . Due to the effect of this distortion, the calculations both of the intensity and of the direction of the VCM vector are considerably altered.
- The lack of accuracy in itself can be remedied only by introducing appropriate equalising functions, to be established by trials; but nothing can be done to obviate the loss of sensitivity and the consequent greater uncertainty which are inevitably inherent in all the direct and indirect measurements relating to the VCM vector, when its direction falls within the critical angular field α shown in fig.8.

OBJECTS OF THE INVENTION

[0013] The main object of the invention is to provide a multi-axial magneto-electric transducer comprising an integrated system of directional antennas, capable of generating electromotive forces whose intensities are proportional to the components, according to the axes of a Cartesian system of reference, of a variable magnetic field which is propagated in the air space, and to comply with the following requirements as far as possible:

- High sensitivity in measuring and detecting the magnetic field in at least two of the three components of the magnetic field vector VCM.

- Reduced overall dimensions and weight compared to those which would be obtained, with the same performances, by simply combining two or more transducers of the mono-axial type.

BRIEF DESCRIPTION OF THE INVENTION

[0014] The above can be achieved by a magneto-electric transducer comprising an integrated system or assembly of directional antennas according to claim 1. In particular, according to the invention a multi-axial magneto-electric transducer has been provided, for variable magnetic fields propagating in the space, comprising an assembly of directional antennas oriented according to Cartesian reference axes, in which each antenna comprises a core member of magnetically conductive material, having high magnetic permeability, for concentration or thickening of the flux, and an electric winding oriented according to a Cartesian reference axis, characterised by comprising an integrated core assembly, in which:

the core member of each antenna is disposed in magnetic continuity with the core member of at least one other antenna;

the core member of at least one first antenna being arranged, with respect to the core member of a second antenna, to provide a flux draining and flux thickening element for the core member of the second antenna of the assembly.

[0015] Preferably, the core members of the antennas are disposed symmetrically with respect to at least one reference plane passing through at least one of the Cartesian reference axes.

[0016] According to another feature of the invention the magneto-electric transducer is characterised in that at least one first antenna of the assembly comprises a plurality of antenna elements each having an elongated core portion oriented in the direction of a Cartesian reference axis;

said core portion of each antenna element being disposed in magnetic continuity with the core member of a second antenna;

said core portion being conformed and arranged to contribute to the flux thickening in the core member of the second antenna; and

in that the electric winding of said first antenna comprises one or more winding sections coaxially disposed to respective core portions oriented according to said Cartesian axis of reference.

[0017] According to a still further feature of the invention, the core members of the individual antennas define an integrated core assembly, in which various core portions of the individual antennas are disposed according to a ring-like, cross-like, double T-like, cubic cage-like, and parallelepiped-like shaped structure, or other suitable disposition.

[0018] Preferably, the disposition of the core mem-

bers, or core portions of the integrated antenna assembly, must be symmetrical with respect to one or more reference planes passing through the Cartesian reference axes.

[0019] For the purposes of this invention, "disposition in continuity" of the core members or the core portions of the antennas, is understood to mean a "magnetic continuity" in which the core members or the core portions are physically in contact with one another, providing, at the most, slight structural, or even functional magnetic air gaps for the purpose of limiting certain problems deriving from possible unavoidable manufacturing defects.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The general features of the magneto-electric transducer according to this invention, and some embodiments, will be more clearly evident from the following description, with reference to the accompanying drawings, in which:

Figs. 1-8 show conventional magneto-electric transducers of the mono-axial type, belonging to the prior art;

Fig. 9 shows, in the XY plane, how the magnetic flux of X direction relating to one antenna, is thickened or sucked in by the draining tubes of the core members of a second antenna, in a double T-like disposition;

Fig. 10 shows, in the XZ plane, according to the line 10-10 of fig. 9, how the magnetic flux of X direction is sucked into the draining tubes of the core member of the second antenna of fig. 9;

Fig. 11 shows the square ring-shaped integrated core assembly of a transducer comprising two directional antennas;

Fig. 12 represents a detail of fig. 11 to show how the magnetic flux in the direction of the X axis, destined to be conveyed along the right side parallel to the aforesaid axis X, is prevalently sucked in by the adjacent half-side oriented in the direction of the Y axis;

Fig. 13 shows the flux path in the square ring-shaped core of fig. 11, whose X and Y reference axes are disposed in a slanted direction with respect to the flux lines;

Fig. 14 shows an integrated core assembly with a cage-shaped structure, for a tri-axial transducer, where each core member does have its own winding portion;

Fig. 15 shows a first variation of the transducer of fig. 14, in which the winding relating to the Z axis is composed of two winding sections wound on Z axis parallel core members of two opposite sides;

Fig. 16 shows a second variation of the transducer of fig. 14, in which the winding relating to the Z axis is composed of a single winding section wound around all the Z axis parallel core members of the entire cage-shaped structure;

Fig. 17 shows a possible embodiment of the cage-shaped structure of fig. 14;

Figs. 18 and 19 show simplified structures derived from the structure of fig. 17;

Figs. from 20 to 22 show other variations of integrated core assembly for a multi-axial transducer according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0021] This invention is based on a particular integrated structure of the core members of directional antenna assembly for a multi-axial magneto-electric transducer which combines two expedients:

- the first one aims compensating for a possible reduced length of the core member or core portion of a magneto-electric mono-axial transducer, by adding at the ends (or close to the ends) of the core member, or of each core portion of a mono-axial transducer, hereinafter also referred to as "flux collector tube", one or more cross core portions, hereinafter referred to as "flux draining tubes".
- the second one expedient consists in conforming the core assembly of a multi-axial magneto-electric transmitter, into a magnetically integrated structure, of such kind that each core member or part thereof, performs a dual function: a flux collecting tube function for the flux directed according to the reference axis of the same core member, and a flux draining tube function for the flux or the fluxes directed according to the remaining axes of a Cartesian reference system.

[0022] The foregoing can be more clearly understood by reference to the example of figures 9 and 10 which show the case of a double T-shaped integrated core structure or assembly for a bi-axial magneto-electric transducer. Figures 9 and 10, purely by way of example, indicate the paths of the flux Φ_X of X direction, in the XY and respectively ZX planes of a Cartesian reference axes system.

[0023] Briefly, reference number 15 has been used to indicate a central core member, of magnetically conductive material, while reference number 16 has been used to indicate four side core members of the same material, disposed on both sides, at the ends of the central core member 15. Also by way of example, in fig. 9, reference W1 has been used to indicate the winding linked with the flux of X direction which flows along the flux collecting tube comprising the core member 15, while references W2.1, W2.2, W2.3 and W2.4 have been used to indicate the four winding sections of the winding linked with the flux of Y direction (not shown) which flows along a respective flux collecting tube comprising the core members 16, in a magneto-electric transducer TME characterised by a bi-axial antenna assembly.

[0024] In the example of figures 9 and 10 it can be

seen that the core members 16 of Y direction are in magnetic continuity with the core member 15 of X direction, thereby significantly contributing to drainage of the Φ_X flux, and to its concentration in the core member 15.

In the case of figures 9 and 10, the cross core members 16 are positioned in correspondence with the ends of the central core member 15, maintaining a symmetrical disposition with respect to a reference plane passing through the X axis; however, the core members 16 relating to the antenna of Y direction could also be arranged in a more or less backward position with respect to the ends of the central core member 15.

SQUARE RING-SHAPED, BI-AXIAL TME

[0025] A first preferential embodiment is obtained by using an annular structure for the core of a bi-axial X-Y TME, in particular the square ring-shaped structure 20 of fig. 11.

[0026] In this case, references W3.1 and W3.2 have been used to indicate the winding sections of winding W3 relating to the antenna AX of X direction, while references W4.1 and W4.2 have been used to indicate the two winding sections of winding W4 of the antenna AY of Y direction; in both cases, the winding sections W3.1, W3.2 and W4.1, W4.2 of each antenna, should be wound and connected in series to one another in such a way that the electromotive forces, induced by the linked magnetic fluxes of X and Y directions, are in phase with one another.

[0027] If the structure of the core assembly is symmetrical with respect to the planes XZ and YZ, the symmetry of the windings must be considered in the electrical sense, as non-geometrical: that is to say, the X flux, to be understood as direct like the axis X, must induce in the winding sections W3.1 and W3.2, symmetrical electromotive forces with respect to the XZ plane, and likewise for the Y flux, on the basis of the following:

a) the most predominant of the stray capacitive couplings existing between the different winding turns, in a same winding, are those which occur through the body of the core of ferrite, a material characterised by an extremely high dielectric constant (10,000-100,000). By dividing up each antenna AX and AY into two winding sections W3.1, W3.2 and W4.1, W4.2, it is possible to space apart from one another precisely those turns between which the greatest differences in electric potential occur, thereby attenuating those capacitive couplings associated with the greatest losses in the dielectrics represented by the insulation of the electric wire, by the windings spool and by the container, generally to the benefit of the resonance factor. With regard to the capacitive couplings between the windings of the antennas AX and AY, no reciprocal interferences occur because, thanks to the symmetry of the antenna assembly, each and every spurious signal induced is

fully compensated by its opposite counterpart.

b) The somewhat intense electric current which in the condition of resonance is flowing for example in the resonating electric circuit of the antenna AX, comprising the electric winding and a capacitor (not shown), generates a magnetic flux which closes on the outside of the ferrite ring 20, because the fluxes which close on the inside cancel each other out; the inductance associated with the AX winding of such external flux indicated as "external" is precisely the inductance which, by combining itself with the capacitance of the capacitor and that of the stray couplings, determines the resonance frequency. However if, due to inaccuracies in the manufacturing process, the symmetry of the ferrite ring and of the windings were not respected, the magnetic fluxes flowing in the ferrite ring 20 could fail to compensate one another perfectly; this would lead to two troublesome drawbacks:

- i) the first one is that an "internal" inductance would be added to the external inductance and the resonance capacity would become a random variable, to be established by trial for each apparatus;
- ii) the second one is that the spurious voltages induced in the winding of AY antenna could fail to compensate one another, and consequently a phantom component would be perceived.

[0028] The preceding propositions also apply for the resonant circuit relating to the AY antenna.

[0029] Fig. 11 shows a square ring-shaped structure of the core 20; it is obvious however that the same remarks could be made for a "rectangular ring-shaped" structure, or of any other suitable shape.

TRI-AXIAL TME WITH A RETICULATED STRUCTURE

[0030] The properties of the bi-axial TME having the square ring-shaped structure of fig. 11, can all be found, properly extended, in a most complex reticulated structure of any suitable geometrical shape, for example the cubic shape of Fig. 14, or a parallelepiped shape, that can be adopted for a tri-axial TME.

[0031] Also in this structure, as in the preceding one, a slight variation of one dimension can be compensated by an adequate variation of opposite sign of the other two; for the sake of convenience, in the continuation of the description, the aforementioned cages shall still be referred to as "cubic", reserving the qualification of "parallelepiped" for the one in which at least one dimension is considerably different from the others.

[0032] As shown schematically, the cubic cage-shaped structure of the integrated core assembly of fig. 14 consists of a frame of ferrite, or other magnetically conductive material, comprising a plurality of bars members 21, 22, 23 oriented according to X, Y and Z reference

axes, disposed according to the edges of an ideal cube.

[0033] Each winding of AX, AY and AZ antennas is composed of four winding sections $WX_{1,2,3,4}$, $WY_{1,2,3,4}$ and $WZ_{1,2,3,4}$, which must be connected in series with one another in such a way that the electromotive forces induced by the respective fluxes of X, Y and Z direction, are concordant with one another, as mentioned previously.

[0034] In the case of fig. 14 the winding sections $WX_{1,2,3,4}$, $WY_{1,2,3,4}$ and $WZ_{1,2,3,4}$ of each winding AX, AY and AZ are wound around respective core elements consisting of a plurality of bars 21, 22 and 23.

[0035] All the described properties hold good even whenever it is preferred to make one or more of the windings of antenna AX, AY and AZ in a smaller number of sections, instead of four; this is shown by way of example in figures 15 and 16 where the same reference numbers of fig. 14 have been used to indicate similar or equivalent parts.

[0036] A first solution is shown in fig. 15 which differs from the preceding solutions due to the fact that the winding of antenna AZ in this case is composed of only two winding sections $W'Z1$ and $W'Z2$ each of which is wound around a pair of bars 23 oriented according to the Z axis and positioned on a same face of the cube.

[0037] A second solution is shown in fig. 16; in this case the antenna AZ is provided by a single winding section $W'Z3$ wound directly around the four bars 23 of the cubic cage, parallel oriented to the reference axis Z.

[0038] The tri-axial cubic cage TME is unlikely to fit into a container of limited dimensions, for example in a rather flat container, such as for example the container of an ARVA apparatus. Consequently, it is possible to compress or reduce one of the dimensions. Assuming, for example, to reduce the dimension directed as the axis Z of a cubic cage whose bars have an L-shaped cross section, as shown for example in fig. 17, until the two square rings of the two opposite faces join overlapping together, parallel to the plane XY as shown in fig. 18; a square ring-shaped magnetic structure is thereby obtained, having a "C"-shaped cross-section, with an internal groove. This structure involves antenna windings by two sections $WX_{1,2}$ and $WY_{1,2}$, only instead of four, for the antennas AX and AY, and by a single section $W'Z3$ for the antenna AZ. The Flux Aggregation Factor FAF, concerning the axis Z, in this case is reduced to a few units, but this is balanced by the larger amplitude of the surface impinged by the flux.

[0039] Fig. 19 shows a simplification of the ring-shaped structure of the core assembly of fig. 18, which in this case has a simple "I"-shaped cross section.

[0040] In the case of fig. 19, as well as in the case of fig. 18, the ferrite ring can be divided into four portions, separated by respective magnetic air gaps in a range of about one millimetre or less, so as not to cause a flux leakage, and therefore granting a substantial magnetic continuity of the ring-shaped structure; the magnetic air gaps, disposed in such a way as to safeguard the sym-

metry of the ring, with respect to the coordinates defined by the Cartesian axes of reference, have the purpose of reducing the internal fluxes and the related inductances.

[0041] Whenever the ferrite ring is somewhat large and heavy, in order to minimise the risks of breakage in the event of the apparatus being dropped, it is possible to provide suitable elastic bearings conformed and disposed so as to react to stresses and couples of inertial forces directed as the three Cartesian reference axes.

[0042] Preferably the winding turns are maintained spaced apart from the core members of the transducer, for the dual purpose of not subjecting the windings (the ends of which are normally fastened to the casing), to the elastic movements of the core itself, and of reducing the capacitive couplings, through the core, both between the turns of the same circuit, thereby reducing leakages in the coil, as well as between the turns of separate circuits, thereby reducing the risk of interferences.

[0043] The square ring with an I-shaped profile of fig. 19, compared to the square ring with a C-shaped profile, the other factors being equal, entails a reduction of the FAF for the fluxes of all three directions. However, it is lighter, less fragile, and also allows for the use of rigid suspensions at least in the direction of the axis Z.

[0044] Starting from the cubic or rectangular cage of the core structure of fig. 14, by suppression of several of the core elements, or bars, of one or more antennas of the assembly, it is possible to derive other forms of integrated cores for bi-axial or tri-axial transducers, which forego several good points of the solution of fig. 14 in order to comply with particular requirements; the foregoing is shown in the following examples.

[0045] Fig. 20 schematically shows an "offset square ring" or "three-dimensional" embodiment, in which several reference numbers of fig. 14 have been used to indicate similar or equivalent parts.

[0046] As it can be seen, the structure of the core of fig. 20 comprises two C-shaped dispositions of bars 21 and 23, relating to the axes Y and Z, on two parallel sides of an imaginary reference cube, in which the four bars 23 of the axis Z at one of their ends are connected by the bars 22 relating to the axis X.

[0047] The solution of fig. 20 offers the advantage of reducing the number of the bars or of the structural elements which make up the entire integrated core assembly, with a consequent reduction in the weights and the costs. The symmetry with respect to the XY plane is lost, however the drawbacks resulting from the lack of symmetry can be compensated for and made acceptable if the dimension of the composite core, in the direction of the axis Z, is considerably smaller than the dimensions relating to the other two directions X and Y.

[0048] Fig. 21 is a double cross-shaped solution, also for a tri-axial transducer, which can be derived from four juxtaposed cubic cages. In practice, it comprises a first upper core portion and a second lower core portion, both in the form of a cross, whose bars 21 and 22 are oriented according to the axes X and Y, and in which the nodes

at the centre of the two crosses are connected by a central magnetic bar 23 oriented according to the axis Z.

[0049] Also in this figure, as in the preceding ones the same reference numbers have been used to indicate similar or equivalent parts.

[0050] Lastly, Fig. 22 shows a double offset T-shaped, or three-dimensional solution, in which the bars 21, 22 are oriented according to the axes X, Y, while the bar 23 is directed according to the axis Z of the antenna assembly; this solution makes it possible to considerably reduce the number of bars or elements which make up the composite structure of the core of a tri-axial transducer.

[0051] In addition to the shown examples, other core structures are possible; for example by crossing two double T-shaped structures of fig. 9, it is possible to obtain a double T-shaped structure according to the axes X and Y for a bi-axial transducer; it is also possible to obtain a triple double T-shaped structure by placing three double T-shaped structures according to the three axes X, Y and Z, in which the various core members are joined in a central node.

[0052] From what has been described and shown in the accompanying drawings, it will be evident that a multi-axial magneto-electric transducer can be provided, for variable magnetic fields which propagate in the space, characterised by particular conformations and dispositions of the core members of the antenna system or assembly.

[0053] For example the square ring-shaped core of fig. 11 could have a rectangular, circular or other suitable annular shape; the profile of the cross section could be of any type, for example a square, rectangular, polygonal, elliptic or circular-shaped closed profile. In the case of an open C-shaped profile, the groove could be on the inner side or on the outer side, or on both sides in the case of an "H"-shaped profile, with the depth of the grooves being identical to or differing from one another.

[0054] It is understood however that what has been described and shown with reference to the examples of the accompanying drawings has been given purely in order to illustrate the general characteristics of the invention and of several possible embodiments.

[0055] Consequently, other modifications and/or variations to the shape, disposition and/or dimensions of the elements or of the parts which make up the composite structure of the core, may be made without thereby deviating from the accompanying claims.

Claims

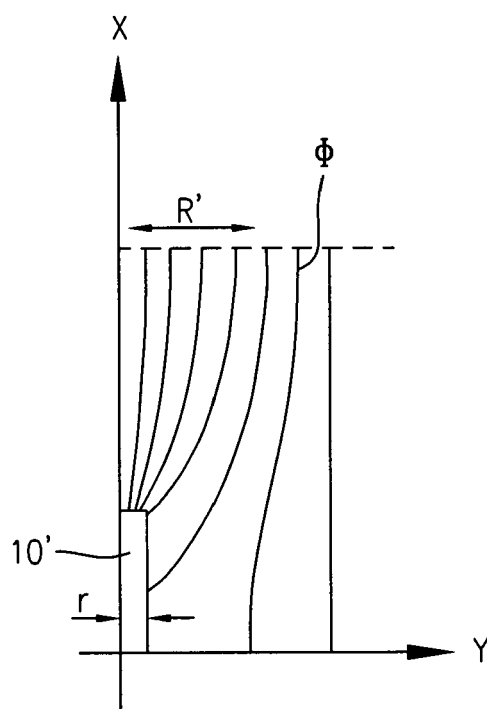
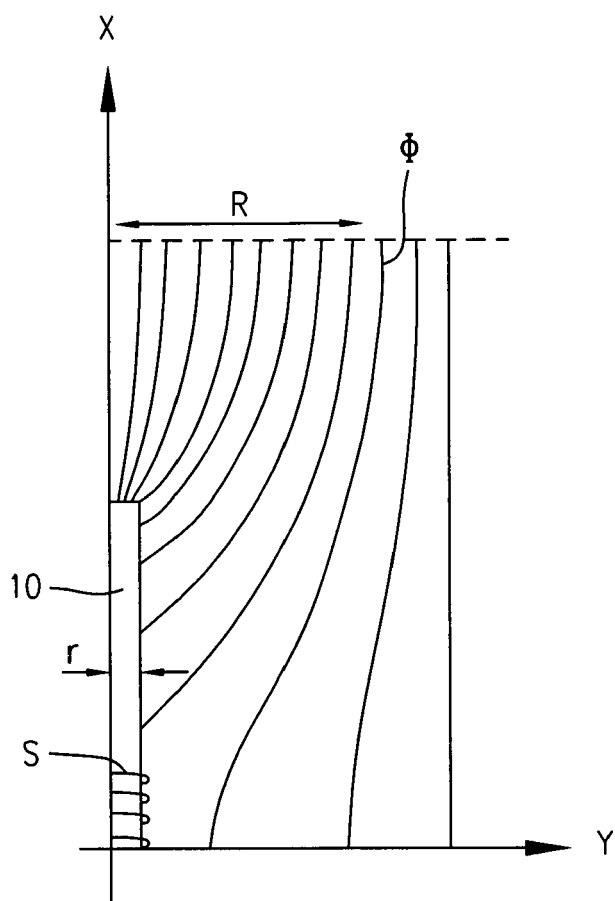
1. Multi-axial magneto-electric transducer, for variable magnetic fields propagating in the air space, comprising an assembly of directional antennas oriented according to Cartesian reference axes (X,Y,Z), in which each antenna comprises a core member (15, 16; 20; 21, 22, 23) of magnetically conductive material having high magnetic permeability for concen-

tration of the flux, and an electric winding (W1, W2; W3, W4; WX, WY, WZ) oriented according to a Cartesian reference axis (X,Y,Z), **characterised by** comprising an integrated core assembly in which:

the core member (15, 16; 20; 21, 22, 23) of each antenna is disposed in magnetic continuity with the core member of at least one other antenna; the core member (16; 20; 21, 22, 23) of at least one first antenna being disposed with respect to the core member (15; 20; 21, 22, 23) of at least a second antenna, to provide a flux draining and a flux concentration element for said second antenna of the assembly.

2. Magneto-electric transducer according to claim 1, **characterised in that** the core members (15, 16; 20; 21, 22, 23) of the antennas assembly are symmetrically disposed with respect to at least one reference plane (XY, XZ, YZ) passing through at least one of the Cartesian reference axes (X, Y, Z).
3. Magneto-electric transducer according to claim 1, **characterised in that** at least said first antenna comprises a plurality of core members (16; 20; 21, 22, 23) oriented in the direction of a first Cartesian reference axis (X, Y, Z), each core member (16; 20; 21, 22, 23) of the first antenna being in magnetic continuity with the core member (15; 20; 21, 22, 23) of at least a second antenna, the electric winding of said first antenna comprising a plurality of winding sections (W2.1, W2.2, W2.3, W2.4; W3.1, W3.2; W4.1, W4.2; WX1 to WX4, WY1 to WY4, WZ1 to WZ4) each wound coaxially to a respective core member (16; 20; 21, 22, 23), the winding sections of said first antenna being connected in series to one another.
4. Magneto-electric transducer according to claim 1, **characterised in that** the integrated core assembly (20) of at least one first and a second antenna, have an annularly-shaped structure.
5. Magneto-electric transducer according to claim 4, **characterised in that** the integrated core assembly (20) has a square, rectangular or circular-shaped structure.
6. Magneto-electric transducer according to claim 1, **characterised in that** the integrated core assembly has a closed cross sectional profile selected from the following: square, rectangular, polygonal, elliptic, circular.
7. Magneto-electric transducer according to claim 4, **characterised in that** the integrated core assembly has a C-shaped cross sectional profile.

8. Magneto-electric transducer according to claim 7, **characterised in that** the C-shaped profile has a peripheral groove facing inside of an annular core assembly (20).
9. Magneto-electric transducer according to claim 7, **characterised in that** the C-shaped profile has a peripheral groove facing outside of an annular core assembly (20).
10. Magneto-electric transducer according to claim 1, **characterised in that** the integrated core assembly of the antennas has an H-shaped cross sectional profile.
11. Magneto-electric transducer according to claim 10, **characterised in that** the integrated core assembly of the antennas has internal and external peripheral grooves of a same depth.
12. Magneto-electric transducer according to claim 10, **characterised in that** the integrated core assembly of the antennas has internal and external peripheral grooves of different depths.
13. Magneto-electric tri-axial transducer according to claim 1, **characterised in that** the integrated core assembly of the antennas comprises a plurality of core members (21, 22, 23) disposed according to at least some edges of a cube or of a parallelepiped structure.
14. Magneto-electric transducer according to claim 13, **characterised in that** each winding of antenna comprises a plurality of winding sections (WX1 to WX4; WY1 to WY4; WZ1 to WZ4) connected in series, each disposed coaxially to a respective core member (21, 22, 23) of the relevant antenna.
15. Magneto-electric transducer according to claim 13, **characterised in that** one of the windings of antenna comprises a first and a second winding section W'Z1, W'Z2, each wound around respective core members (23) lying on a respective face of the cube or the parallelepiped, and oriented according to a same Cartesian reference axis (Z).
16. Magneto-electric transducer according to claim 13, **characterised in that** the winding of an antenna consists in a single winding section, W'Z3 wound around all the core members (23) of that antenna.
17. Magneto-electric transducer according to claim 1, **characterised in that** the integrated core assembly of the antennas comprises a plurality of core members (21, 22, 23) disposed parallel to the edges a reticulated structure, oriented according to at least two Cartesian reference axes (X, Y, Z).
18. Magneto-electric transducer according to claim 17, **characterised in that** said reticulated structure has a cubic or parallelepiped shape.
19. Magneto-electric transducer according to claim 1, **characterised in that** the integrated core assembly (15, 16; 21, 22, 23) has a double T shape.
20. Magneto-electric transducer according to claim 17, **characterised in that** the integrated core assembly has a double T shape, in which the core members (21, 22) of a first and of a second antenna are oriented according to respective Cartesian reference axes (X, Y), and in which a core member (23) of a third antenna is oriented according to a third Cartesian reference axis (Z) which extends in an intermediate position between the core members (21, 22) of the first and second antennas.
21. Magneto-electric transducer according to claim 1, **characterised in that** the integrated core assembly has a double cross shape, comprising a first and a second core members (21, 22) of a first and of a second antenna, oriented according to a first and a second reference axis (X,Y) interconnected by an intermediate core member (23) of a third antenna oriented according to a third Cartesian reference axis (Z).



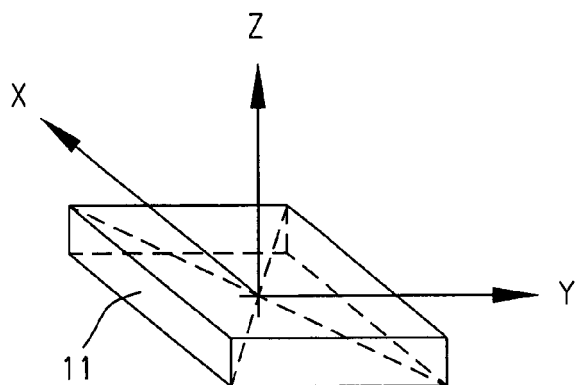


Fig. 3

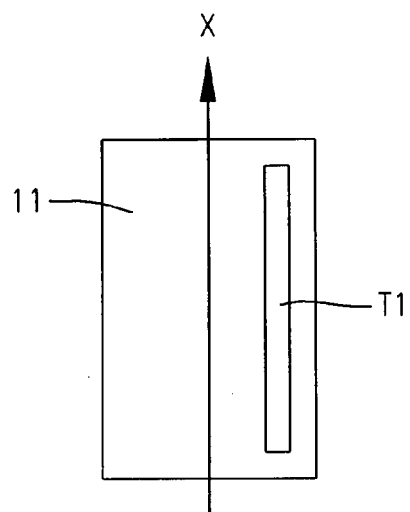


Fig. 4

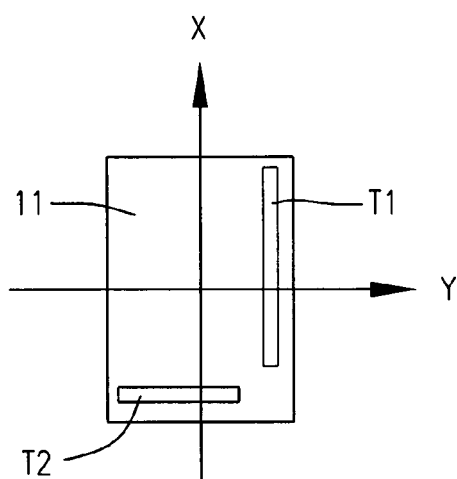


Fig. 5

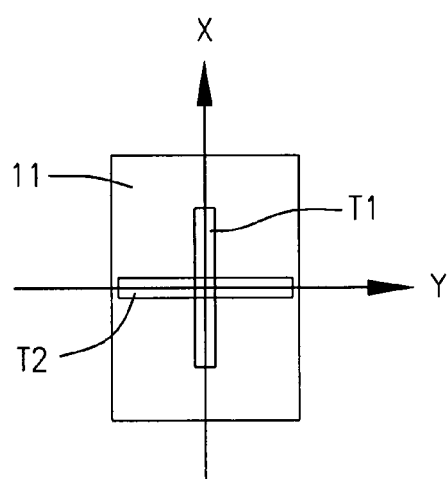


Fig. 6

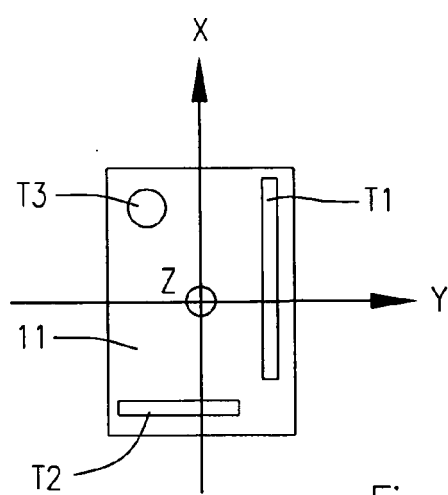


Fig. 7

$T_g (\text{VCM}_{XY} \wedge X)$

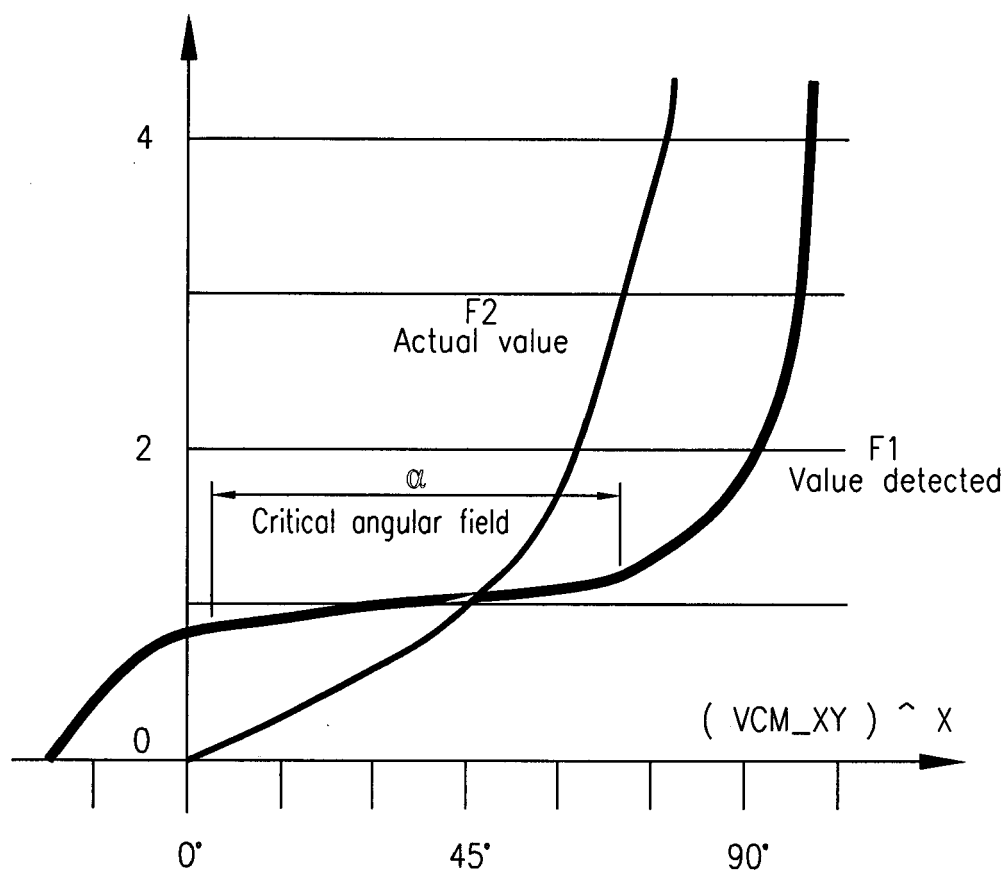


Fig. 8

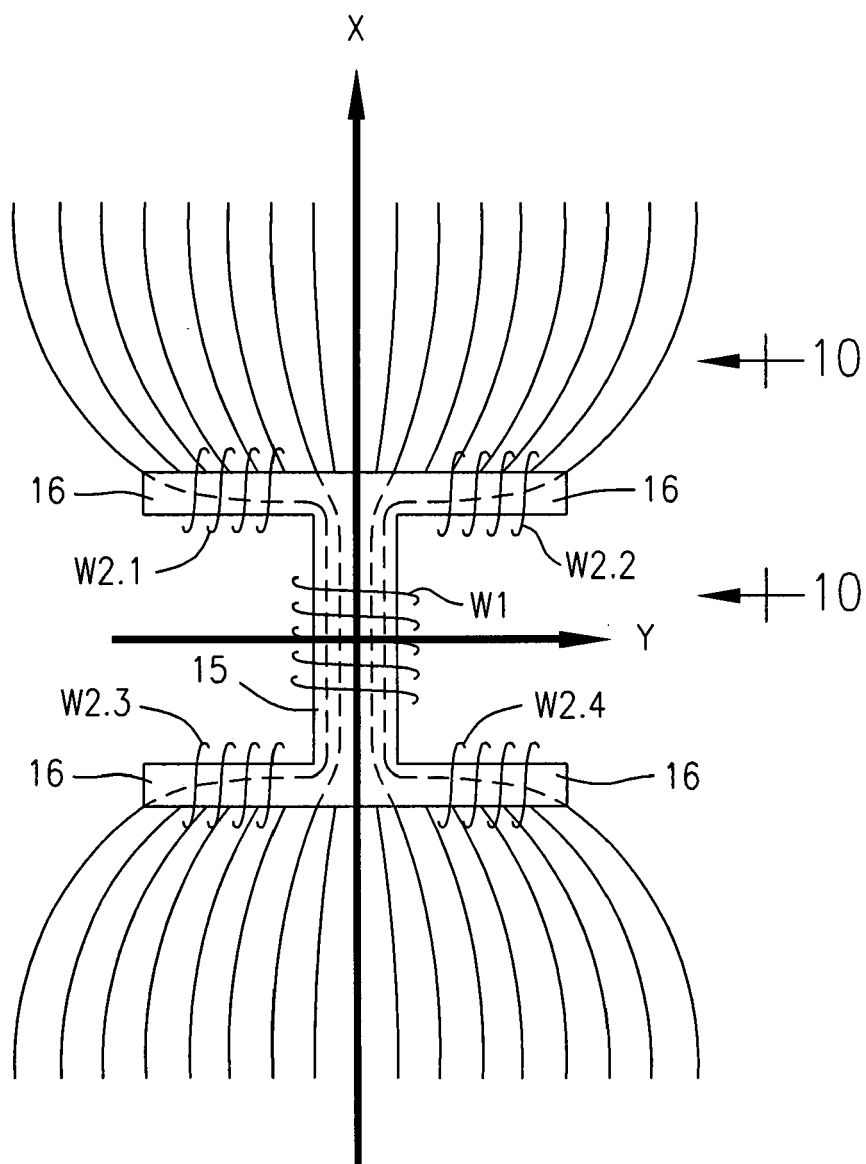


Fig. 9

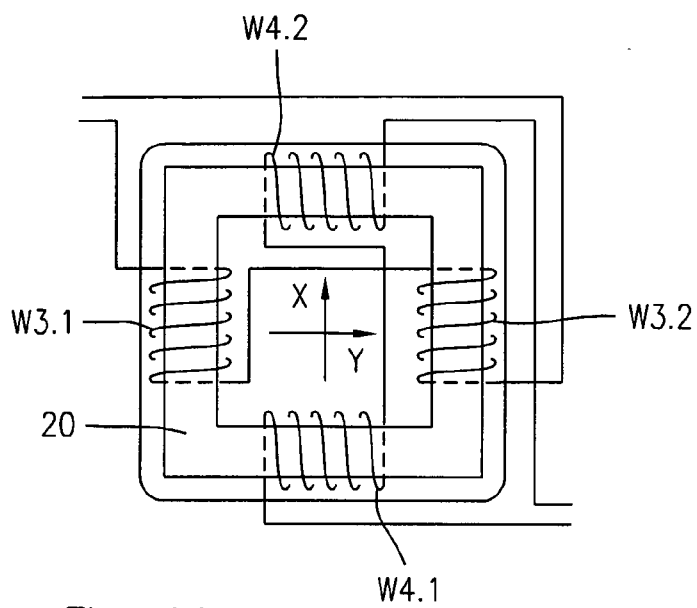


Fig. 11

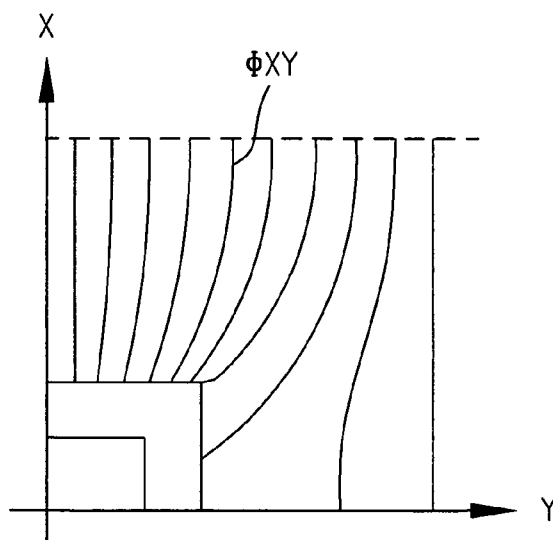


Fig. 12

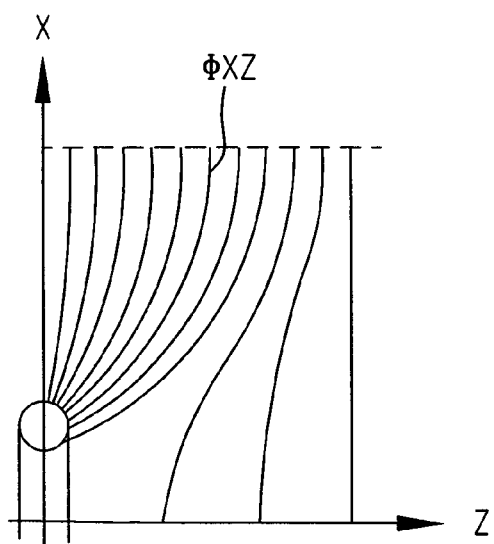


Fig. 10

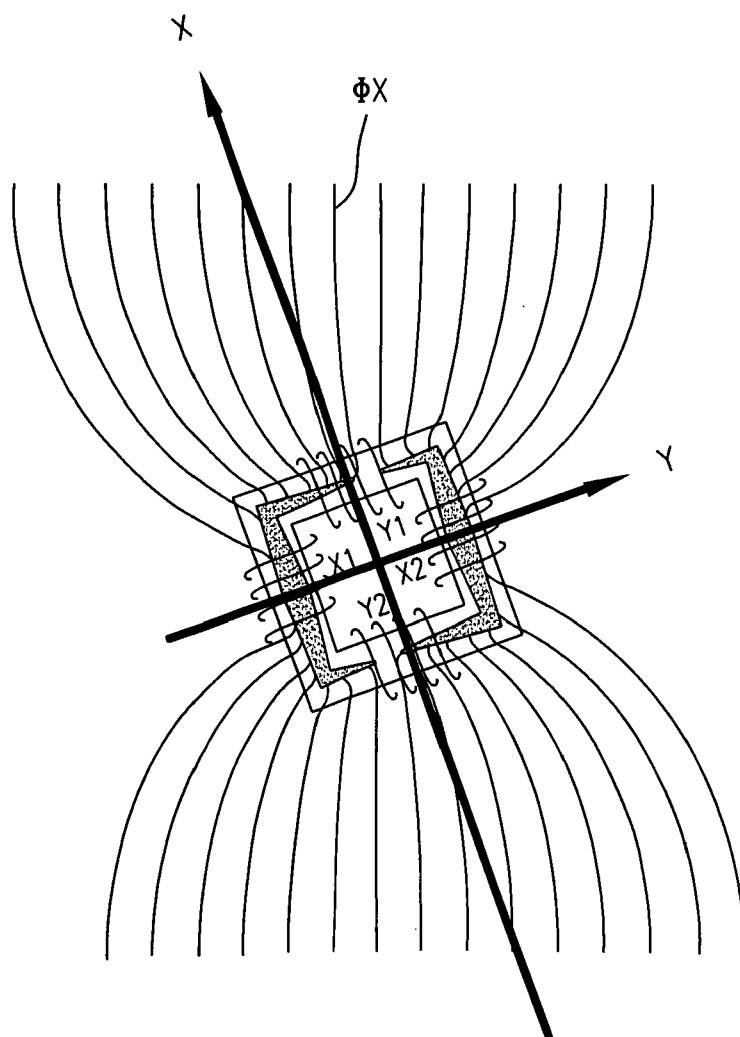


Fig. 13

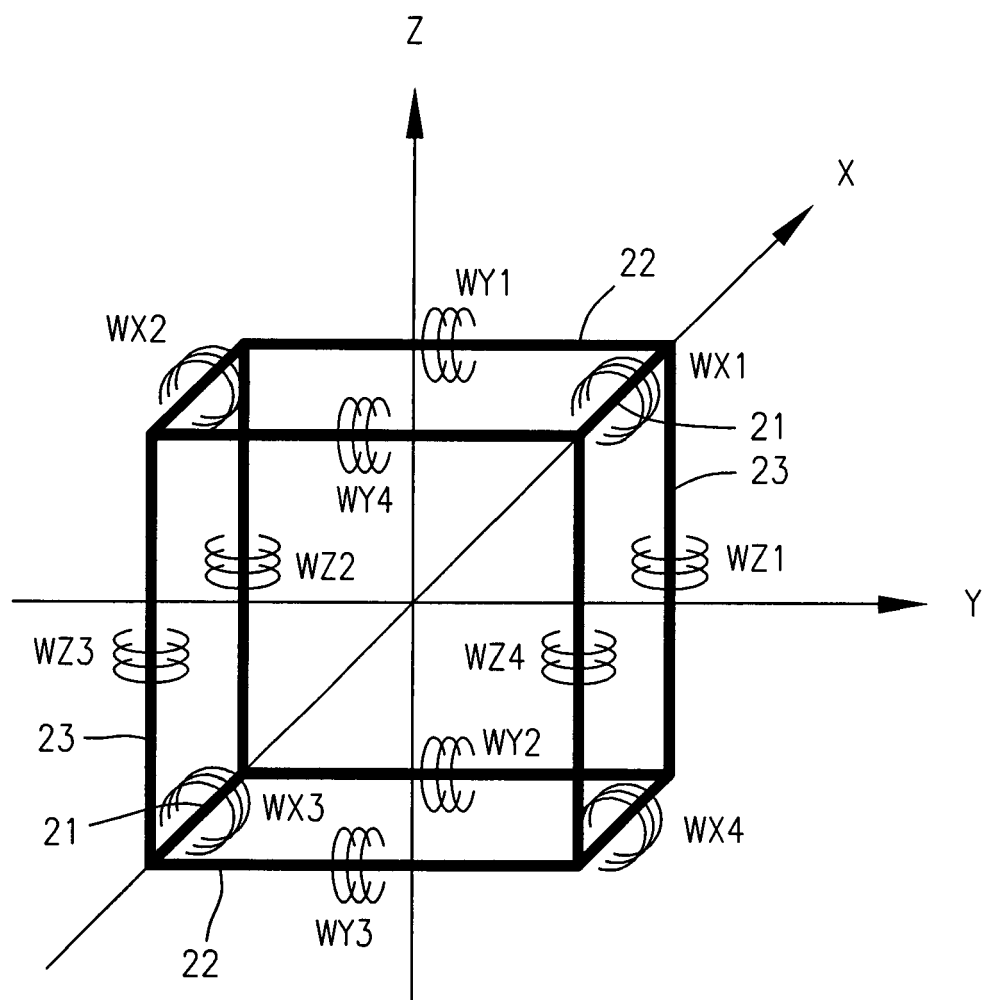


Fig. 14

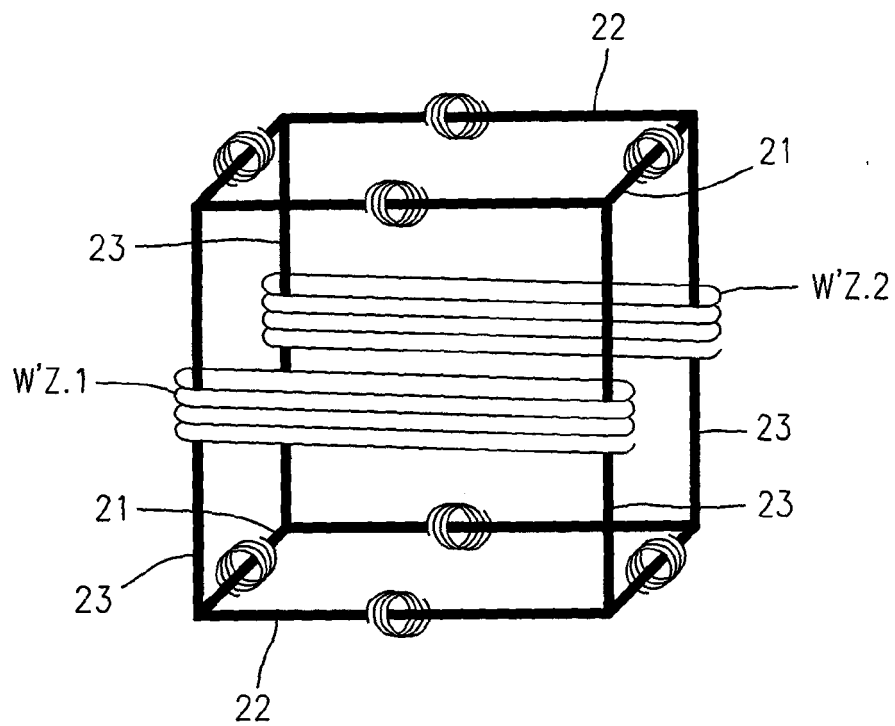


Fig. 15

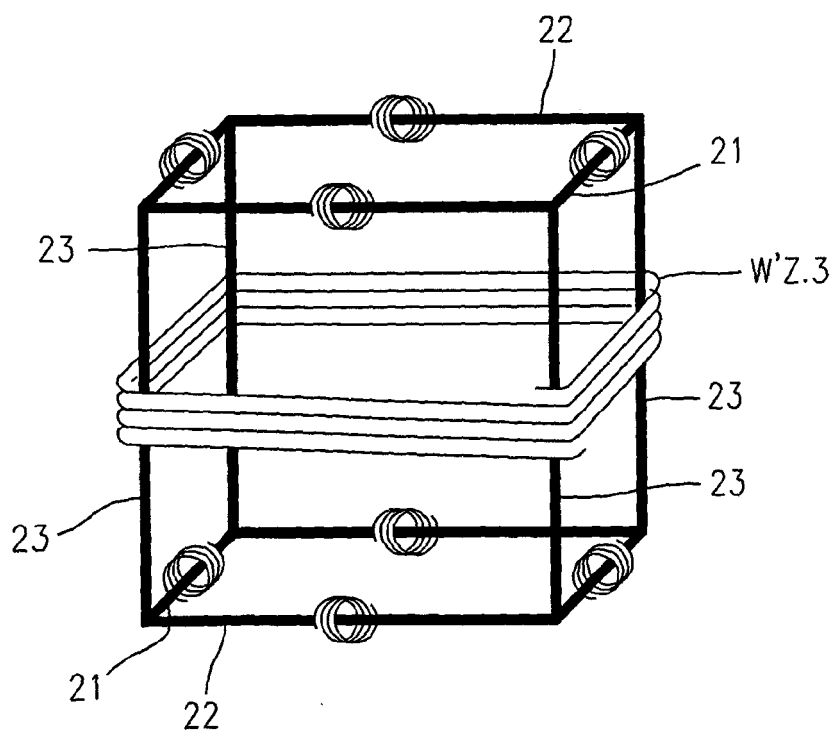


Fig. 16

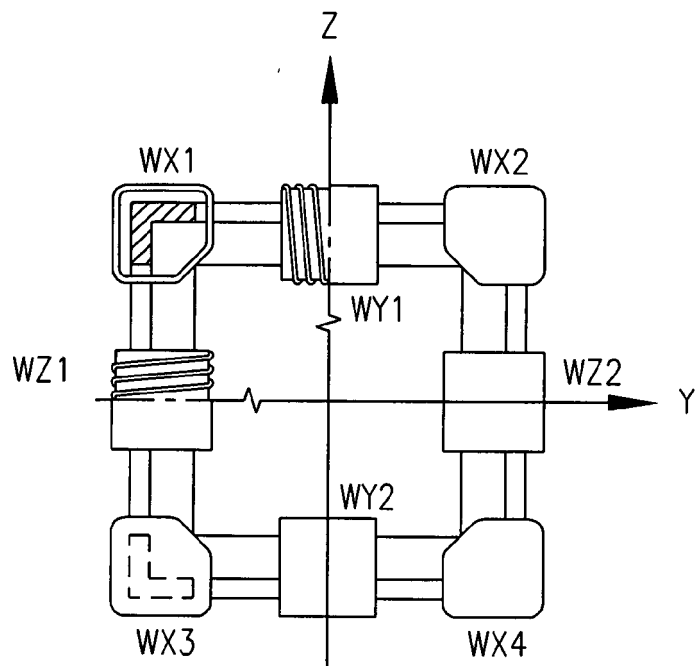


Fig. 17

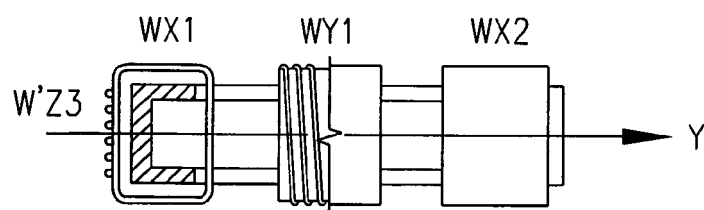


Fig. 18

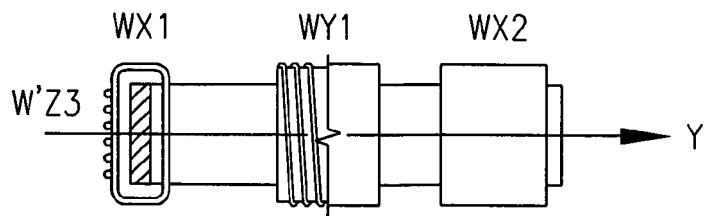


Fig. 19

Fig. 20

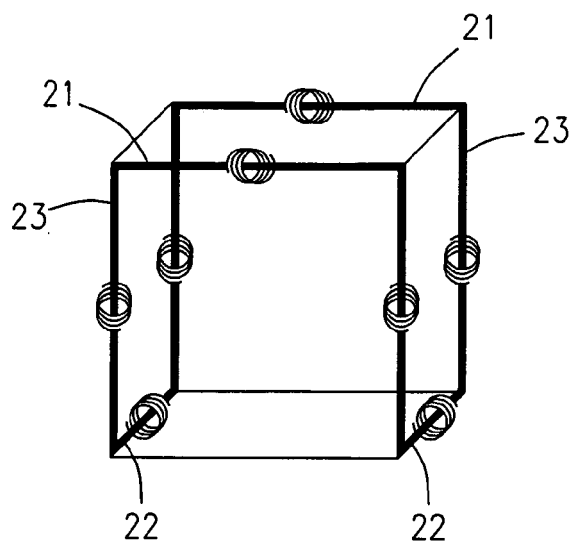


Fig. 21

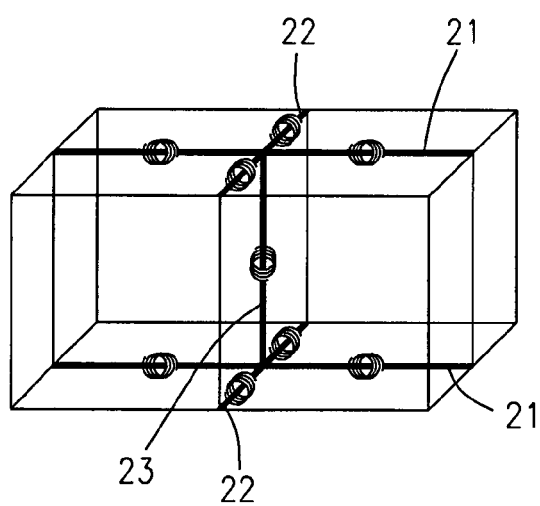


Fig. 22

