



(51) International Patent Classification:
H01B 7/30 (2006.01)

(21) International Application Number:
PCT/US2014/019823

(22) International Filing Date:
3 March 2014 (03.03.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/785,209 5 March 2013 (05.03.2013) US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:
US 13/785,209 (CIP)
Filed on 5 March 2013 (05.03.2013)

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

[Continued on next page]

(54) Title: ELECTRICAL POWER TRANSMISSION SYSTEM AND METHOD

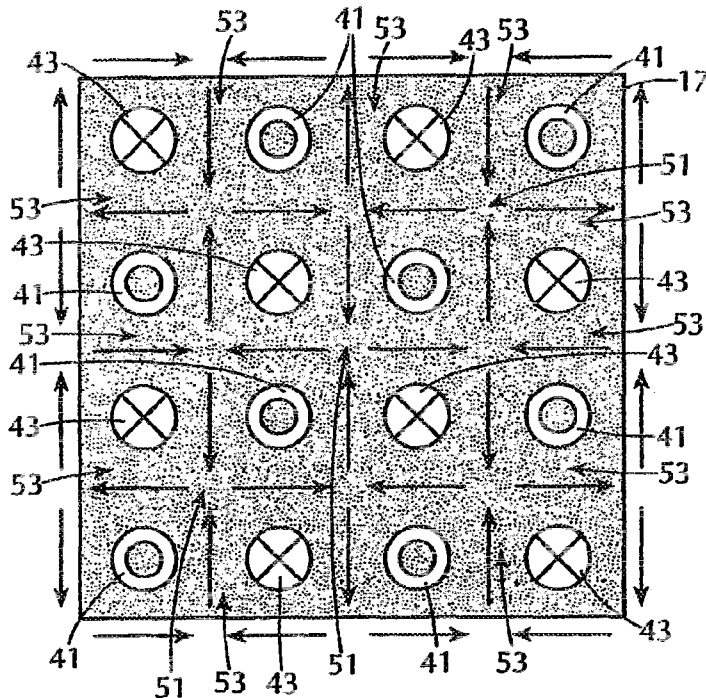


FIG. 3

(57) Abstract: A power carrier transmits an electrical current to and from a load. The carrier has a set of wires carrying electricity in parallel to the load and another set of wires carrying the electricity back in parallel from the load. The wires are organized with equal numbers of wires from each set grouped around a junction alternatingly, so that as a result the magnetic fields created by the electricity flowing through the two sets of wires cancel each other out in the junction. The carrier may have several junctions in a rectangular matrix pattern or a hexagonal dose-packed pattern, or other patterns, e.g., octagonal, which may be combined with junctions with different numbers of wires.

WO 2014/137873 A1



(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

ELECTRICAL POWER TRANSMISSION SYSTEM AND METHOD

[0001] Related Applications

5 [0002] This application is a continuation-in-part of U.S. patent application serial number 13/785,209 filed March 5, 2013, which is herein incorporated by reference in its entirety.

[0003] Field of the Invention

[0004] This invention relates to systems for transmitting power, and more particularly to
10 transmitting power with reduced magnetic field effects outside the conductor.

[0005] Background of the Invention

[0006] The use of conducting wires to carry electrical power is well known, as is the fact
that a current passing through a conductor generates an external magnetic field around the
15 conductor.

[0007] In many environments, magnetic fields of this type are undesirable, such as under
high-power transmission lines or in power cords in certain locations, or generally any area
where people or animals are exposed to high magnetic fields. For example, power supplies
for pacemakers implanted in a person's body transmit power inside the person's body, and a
20 magnetic field there is undesirable. As another example, in the context of hybrid cars, power
is supplied via cables within the body of the car, usually as relatively high-amperage, high-
voltage alternating current, e.g., 360 volt AC, which can produce undesirable exposure of
people in the car to high magnetic fields.

[0008] The prior art reflects some efforts to reduce the effect of a magnetic field around a conductor. For example, shielding methods have also been employed in the prior art using magnetized materials. Shielding to block magnetic fields generally involves application of a coating or surrounding cover that prevents some of the magnetic field around the conductors
5 from extending through it.

[0009] Depending on the material used, the coating material can be relatively expensive. Also, it may be vulnerable to damage so that the magnetic field leaks through. Even if intact, there is a degree of magnetism that is not interrupted by the shielding, and that may, depending on the conditions, constitute an unacceptable level of magnetic field around the
10 conductor.

[0010] Summary of the Invention

[0011] It is therefore an object of the present invention to provide a system and method for transmitting electrical power that overcomes the drawbacks of the prior art.

15 [0012] According to an aspect of the invention, a power carrier for transmitting an electrical current to and from a load comprises a proximal end having first and second proximal electrical connections leading thereto. A first set comprising at least three electrical conductors are all electrically connected in parallel with the first proximal electrical connection, and a second set comprising at least three electrical conductors are all
20 electrically connected in parallel with the second proximal electrical connection. The electrical conductors extend over a length of the carrier and are supported so as to be electrically separate from each other over the length in a cross-sectional arrangement

relative to one another in the carrier. A distal end is opposite the proximal end and has first and second distal electrical connections leading therefrom. The first set of electrical conductors are all electrically connected in parallel with the first distal electrical connection, and the second set of electrical conductors are all electrically connected in parallel with the second distal electrical connection. The first and second sets of electrical conductors are positioned in the cross-sectional arrangement such that the arrangement includes at least one junction area surrounded by at least two electrical conductors of each of the sets that are organized so as to alternate between the electrical conductors of the first set and the electrical conductors of the second set. The electrical conductors around the junction area are at a distance from adjacent electrical conductors of the other set so that respective magnetic field passageways are defined between each of the electrical conductors and the adjacent electrical conductors.

[0013] According to another aspect of the invention, a power carrier for transmitting an electrical current comprises a proximal end having first and second proximal electrical connections leading to it. A distal end is opposite the proximal end and has first and second distal electrical connections leading from it. A first set of electrical conductors are all electrically connected in parallel between the first proximal electrical connection and the first distal electrical connection, and a second set of electrical conductors are all electrically connected in parallel between the second proximal electrical connection and the second distal electrical connection. The electrical conductors extend over a length of the carrier and each is surrounded by insulating material so as to be electrically separate from each other over the length in a cross-sectional arrangement relative to one another in the carrier. The cross-sectional area remains constant over the length of the carrier. The first set of electrical

conductors all are electrically connected in parallel with the first distal electrical connection, and the second set of electrical conductors are all electrically connected in parallel with the second distal electrical connection. The first and second sets of electrical conductors are positioned in the cross-sectional arrangement so that a number of junction areas are defined
5 between groups of electrical conductors. An equal number not less than two of electrical conductors of each of the sets are positioned so as to be equidistant from a respective center point of each junction area, to be spaced around the centerpoint at equal angular displacements relative to each other, and to alternate between the electrical conductors of the first set and the electrical conductors of the second set. The cross sectional arrangement
10 of the electrical conductors is a rectangular matrix with at least four junction areas or a hexagonally packed pattern with at least seven junction areas.

[0014] According to another aspect of the invention, a method of transmitting electrical power comprises providing a carrier as described above, and supplying electrical current to the first proximal electrical contacts so that the current flows through the first set of
15 conductors to the first distal electrical connection, through a transformer and to a load. A return electrical current is received from the load via the transformer to the second distal electrical connection and through the second set of electrical conductors.

[0015] Other objects and advantages of the invention will become apparent in the specification herein, and the scope of the invention will be set out in the claims.

20

[0016] Brief Description of the Drawings

[0017] FIG. 1 is a schematic diagram of a circuit utilizing an electrical power transmittal

system according to the invention.

[0018] FIG. 2 is a schematic diagram of the parallel connection of wires in an electrical carrier according to the invention.

[0019] FIG. 3 is a schematic diagram of a cross-section of a 16-wire embodiment according
5 to the invention.

[0020] FIG. 4 is a detail partial diagram illustrating an exemplary one of the magnetically balanced junctions in the carrier of FIG. 3.

[0021] FIG. 5 is a schematic diagram of a cross-section of a 24-wire embodiment according to the invention.

10 [0022] FIG. 6 is a detail partial diagram illustrating an exemplary one of the magnetically balanced junctions in the carrier of FIG. 5.

[0023] FIG. 7 is a diagram of a magnetically balanced junction surrounded by eight wires.

[0024] FIG. 8 is a cross-sectional diagram of another alternate embodiment of carrier according to the invention.

15 [0025] FIG. 9 is a schematic diagram of another circuit making use of a carrier according to the invention.

[0026] FIG. 10 is a schematic diagram of a three-phase AC power distribution circuit employing carriers according to the invention.

[0027] FIG. 11 is a cross-sectional diagram of the arrangement of the wire conductors in the
20 carrier used in the example.

[0028] FIG. 12 is a cross-sectional diagram of an alternate embodiment of carrier having metallic inserts to reduce capacitance.

[0029] FIG. 13 is a cross-sectional diagram of an alternate embodiment of a carrier according to the invention with a lattice of metallic elements surrounding the conductors.

5 [0030] FIG. 14 is a perspective diagram of one of the elements of FIG. 13.

[0031] FIG. 15 is a side view of a stack of elements in the embodiment of FIG. 13.

[0032] FIG. 16 is a perspective diagram of a portion of the embodiment of FIG. 13.

[0033] FIG. 17 is a detailed cross-sectional diagram of another alternate embodiment of a carrier according to the invention with a surrounding lattice of metallic elements.

10 [0034] FIG. 18 is a perspective diagram of one of the elements of the embodiment of FIG. 17.

[0035] FIG. 19 is a cross-sectional view of still another alternate embodiment of carrier in which a metallic structure surrounds the conductors.

[0036] FIG. 20 is a cross-sectional view of a further alternate embodiment of carrier in
15 which a metallic structure surrounds the conductors.

[0037] Detailed Description

[0038] FIG. 1 is a schematic diagram of a basic circuit with an electrical power transmittal system carrying an electrical current, both a forward and a return current, between a power
20 source 3 and a load 5. Power source 3 applies either two poles of electrical power to two

wires or electrical conductor lines 7 and 9. The power source may be DC or AC, and the two poles of electrical power may be positive and negative poles of DC current, two complementary phases of AC, or a phase or pole of AC or DC and a connection to ground.

[0039] Lines 7 and 9 are connected with a step-up or step-down transformer generally

5 indicated at 11. Transformer 11 increases or decreases the voltage of electrical power applied via lines 7 and 9 and outputs the increased or decreased voltage electrical power on leads 13 and 15 that lead to a proximal end 23 of power carrier 17. Power carrier 17 extends over a length that may be as long or short as required by the specific application.

[0040] The distal end 25 of the carrier 17 has two output wires or electrical conductor lines

10 19 and 21. Output lines 19 and 21 are connected to two respective connections to load 5 and transmit the electrical power to them. Load 5 can be any electrical device, e.g., a light source, a motor, or any kind of circuitry that uses the electrical power for its operation.

[0041] In operation, the power source applies electrical power to line 7, the power is

15 converted to a different voltage current flowing on wire 13, flows through power carrier 17 and output wire 19 to reach load 5. On the other side of load 5, a return electrical current flows along line 21, through carrier 17, and line 15 to reach the other side of the transformer 11. The other input side of transformer 11 connects with wire 9 going back to power source 3, or to ground if appropriate.

[0042] Referring to the schematic diagram of FIG. 2, the power carrier 17 comprises two

20 sets of wires 27 and 29, with all of the wires of each set being connected in parallel. The first ends of wires of set 27 connect electrically in parallel to line 13 via a branch structure generally indicated at 31, and the opposite second ends of the wires of set 27 connect in

parallel to line 19 via a branch structure 33. The first ends of wires of set 29 connect electrically in parallel to line 15 via a branch structure generally indicated at 35, and the opposite second ends of the wires of set 29 connect in parallel to line 21 via a branch structure 37. While FIG. 2 shows each set of wires comprising eight wires, it may be understood that the sets of conductors may comprise a variety of numbers of wires all connected in parallel, as will be discussed further below.

[0043] FIG. 3 is a schematic diagram of a cross-section of the carrier 17 of a preferred embodiment of the invention. In this embodiment, the wires are supported in a square or rectangular 4 x 4 matrix, and that cross-sectional arrangement is preferably constant over the length of the carrier. There are two sets of wires connected in parallel, eight wires 41 and eight wires 43. The material of the carrier 17 is generally square in cross-section and is electrically insulating, so that each of the wires 41 and 43 is electrically insulated from the others.

[0044] Wires 41 carry the electrical current in one direction (i.e., coming out of the diagram in FIG. 3) and wires 43 carrying the returning current (i.e., in the direction into the diagram of FIG. 3). Magnetic fields around wires 41 flow counter-clockwise in the plane of FIG. 3, and the magnetic fields around wires 43 flow clockwise. The arrows indicate the direction of the magnetic field formed by the wires as current flows through them to and from the load.

[0045] In the matrix arrangement of FIG. 3, the wires are organized in four rows and columns. The wires adjacent each wire in the same row or column are of the other set of wires, i.e., wires 41 have wires 43 adjacent them in the same row or column, and wires 43

have wires 41 adjacent them in the same row or column. Because the magnetic fields of these row-adjacent or column-adjacent wires flow in the opposite direction, in the interstitial magnetic flow regions 53 between the row-adjacent or column-adjacent wires, the magnetic fields around the two neighboring wires extend in the same direction.

5 [0046] FIG. 4 shows a detail of one of the junctions 51. Junction 51 has four conductors surrounding its center point C, a first pair of conductors 41 carrying current in a direction out of the diagram, and a second pair of wires 43 carrying current into the diagram. The four conductors are arranged to surround the junction 51 spaced angularly from each other at a 90 degree offset, so that their centers are located at 45° , 135° , 225° , and 315° , and they define
10 interstitial magnetic flow regions 52 aligning at 0° , 90° , 180° , and 270° of counterclockwise rotation measured from the horizontal axis around the center point C. In the junction area 51, the magnetic fields around wires 41 and 43 in the row-direction flow away from the junction 52 in opposite directions, and they also combine to cancel each other out. Similarly, the magnetic fields around wires 41 and 43 in the column-direction flow in opposite
15 directions into the junction 52, and combine to cancel each other out. There is as a result substantially no magnetic field at each junction 52.

[0047] As seen in FIG. 3, two of the wires 41 and 43 of each junction 51 are shared with the neighboring row-adjacent or column-adjacent junctions. Each junction has a net magnetic field that is canceled out to zero in the vertical and horizontal directions.

20 [0048] On the outer surface of the carrier, at the inter-row and inter-column magnetic flow regions 53 between the wires, the magnetic field extending along parallel to the surface by the adjacent wires cancels out the magnetic field extending along the surface on the other

side of the magnetic flow region, reducing the magnetism outside the carrier 17. There is some magnetic field created by the current in the adjacent surface wires that extends directly outward or inward, but its magnitude is not as great as the magnitude around an ordinary conductor pair. The ultimate result is a reduced magnetic field around the carrier 17.

5 [0049] The cross-sectional arrangement of FIG. 3 is substantially constant over the length of the carrier 17, and preferably the carrier 17 is a rectangular parallelepiped. Alternatively, the cross-sectional arrangement rotates spirally over the length of the carrier, with the relative positions of the wires staying the same at all cross-sections over the length of the carrier 17.

[0050] The relative positions and currents flowing in the wires in the carrier 17 may result in
10 some capacitance between the wires. The degree of capacitance can be adjusted or reduced by the presence in the interstitial regions 53 of material that has a dielectric-altering effect. In particular, conductive or ferromagnetic material may be placed in the interstitial regions so as to reduce the capacitance in the carrier 17.

[0051] In addition to the matrix arrangement shown in FIG. 3, other square or rectangular
15 matrix-type configurations may be employed as a carrier, e.g., carrier 17, to reduce magnetic field outside the carrier as well. The matrix preferably has two or more junctions, e.g., the cross section should be a 2x3 matrix of wires or larger.

[0052] FIG. 5 shows another embodiment of the invention, which may also be used as the
20 carrier 17 in the circuit of FIG. 1. The cross section shown in FIG. 5 is the same over the length of the carrier, and the carrier has two connections at each end, as seen in FIG. 1.

[0053] In the embodiment of FIG. 5, conductors 65 carry current in the carrier 71 in one direction and conductors 67 carry the return current in the other direction. All the wires of a

given respective set 65 or 67 are connected in parallel with each other by branching structures similar to those of FIG. 2, so as to carry the associated current in parallel with the other conductors of the same set, and so as to deliver the current to a single connector at the opposite end of the carrier 71, essentially with pairs of lines 13 and 15, 19 and 21, as seen in
5 FIG. 1.

[0054] In FIG. 5, the arrows indicate the direction of the magnetic fields formed by the conductors. Conductors 65 generate a counterclockwise magnetic field and conductors 67 generate a clockwise magnetic field as shown in the diagram. The triangular channels 64 each have three sides, each side inwardly facing the three wires of the associated conductor
10 and outwardly facing either a conductor of the other set of conductors or the outer surface of the carrier 71. As a result, the magnetic fields in the interstitial magnetic flow regions between the faces of adjacent triangular channels extend in the same direction, and do not conflict with each other.

[0055] Magnetic fields also extend along the outer surface of the carrier 71, canceling each
15 other out perpendicular to the surface, but with partial outwardly or inwardly directed magnetic fields, as indicated by the arrows in FIG. 3. Radially inward of the carrier 71, the magnetic fields meet and cancel each other out at the six-direction intersections or junctions 73 in the interior, resulting in no net magnetic field at these intersections.

[0056] FIG. 6 illustrates the geometrical relationship and the mutual cancelation of
20 magnetic fields inside the carrier at each junction 73. Six conductors surround the junction 73, and three of these, conductors 75, carry the current in one direction and three, conductors 77, carry the returning current in the opposite direction. The three conductors 75

are each adjacent two of the other conductors 77 such that in half of the interstitial regions the magnetic fields produced flow outwardly away from the junction 73, as indicated by magnetic field arrows 80, and, on the other side, inwardly toward the junction 73, as shown by arrows 81.

5 [0057] It will be apparent that the outgoing magnetic field flow arrows 80 are approximately equally distributed about a circle centered at the center point C at 120 degrees displacement to each other. As a result, the three magnetic fields indicated by the arrows 80 at 30°, 180° and 270° combine to cancel each other out. Similarly, the 120-degree staggered three inward flowing magnetic fields 81 at 90°, 210° and 330° also cancel each
10 other out, resulting in little or no total magnetic field at junction 73.

[0058] The carrier with this type of six-wire junction is preferably a hexagonal carrier as seen in FIG. 3, but may alternatively be smaller, e.g., a single hexagonal group of six wires with a single junction, or may also be any configuration made by combining two or more
15 junctions 73 each having six surrounding conductors 75 and 77, some of which may be shared between adjacent junctions 73. The conductors may each comprise one, three, or generally any number of wires. As with the rectangular matrix arrangement of FIG. 3, each junction 73 shares at least two of its wires, one from each set 75 and 77, with an adjacent
junction 73.

[0059] A general principle of the conducting carrier of the invention is that the sets of
20 incoming and outgoing power lines are organized in a matrix or other pattern configuration in a plane perpendicular to the diameter of the extension of the lines. That pattern has the lines grouped around junctions or intersections of the magnetic field pathways between the

lines. Each junction is surrounded by a number $2N$ of lines, N lines of which carry the electrical connection in one direction, and the other N lines of which carry the returning electrical current in the opposite direction. The $2N$ lines are grouped substantially equally staggered about the junction center point C , each at $180/N$ degrees rotational displacement
5 relative to the next adjacent line in the group around the junction. The lines are also alternated as one proceeds around the junction so that if a given line carries current in one direction, the adjacent lines on either side of it, which are rotationally separated by $180/N$ degrees around the center of the junction from the line on either side, carry power in the opposite direction.

10 [0060] In this configuration, the opposing current lines cooperate in creating magnetic fields flowing, either toward or away from the junction, in the same direction in the intersectional pathways between the wires. By "pathways," it is meant the magnetic flow regions between the lines, which may be filled with insulation or spaces containing air, or in any case preferably magnetically-neutral, non-conductive material or gas. Metallic, ferromagnetic or
15 other materials having an effect on the dielectric properties of the separating distance between the lines may be placed in the passageways to reduce any capacitance in the system.

[0061] The number N may be 2, as in FIGS. 3 and 4, or it may be 3, as in FIGS. 5 and 6.

Even larger numbers N of conductors, e.g., 4 or 5 or higher, may also be used to form a ring
20 around each the junction. In the various configurations where N is 2 or greater, some of the wires around a first junction may also serve as wires in other adjacent junctions in the cross sectional arrangement. Depending on the number N employed, adjacent junctions may have

different numbers of wires arranged around their respective center points.

[0062] Fig. 7 shows a detail of an alternate embodiment carrier in which a junction 82 is surrounded by eight wires, i.e., $N=4$. Four wires 83 carry current in one direction (out of the page of the diagram) and the other four wires 84 carry current in the opposite direction (into the page of the diagram). The magnetic fields flow away from junction 82 in passageways 85 generally following the arrows at 45° , 135° , 225° and 315° , canceling each other out to zero. The magnetic fields flow into the junction 82 through passageways 85 generally following the arrows at 0° , 90° , 180° and 270° , also canceling each other out to zero. The result is overall a zero net magnetic field in the junction 82.

10 [0063] The junction structure of FIG. 7 may be adjacent one or more other similar eight-wire junctures. For each additional eight-wire junction, one wire 83 and an adjacent wire 84 from the first junction 82 are part of the additional junction, together with six other wires in addition to those of the first junction 82.

[0064] Referring to FIG. 8, an alternate embodiment of a carrier according to the invention 15 has a carrier body 85 preferably of insulating material with a cross section as shown. A first set of wires 86 extend through the carrier body 85 in parallel carrying electrical current in one direction, and another set of wires 87 linked in parallel extending through the carrier body 85 and carrying electrical current in the opposite direction. The wires 85 and 86 are organized in a pattern over the length of the carrier.

20 [0065] In this pattern, the wires are in octagonal or square groups, as shown in the FIG. 7 and FIG. 4. Each octagonal group has a center point C1, and each square group has a center point C2. The wires are arranged therearound equally distributed rotationally, alternating

between wires 86 and wires 87. The result is that the magnetic fields produced by wires 86 and 87 combine to cancel each other out in the individual junctions C1 and C2, as has been described above in regard to the previous embodiments with octagonal or square junction groups of wires, so that the magnetic fields total to approximately zero at each junction about a center point C1 or C2.

[0066] Circuits for application of conductors according to the invention include the circuit of FIG. 9. A power source 97 supplies AC or DC current via two opposing contacts 98 and 99 leading two and from an input coil 101 of a transformer 103, which is preferably a step-up transformer that increases the current voltage. Transformer 103 has an output coil 105 connecting with output lines 107 and 108 that lead to a carrier 111 configured with multiple wires is a parallel arrangement with cross-sectional pattern having one or more zero-net-magnetic-field junctions, such as found in, e.g., any of the previously described embodiments. The electrical current of the lines 107 and 108 is carried to and from the opposing end of carrier 111, where the parallel sets of wires thereon connect with lines 113 and 115, which connect to the input coil 117 of a second transformer 119, which preferably steps down the voltage received. Transformer 119 has a second coil 121 connected to two lines 123 and 125 connecting with load 127. As in the embodiment of FIG. 1, load 127 may be a lamp or motor, or any device powered by the electrical current. The circuit of FIG. 9 provides for efficient transmission of power from source 97 to load 127 with reduced external magnetic fields produced.

[0067] Referring to FIG. 10, another embodiment of circuit employing power carriers according to the invention transmits multi-phase AC current from a power source that

produces three phases x, y, and z of AC electrical power. Each phase x, y and z is supplied to the input coil of a respective step-up transformer 131, which taps at its other end to the ground. Transformers 131 have output coils each of which is connected to an end of a respective carrier 133 configured according to the various embodiments described above.

5 The outputs of the carriers 133 are each connected with a respective step down transformer 135, which reduces the voltage of current in the carrier 133 back to its original level. The transformers 135 each have an output line 136 that connects to and supplies a respective phase x, y, or z of the AC power to load 137, which may be anything that uses or operates on AC power. The other line from the transformer output coil goes to ground. In this
10 embodiment, AC power is efficiently supplied via low magnetic field carriers 133 to load 137.

[0068] In any of the above embodiments, the conducting wires may be superconducting wires.

[0069] The carrier according to the invention may have a capacitance created over its length
15 between the incoming and returning currents, which may be undesirable. FIG. 12 shows a carrier 151 in which the capacitance is reduced, as has been mentioned above. Two sets of incoming and outgoing wires 153 and 155 are supported in insulating material 157. Also supported in the insulating material 157 are a number of bars 159 of conductive or ferromagnetic materials between the wires 153 and 155 in the magnetic passageways
20 between them. The pieces of conductive or ferromagnetic material 159 extend over the entire length of the carrier 151, each lying in a respective passageway between wires 153 and 155 so as to reduce the dielectric between the wires, and as a result the capacitance. The

individual pieces 159 may have slight contact at their corners, but are generally electrically separate from each other.

[0070] FIG. 13 is a cross-sectional view of another embodiment of power carrier for use in place of the carriers shown in FIGS. 1, 9 or 10. The power carrier 200 has a first set of
5 conductors or wires 208 and a second set of conductors or wires 209, each set of wires 208 or 209 carrying electrical current in opposite directions, with each set of wires electrically connected in parallel, similarly to the embodiment of FIGS. 1 to 4. The conductors or wires may also be formed as bundles of insulated wires held together in the space for the
conductors.

10 [0071] The conductors or wires 208 and 209 alternate with each other, and form a six by six (6x6) matrix, although other sizes of matrix can readily be used advantageously. The alternating of wires 208 and 209 results in each wire 208 having four wires 209 arranged around it, above and below in its column, and left and right of it in its row, except for the wires 208 or 209 on the surface of carrier 200. The cross-section is preferably constant over
15 the length of the carrier 200.

[0072] Wires 208 and 209 are electrically insulated by insulation 207 surrounding each of the wires 208 and 209 over the length of the carrier 200. The wires 209 are connected electrically in parallel with each other, and the wires 208 are also connected electrically in parallel with each other, and the carrier is connected as shown in e.g., FIGS. 1, 2, 9 and 10,
20 with wires 209 carrying the electrical power in one direction and the wires 208 carrying the electrical current in the other direction. A housing 203 of protective preferably insulating material surrounds the conductors 208 and 209, and supports therein a lattice structure.

[0073] Wires 208 and 209 are bound in the lattice structure, which is formed of flat plate members or elements 201 and 202, which are of conductive or ferromagnetic material.

Elements of 201 and 202 have high magnetic permeability and are electrically isolated from one another wherever surfaces of adjacent elements are facing each other. They also may be
5 laminated on their outer surface with appropriate material so as to electrically insulate each element 201 or 202 from adjacent elements.

[0074] The elements 201 and 202 are of metallic material that has a ferromagnetic quality that causes their presence to interact with the magnetic fields created by current flowing through the adjacent conductors 208 or 209, preferably reducing capacitance in the carrier.

10 The ferromagnetic material may be a conductive material such as iron where the elements 201 or 202 are isolated from each other electrically. However, a number of other materials may be employed, including non-conductive ferromagnetic insulator material. For instance, a variety of ferromagnetic insulators exist with the chemical composition La_2NiMO_6 , where M represents Mn, Tc, Re, Ti, Zr or Hf. Another ferromagnetic insulator useable for elements
15 201 and 202 has a chemical composition $\text{K}_2\text{Cr}_8\text{O}_{16}$. It should also be understood that these insulators are sometimes described as being no longer metallic. The term metallic as used herein is intended more broadly to embrace any material containing atoms of metallic elements.

[0075] A large number of elements 201 and 202 together form the lattice as a generally
20 tubular box structure around the wires 208 and 209. The elements define generally octagonal conductor spaces extending the length of the carrier 201 through which the conductors 208 and 209 extend. Each conductor 208 or 209 is surrounded by four elements,

which are preferably supported in stacks, and the stacks extend over the entire length of the carrier 200.

[0076] In addition to defining passages in the lattice or box structure through which the conductors or wires extend, the elements 201 and 202 define between them gaps 205 that also extend the length of the power carrier 200. The gaps 205 may contain air, or another material, including solids and fluids, and a thermal cooling system (not shown) may be connected with the gaps so as to introduce gas or fluid to flowing through the gaps 205, cooling the carrier 200. The wires 209 and 208 are arranged around gaps 205 such that wires 209 and 208 alternate, and the various contributions to the magnetic field inside the gaps 205 net to about zero, substantially canceling out the field in at least one point in the cross-section of each individual gap 205. Although the elements of conductive or ferromagnetic material 201 and 202 provide for greater magnetic permeability inside the system, the arrangement of conducting wires 209 and 208 around gaps 205 in power carrier 200 results in a substantially reduced measurable magnetic field outside of the carrier 200.

[0077] The presence of the elements of conductive or ferromagnetic material 201 and 202 affects the electrical characteristics of the system, which includes altering the inductance and capacitance of the carrier 200. The elements of conductive or ferromagnetic material 201 and 202 are supported between the wires 209 and 208, and they alter the extent of the magnetic field created by the current in the wires 209 and 208, generally increasing the mutual inductance of the wires.

[0078] Referring to FIG. 14, each element 202 has a narrowed central portion 211, and forked prongs 213, 215, 217 and 219. As mentioned above, the element 202 is preferably

completely made of a magnetically permeable material, e.g. a ferritic or ferromagnetic material. The prongs 213, 215, 217 and 219 are set at approximately 45° angles from the central section 211, and each terminates in a perpendicular face at 45° to the central portion 211. In the embodiment shown, the element 202 is about 1 mm thick and about 5 to 15 mm
5 in total length.

[0079] The element 202 may itself be a magnet, and have one magnetic pole, e.g., N, at prongs 213 and 215, and the other magnetic pole, e.g., S, at prongs 217 and 219. Thus prongs 213 and 215 will be attracted to prongs 217 and 219 of another similar element or piece 201 or 202 adjacent to them. This mechanically stabilizes the system, as the elements
10 201 and 202 may be arranged to hold themselves in place by magnetic attraction to other adjacent elements 201 and 202.

[0080] Each element 202 has four indentions or recesses 225, 227, 221, and 223. Elements 201 and 202 and indentations 225 and 227 are sized such that the elements 201 and 202 fit between conductors, e.g. conducting wires 208 and 209 as in FIG. 13. The indentations 221
15 and 223 are sized to provide the gap 205, which may be used as an electrical insulator and/or for thermal cooling. Recesses 225 and 223 combine to form the octagonal space between the four elements 202 grouped around each wire 208 or 209.

[0081] The individual elements 201 and 202 are adjacent each other, but all spaced slightly apart and electrically insulated from each other. This may be accomplished by lamination
20 with an insulating material, or by separation from each other by air, or most preferably, by coating of the elements 201 and 202 with a liquid insulator, e.g., transformer oil, which is well known in the art.

[0082] FIG. 15 shows a detail side view of a partial stack of elements 202. The elements 202 are preferably insulated from adjacent elements 202 above and below them, by, e.g., lamination, transformer oil, or some other relatively thin insulator. This reduces the formation of stray currents, which lead to reduced efficiency and unwanted heat buildup.

5 The stack preferably extends the full length of the carrier 200.

[0083] FIG. 16 shows a partially cut away perspective detail view of an embodiment of the carrier 200 shown in FIG. 13. Conducting wires 208 and 209 carry electrical current, and are electrically insulated by insulators 207. The elements 201 and 202 here are shown stacked. The faces 214 of the elements are all closely positioned but spaced apart enough to prevent
10 electrical current flow between them. Gap 205 is more clearly shown here to be a channel of space, allowing for airflow or flow of a gas so as to provide heat moderation. Alternatively, gap 205 may be filled with a solid or fluid that has desired electrical or thermal qualities.

[0084] FIG. 17 shows a partial cross-sectional view of still another embodiment of power carrier 240. The embodiment shown is similar to that of the embodiment of FIGS. 13 to 16,
15 in that conducting wires 248 and 249 carry electrical current in opposing directions and alternate in row and column as described above for the other embodiments, and elements 241 of ferromagnetic material are stacked so as to form a lattice structure comprising tubular box structures of elements 241 forming generally octagonal passages extending the length of the carrier, and through which respective conductors 248 or 249 extend. Conductors or
20 wires 249 are surrounded by insulating layer 243, which is in turn each surrounded by the adjacent three or adjacent four box structures. Gaps 245 are defined between the box structures, and may be used to provide thermal cooling for the system by gas or liquid

coolant, as described in the previous embodiment. As with the previous embodiment, the individual elements are kept insulated from each other by intervening space, air, material (e.g., plastic or other insulator laminate), or insulating liquid, such as transformer oil. The ferromagnetic material may be conductive or an insulator, as described above with respect to the previous embodiment, as well.

[0085] FIG. 18 shows a perspective drawing of a single generally U-shaped element of conductive or ferromagnetic material 241. The element 241 has central section 251, and prongs 253 and 254. The element also has recess or indentation 255, which forms a side of the octagonal passage receiving a conducting wire, e.g., wire 248. The prongs 253 and 254 are set at an approximately 45° angle from the central section 251 and provide faces 257 at 45° as well as for forming the box structures with other elements 244. The elements 241 may be magnetized, such that prong 253 has one magnetic pole and prong 254 has the other magnetic pole. The dimensions of the element 241 are preferably a length of 5 to 15 mm and a thickness of about 1 mm.

[0086] FIG. 19 shows a cross-sectional view of an alternate embodiment of power carrier 301. The power carrier 301 has a housing 302 of plastic or some other non-conducting material that provides the exterior of the carrier 301 and supports therein an 8x8 rectilinear matrix of conductors 303 and 305 extending the length thereof. Conductors 303 and 305 are preferably each made up of a respective set of conductive wires 307 and 309 that contact the other wires of the given conductor and carry current through the power carrier as has been described above. Conductors 303 are surrounded by insulation 308, and carry current in one direction and conductors 305 carry the returning current in the opposite direction, the

different directions of current being indicated schematically by 0 or + on the relevant wires 307 and 309. The conductors 303 and 305 alternate so that the conductors adjacent each conductor in its row and column are conductors of the other set of conductors 303 or 305, carrying the current in the opposite direction, as described in the previous rectangular
5 embodiments, e.g., FIGS. 3 and 13.

[0087] To adjust the electrical properties of the carrier 301, it has a series of plate members or plate elements 311 stacked on each other over the length of the carrier. The plate members 311 are of ferritic or ferromagnetic material, or some other material that influences magnetic fields passing therethrough, but the plates 311 are preferably of a ferromagnetic
10 insulator material, such as those described above with respect to the embodiment of FIG. 13. The plate members are about 1 mm thick and are separated from each other electrically by spacing them apart with an air gap, by laminating each plate 311 with an insulator material, or by providing some other insulation for transformer components, e.g., transformer oil. Plates 311 are all essentially identical over the length of the carrier 301, and have apertures
15 313 therein that are aligned so as to create tubular passages over the carrier through which the conductors 303 and 305 extend. The plate members 311 also have aligned gaps or apertures 315, through which coolant in the form of air, coolant gas, or coolant liquid is supplied to cool the power carrier 301 and carry away heat created by the electrical currents passing through it.

20 [0088] Referring to FIG. 20, where different electromagnetic properties of a power carrier are desired, the embodiment of FIG. 19 may be modified so that the plate member is divided into discrete elements. The same reference numbers are used for the identical parts of the

power carrier 330 shown in FIG. 20, but, instead of the plate members 311 of FIG. 19, each layer of the stacked metallic plates is composed of electrically isolated discrete elements, i.e., semicircular elements 331 and generally X-shaped or hourglass-shaped elements 333, which are adjacent each other but electrically isolated from each other by lamination or
5 separation by air or other insulating material, e.g., transformer oil. The identical elements are stacked over the length of the power carrier 330, and form passages 335 through which the conductors 303 and 305 extend, as well as gas or liquid cooling passages 337 through which coolant or air is supplied so as to carry heat away from the power carrier 330.

10 EXAMPLE

[0089] An experiment was conducted to determine the efficacy of a carrier according to an embodiment of the invention.

[0090] For the experiment, the carrier used was of a cross section as seen in FIG. 11. The carrier 145 was formed as a matrix of wires 147 and 149, all of which were 28 AWG
15 stranded wire. The wires 147 and 149 were supported in a matrix arrangement as shown, where the wires were spaced 0.05" apart in the rows and the columns. Wires 147 were all connected in parallel and wires 149 were all connected in parallel as in the schematic of FIG. 2. The insulation referenced generally as 151 around the wires 147 and 149 was 300 volt gray PVC insulation.

20 [0091] As a control example, a typical two wire electrical cord was used.

[0092] A 120 volt AC power source was connected at one end of the two-wire electrical cord, and a 950 watt power load was connected at the other end. The magnetic field around

the two-wire cord was then measured, yielding a reading of 72 milliGauss.

[0093] The same 120 volt AC power source was connected at one end of the carrier, and the other end of the carrier was connected to the same 950 watt power load. The magnetic field around the carrier was then measured. The measured field strength was from 5 to 6

5 milliGauss, a reduction of more than 90%.

[0094] While the present invention has been described with reference to the specific embodiments, the description is illustrative of the invention and is not to be construed as limiting the invention. Various modifications can be made to the preferred embodiments without departing from the spirit and scope of the invention as defined by the claims. It will
10 be understood that the invention herein extends well beyond the embodiments of the disclosure, and the terms used in this specification should be understood to be language of description, not limitation, as those of skill in the art with this specification before them will be able to make changes and modifications therein without departing from the spirit of the invention.

15

WHAT IS CLAIMED IS:

1. A power carrier for transmitting an electrical current, said power carrier comprising:
a proximal end having first and second proximal electrical connections leading thereto;

5 a first set comprising at least three electrical conductors all electrically connected in parallel with the first proximal electrical connection, and a second set comprising at least three electrical conductors all electrically connected in parallel with the second proximal electrical connection;

10 the electrical conductors extending over a length of the carrier and being supported so as to be electrically separate from each other over said length in a cross-sectional arrangement relative to one another in the carrier; and

a distal end opposite the proximal end and having first and second distal electrical connections leading therefrom;

15 the first set of electrical conductors all electrically connected in parallel with the first distal electrical connection, and the second set of electrical conductors all electrically connected in parallel with the second distal electrical connection; and

20 the first and second sets of electrical conductors being positioned in said cross-sectional arrangement such that the arrangement includes at least one junction area surrounded by at least two electrical conductors of each of said sets organized so as to alternate between the electrical conductors of the first set and the electrical conductors of the second set, said electrical conductors around the junction area being at a distance from

adjacent electrical conductors of the other set so that respective magnetic field passageways are defined between each of the electrical conductors and the adjacent electrical conductors.

2. The invention according to claim 1, wherein the electrical conductors surrounding the junction area are substantially equidistant from a centerpoint therein and are
5 substantially equally distributed thereabout.
3. The invention according to claim 1, wherein the junction area is surrounded by at least three of said electrical conductors of each of said sets.
4. The invention according to claim 3, wherein the junction area is surrounded by three
10 electrical conductors of each of said sets equidistant from a centerpoint and arranged staggered 60 degrees apart from each other therearound so as to form a hexagonal arrangement around the junction area.
5. The invention according to claim 3, wherein the junction area is surrounded by four
15 electrical conductors of each of said sets equidistant from a centerpoint and arranged staggered 45 degrees apart from each other therearound so as to form an octagonal arrangement around the junction area.
6. The invention according to claim 5, wherein the arrangement includes a second
junction area surrounded by two of the electrical conductors of each of the sets of electrical
conductors, one of said two electrical conductors of each of the sets being also in the
octagonal arrangement of the first junction area.
- 20 7. The invention according to claim 1, wherein the cross-sectional arrangement is constant over the length of the carrier.

8. The invention according to claim 1, wherein first branching structures electrically link ends of the electrical conductors of the first set to the first proximal and distal electrical connectors, respectively, and second branching structures electrically link ends of the electrical conductors of the second set to the second proximal and distal electrical connectors, respectively .
- 5
9. The invention according to claim 1, wherein the arrangement includes a second junction area, the first junction area is surrounded by two of the electrical conductors of each of the sets of electrical conductors in a first square or rectangular configuration, and
- 10 the second junction area is surrounded by two of the electrical conductors of the first rectangular or square configuration and one or more additional electrical conductors of the first set and one or more additional electrical conductors of the second set.
10. The invention according to claim 9, wherein the electrical conductors surrounding the second junction area are in a second square or rectangular configuration.
- 15 11. The invention according to claim 10, wherein the cross sectional arrangement is an array having at least two rows and two columns, wherein the electrical conductors from the first set alternate with the electrical connectors in the second set along each row and along each column, such that junction areas are defined between the rows and columns each surrounded by two electrical conductors of each set.
- 20 12. The invention according to claim 11, wherein the array has at least four rows and four columns.

13. The invention according to claim 1, wherein insulating material surrounds each of the electrical conductors.

14. The invention according to claim 13 wherein pieces of material are supported between electrical conductors in at least some of the magnetic passageways, said material
5 being selected so as to reduce dielectric separation between at least some of the electrical conductors of one of the sets and one or more adjacent electrical conductors of the other set.

15. The invention according to claim 1, wherein the sets each include at least twelve electrical conductors, and the cross-sectional arrangement includes six additional junction areas positioned around the junction area and staggered at approximately 60 degrees relative
10 to each other, each of said junction areas being surrounded by three electrical conductors from the first set and three electrical conductors from the second set, said electrical conductors being staggered at about 60 degrees relative to each other.

16. The invention according to claim 1, and further comprising
and electrical power supply supplying electrical current to the first proximal
15 electrical connection; and

an electrical load connected between the first and second distal electrical connections;

the electrical current flowing through the first set of electrical conductors, then through the load, then back through the carrier through the second set of electrical
20 conductors.

17. The invention according to claim 16, wherein the electrical power supply supplies an opposing pole to the electrical current at the second proximal electrical connection.

18. The invention according to claim 16, further having a first transformer changing the voltage of the electrical current before it is supplied to the first proximal connection and a
5 second transformer changing the voltage of the electrical current between the first distal electrical connection and the load.

19. A power carrier for transmitting an electrical current said power carrier comprising:
a proximal end having first and second proximal electrical connections leading
thereto;

10 a distal end opposite the proximal end and having first and second distal electrical connections leading therefrom;

a first set of electrical conductors all electrically connected in parallel between the first proximal electrical connection and the first distal electrical connection, and a second set of electrical conductors all electrically connected in parallel between the second proximal
15 electrical connection and the second distal electrical connection;

the electrical conductors extending over a length of the carrier and each being surrounded by insulating material so as to be electrically separate from each other over said length in a cross-sectional arrangement relative to one another in the carrier, said cross-sectional area remaining constant over the length of the carrier;

20 the first set of electrical conductors all being electrically connected in parallel with the first distal electrical connection, and the second set of electrical conductors all

electrically connected in parallel with the second distal electrical connection; and

the first and second sets of electrical conductors being positioned in said cross-sectional arrangement so that a number of junction areas are defined between groups of electrical conductors;

5 wherein an equal number not less than two of electrical conductors of each of said sets are positioned so as to be equidistant from a respective center point of each junction area, to be spaced around the centerpoint at equal angular displacements relative to each other, and to alternate between the electrical conductors of the first set and the electrical conductors of the second set; and

10 the cross sectional arrangement of the electrical conductors is a rectangular matrix with at least four junction areas or a hexagonally packed pattern with at least seven junction areas.

20. The invention according to claim 19, and further comprising
a power supply transmitting a pole of the electrical current to the first proximal
15 electrical connection and connecting an opposing pole of the electrical current to the second proximal electrical connection; and

a transformer connected with the distal electrical connections and a load so as to receive the electrical current therefrom, change a voltage thereof and supply the electrical current to the load, and to return the electrical current via the second distal
20 electrical connection to the carrier and the power supply.

21. A method of transmitting electrical power comprising
providing a carrier according to claim 1, and
supplying electrical current to the first proximal electrical contacts so that the current
flows through the first set of conductors to the first distal electrical connection,
5 through a transformer and to a load;
receiving a return electrical current from the load via the transformer to the second
distal electrical connection and through the second set of electrical conductors.
22. The power carrier of claim 1, wherein a plurality of electrically isolated elements of
material interactive with magnetic fields is supported at least partially in the
10 magnetic field passageways.
23. The power carrier of claim 22 wherein said elements are arranged in a stack in which
said elements are isolated electrically from each other and together form a wall between one
of the conductors of each of said sets of conductors; and
wherein additional elements of magnetically interactive material are arranged in
15 isolated stacks forming walls that define a box structure around one of said conductors;
wherein further elements of magnetically interactive material are supported in stacks
forming walls so as to form box structures around others of said conductors;
said elements having outer surfaces defining passages extending in the power carrier
and providing cooling of the power carrier by gas or liquid coolant passing through said
20 passages;
the elements being formed of ferritic or ferromagnetic material and separated from

each other by transformer oil; and

said elements being plate-shaped and having angled end portions facing each other at corners of the box structures.

24. The power carrier of claim 22, wherein the elements each comprises a generally
5 planar member of ferromagnetic material having apertures therein through which the
conductors extend, said elements being spaced from each other and stacked so that the
apertures align lengthwise of the power carrier and the elements together form box
structures around the conductors.

25. The power carrier of claim 19, and further comprising
10 a lattice structure made of ferromagnetic material supported in the power carrier and
extending over a portion of the length of the power carrier, said lattice structure including a
plurality of wall structures separating the conductors of different sets, said lattice being
formed of plate members stacked and electrically separated from each other;

said plate members having apertures therein through each of which a respective one
15 of the conductors extends, or said plate members comprising a plurality of plate elements
organized to define a plurality of box structures each surrounding a respective one of the
conductors.

26. The power carrier of claim 25, wherein the plate members are laminated
ferromagnetic material.

20 27. The power carrier of claim 22, wherein the plate members define gaps in the power
carrier extending over the length of the carrier, and wherein the power carrier is cooled by

supplying cooling gas or cooling liquid flowing through the gaps so as to receive heat therefrom.

28. The power carrier according to any of the foregoing claims 22 to 27, wherein the material is a ferromagnetic insulator material.

5 29. The power carrier according to any of the foregoing claims 22 to 27, wherein the material is a ferromagnetic insulator material.

30. A method of transmitting electrical power comprising

providing a carrier according to any of the previous claims, and

10 supplying electrical current to the first proximal electrical contacts so that the current flows through the first set of conductors to the first distal electrical connection, through a transformer and to a load;

receiving a return electrical current from the load via the transformer to the second distal electrical connection and through the second set of electrical conductors.

15

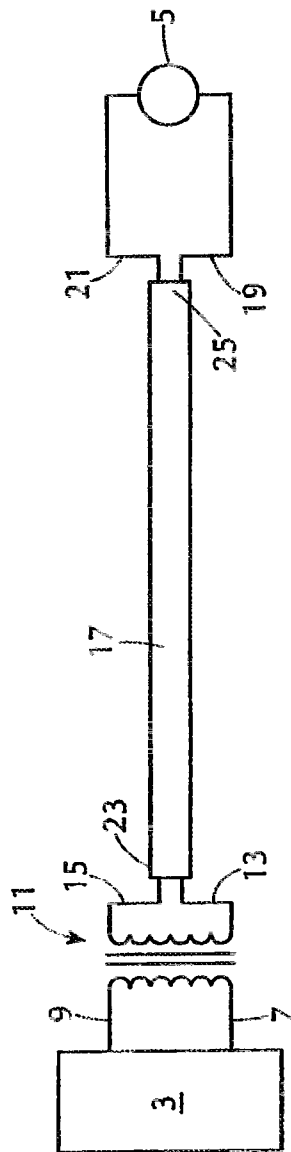
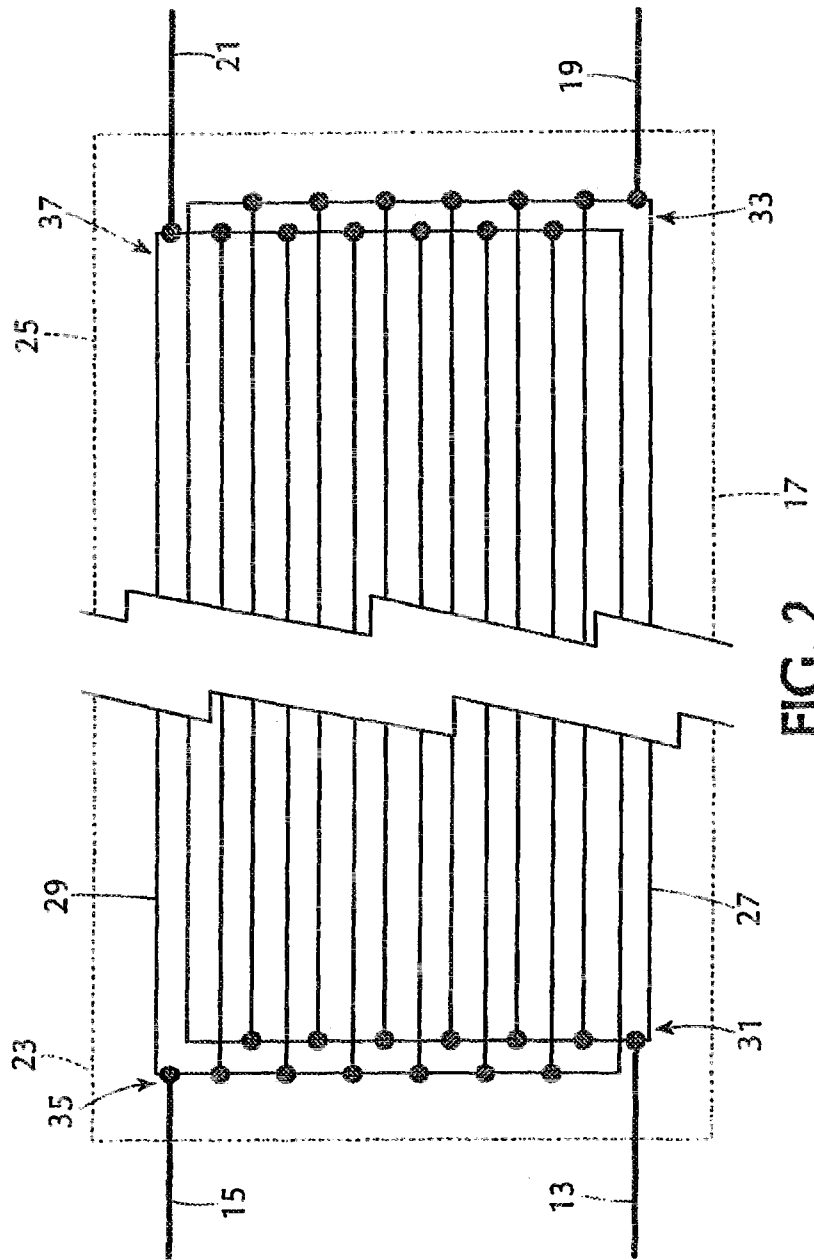


FIG. 1



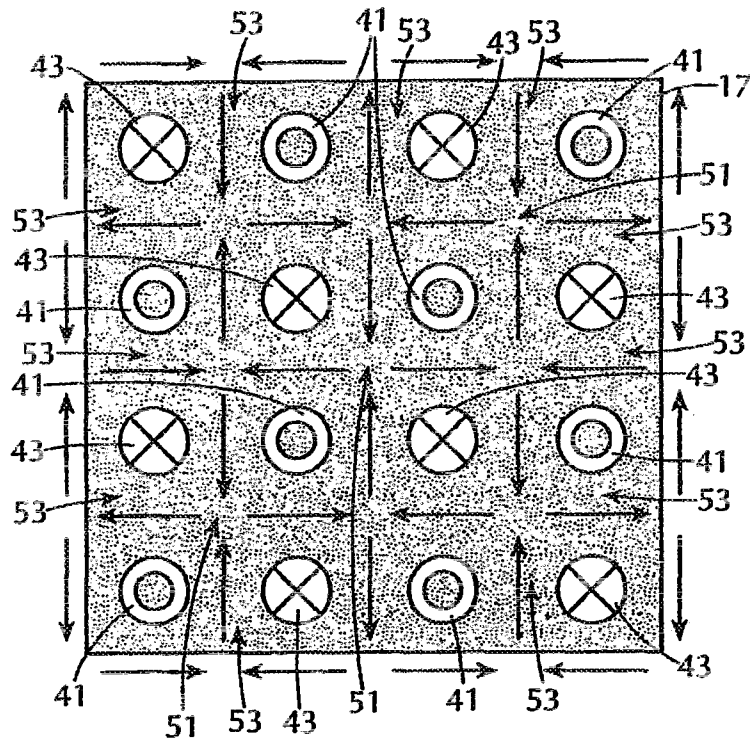


FIG. 3

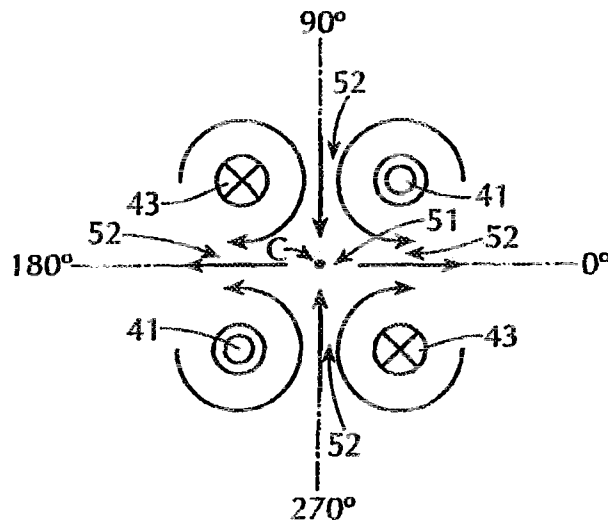


FIG. 4

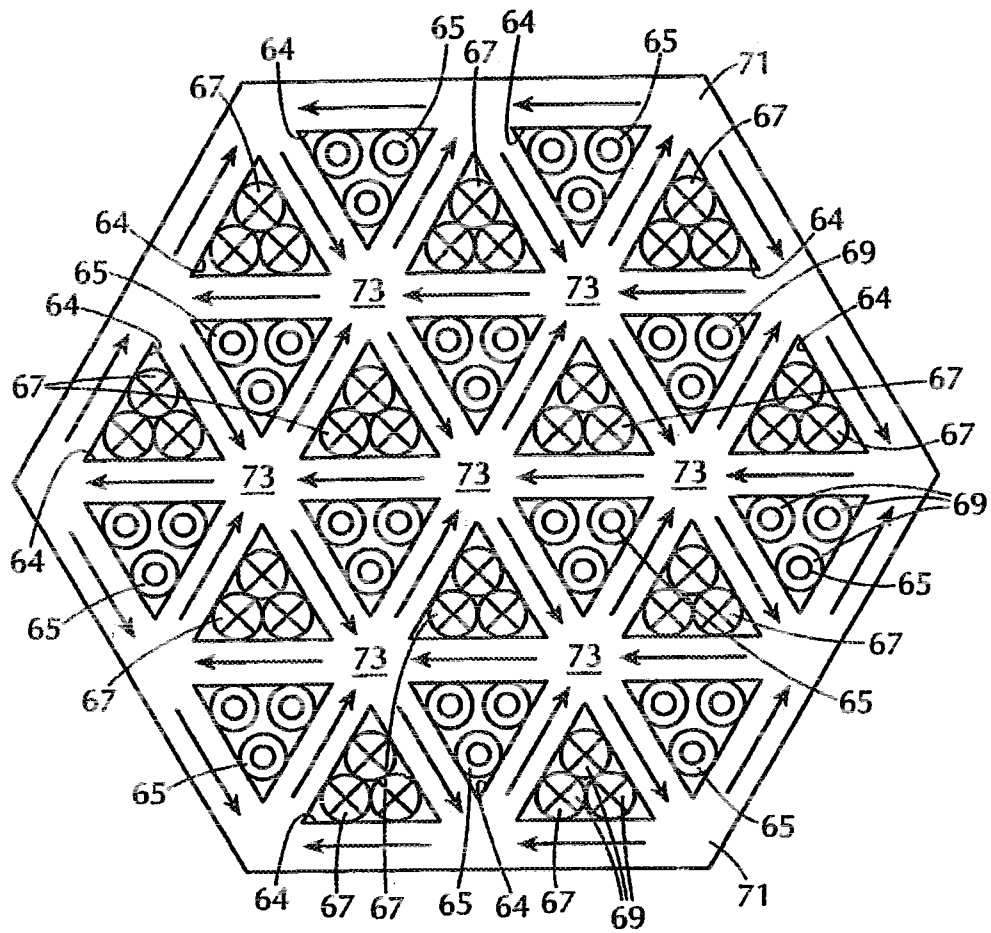


FIG. 5

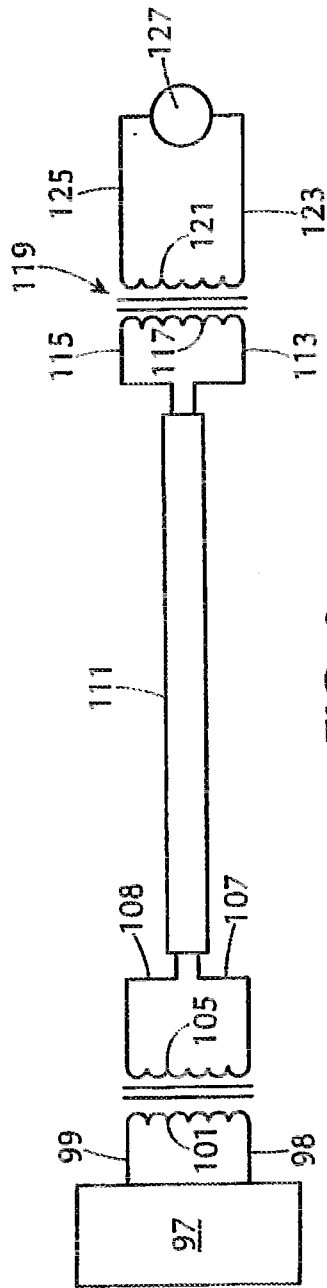


FIG. 9

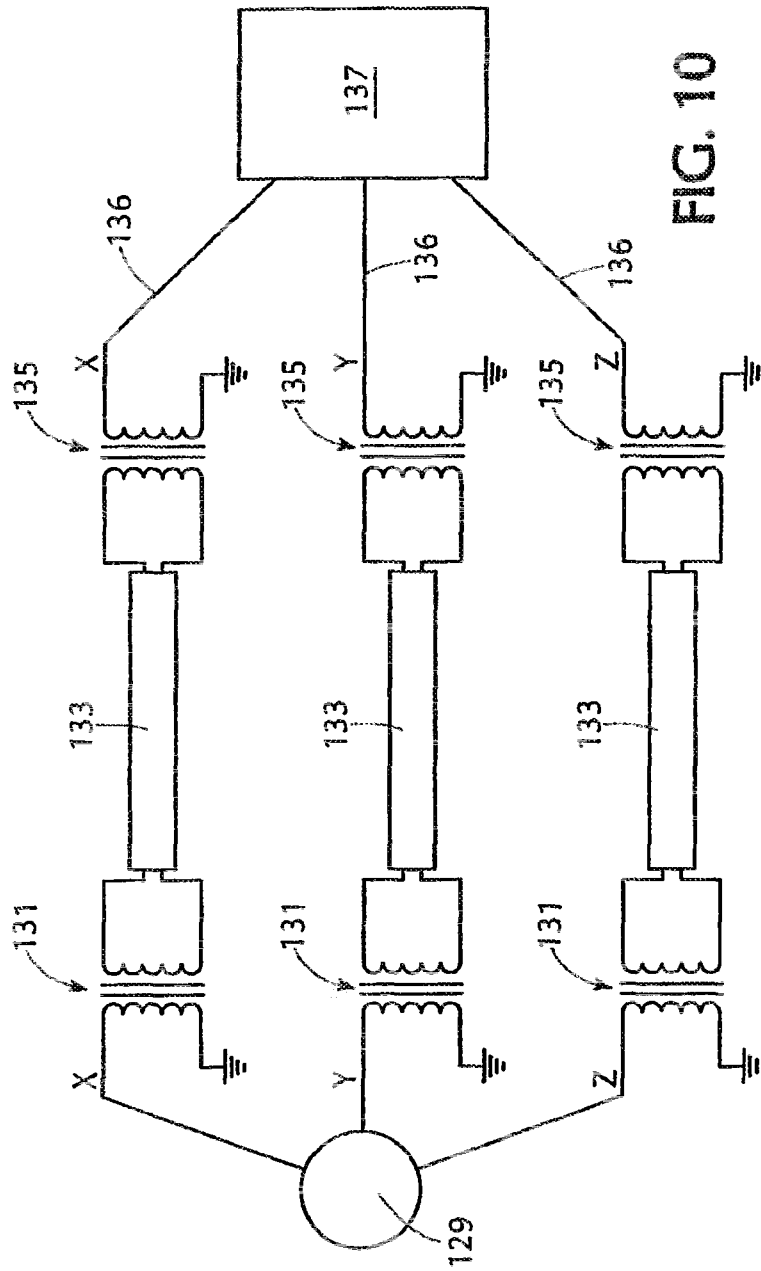


FIG. 10

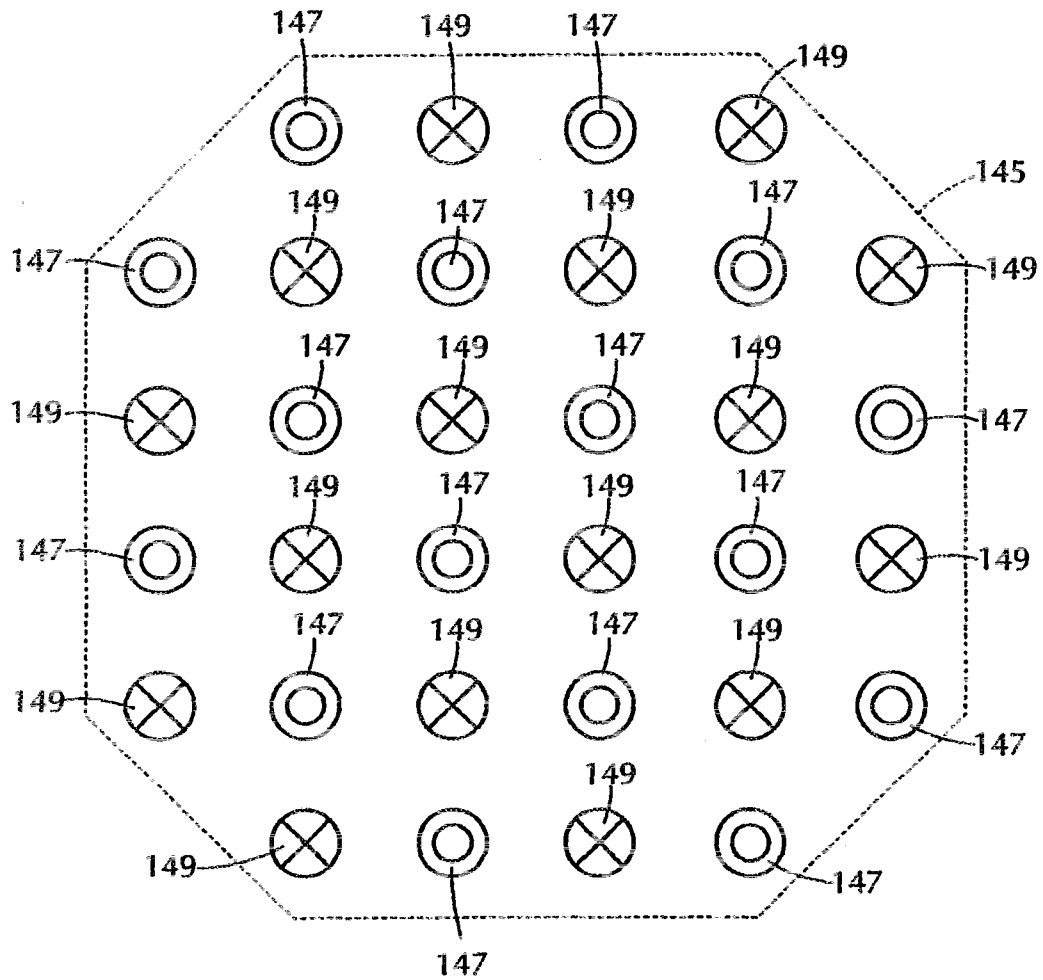


FIG. 11

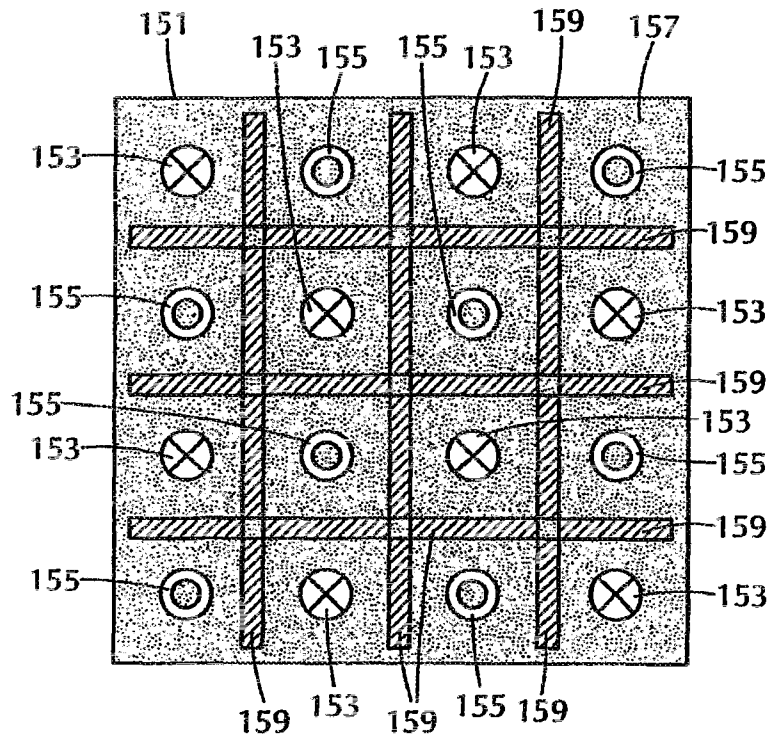


FIG. 12

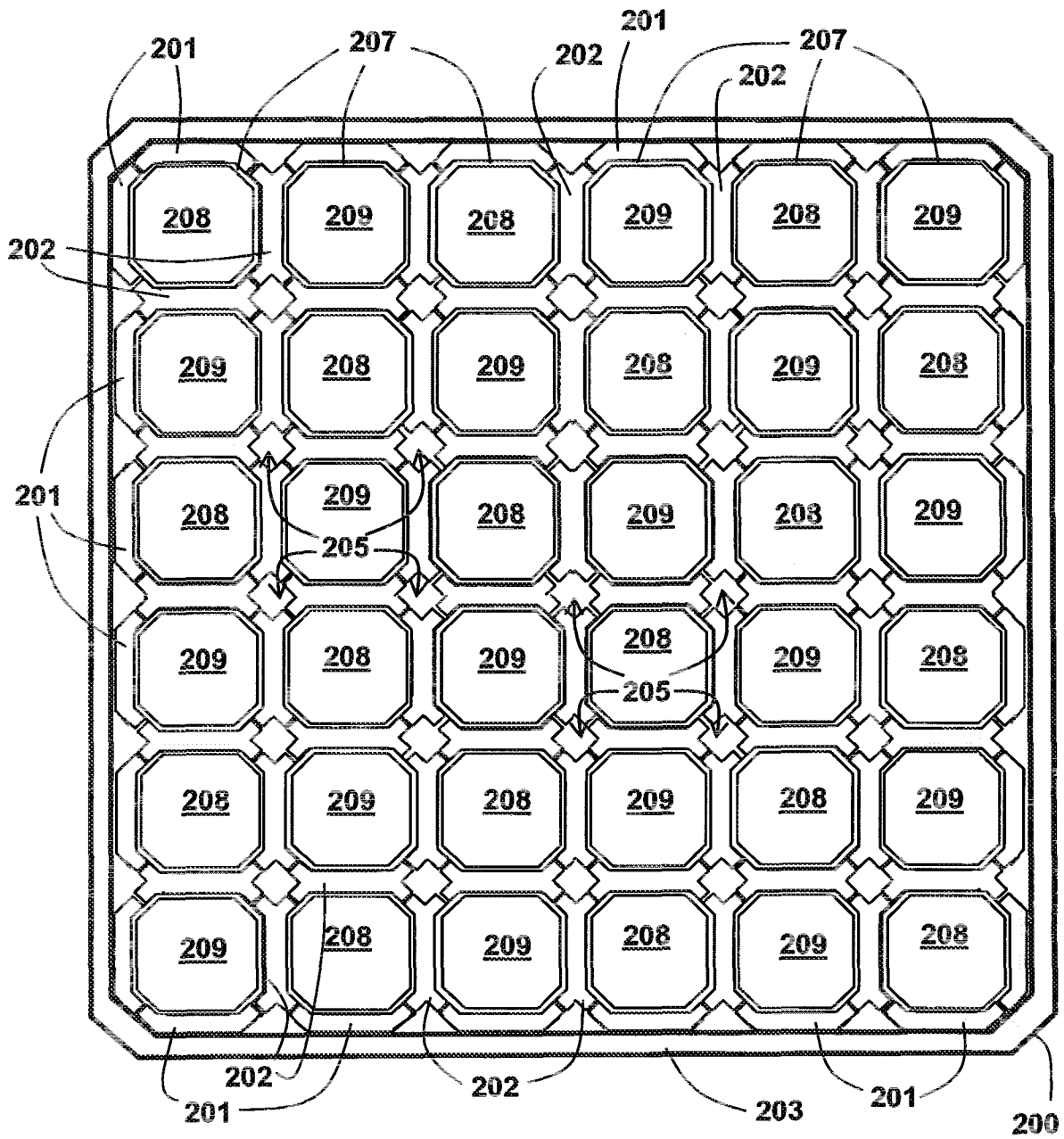


FIG. 13

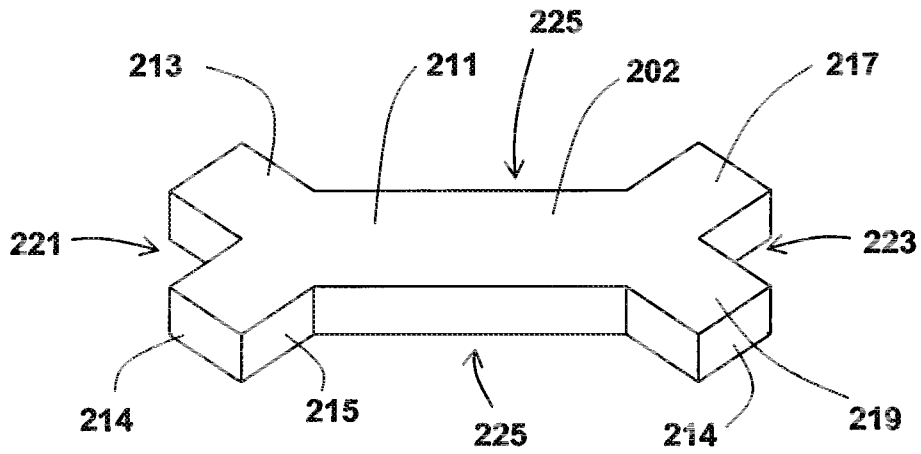


FIG. 14

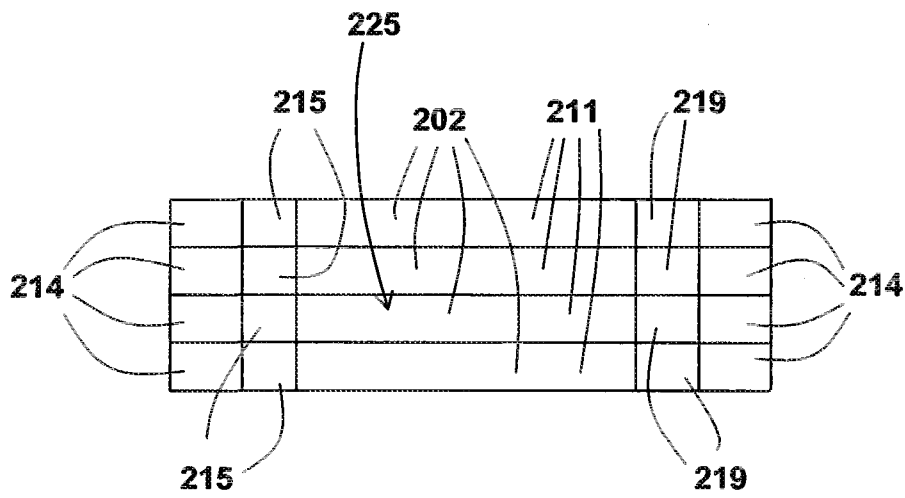


FIG. 15

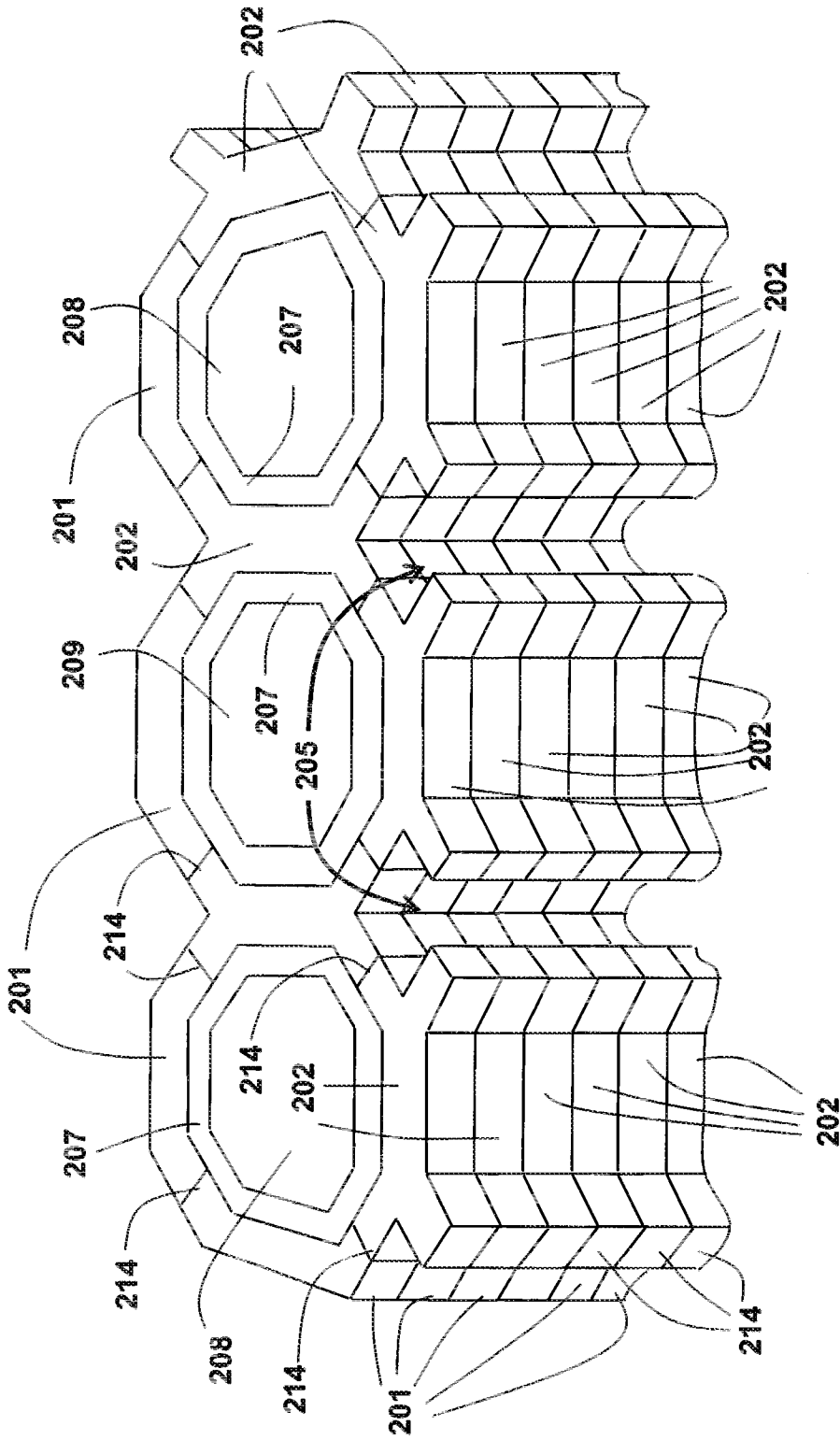


FIG. 16

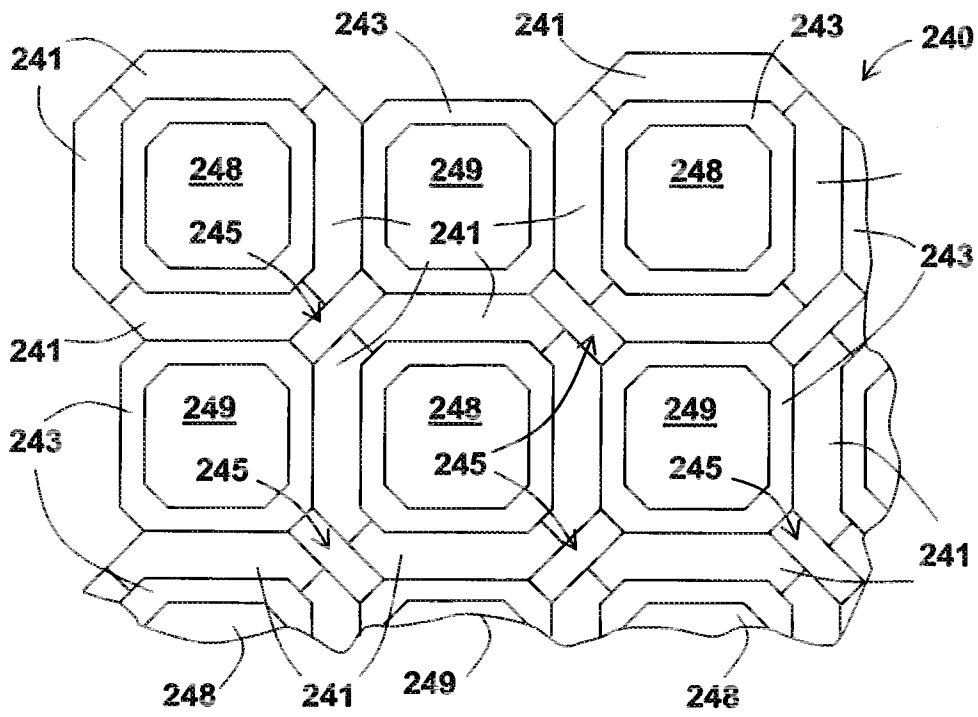


FIG. 17

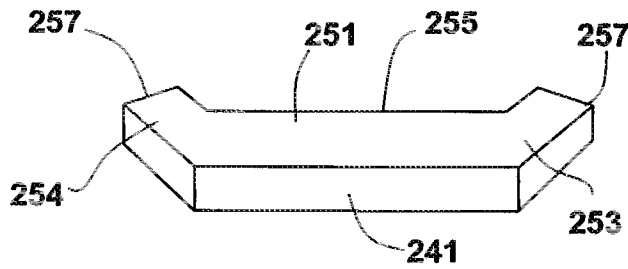


FIG. 18

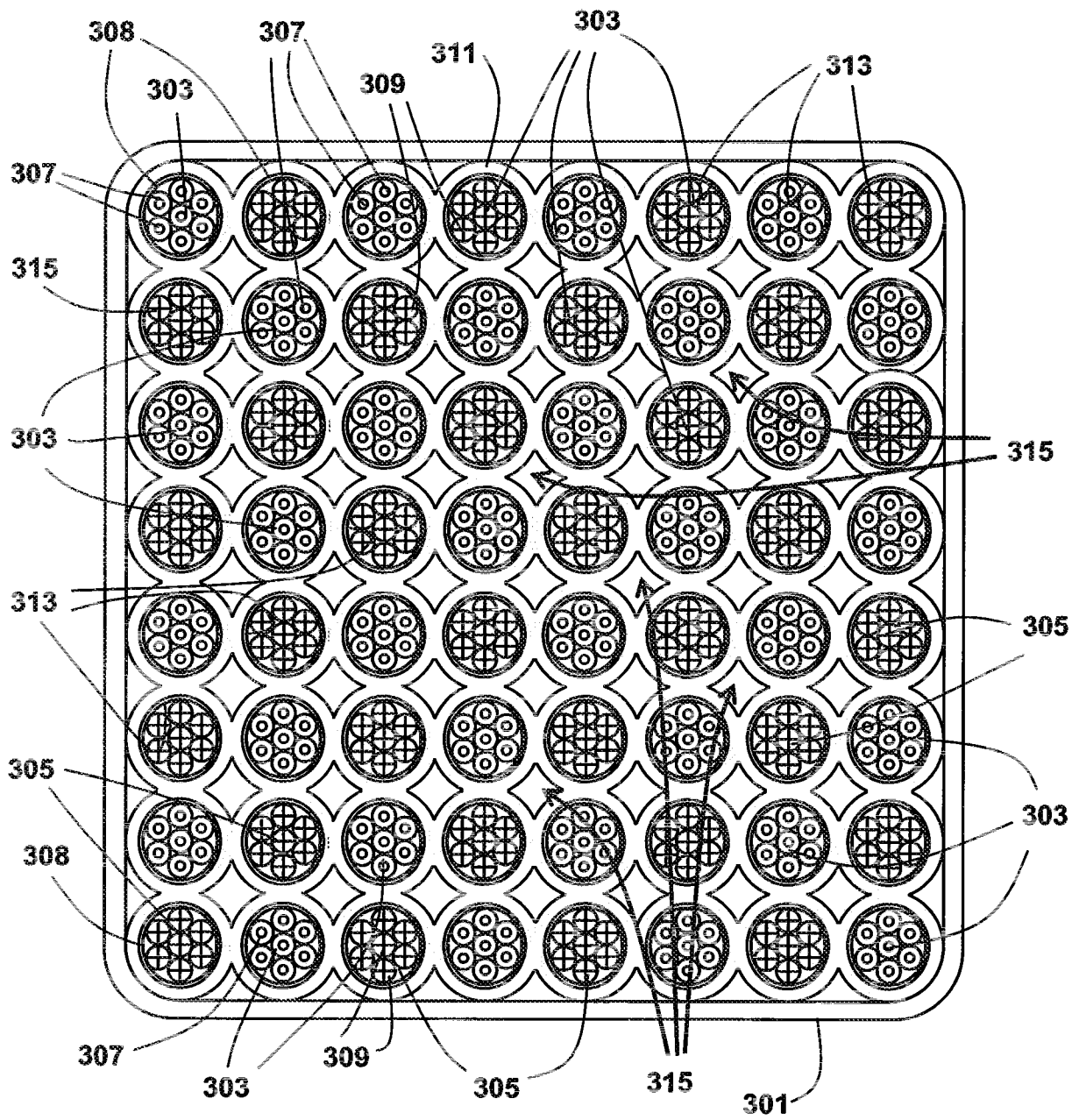


FIG. 19

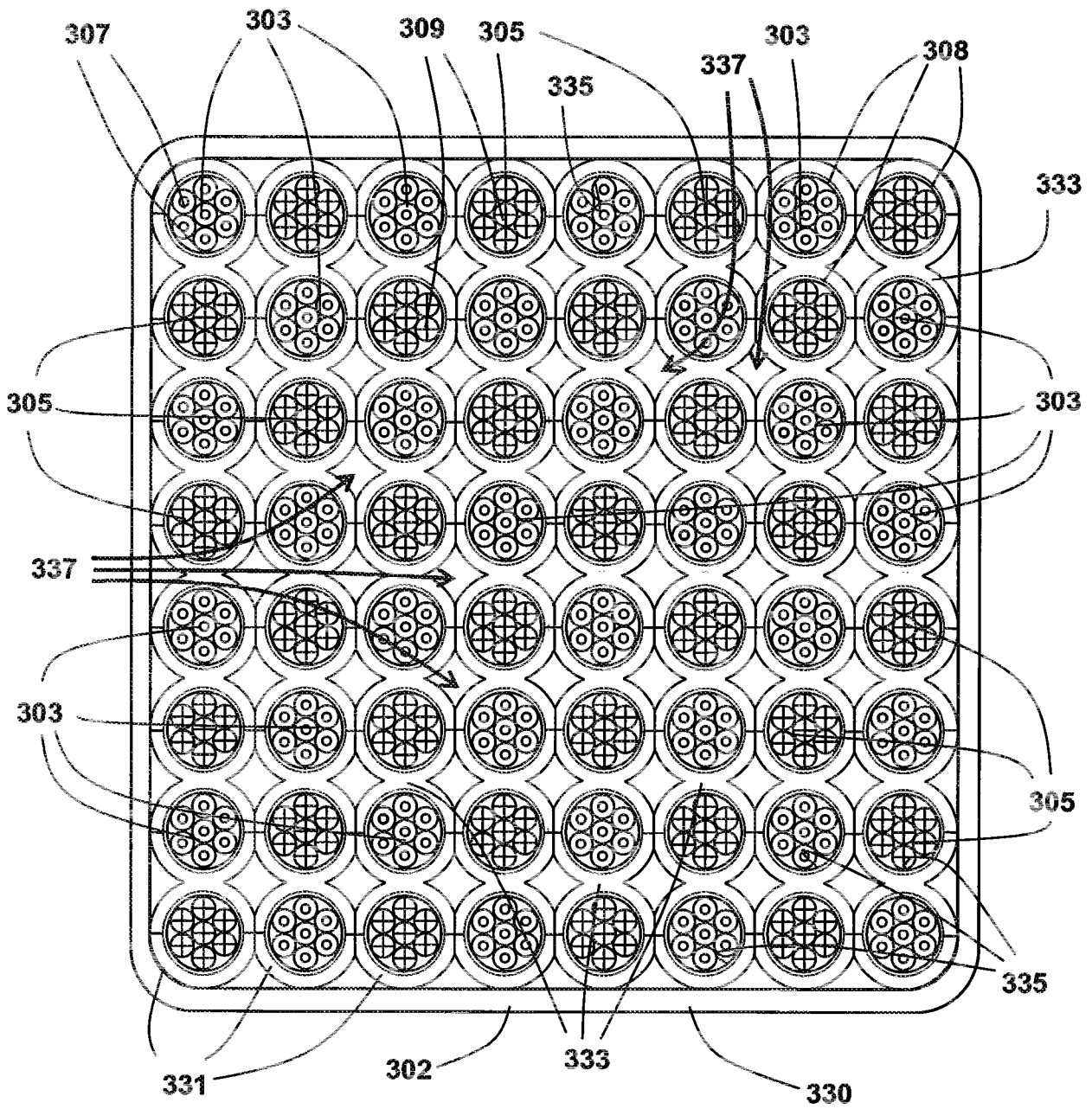


FIG. 20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/019823

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(8) - H01B 7/30 (2014.01)
 USPC - 174/34
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 IPC(8) - H01B 7/00, 30, 9/00, 02 (2014.01) (2014.01)
 USPC - 174/32, 33, 34, 35, 113R, 307/91, 147

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 CPC - H01B 7/30, 303, 306, 9/00, 9/02, 9/006 (2014.02)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 Orbit, Google Patents, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 9-180550 (SASAGAWA et al) 11 July 1997 (11.07.1997) see machine translation	19
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Y		1-18, 20-30
Y	US 6,506,971 B1 (GRACH et al) 14 January 2003 (14.01.2003) entire document	1-18, 21-24, 28, 29
Y	US 2008/0179969 A1 (DOOLEY et al) 31 July 2008 (31.07.2008) entire document	6, 9-12, 15
Y	US 2009/0205866 A1 (BREMNES) 20 August 2009 (08.20.2009) entire document	14, 22-24, 28, 29
Y	US 6,365,836 B1 (BLOUIN et al) 02 April 2002 (02.04.2002) entire document	14, 22-28, 29
Y	US 5,616,969 A (MORAVA) 01 April 1997 (01.04.1997) entire document	18, 20, 21, 30
Y	US 5,036,891 (VOGELSANG) 06 August 1991 (06.08.1991) entire document	23-27
Y	US 6,241,920 B1 (COTTER et al) 05 June 2001 (05.06.2001) entire document	23
Y	US 2011/0240341 A1 (LIPIANSKY et al) 06 October 2011 (06.10.2011) entire document	23, 25-27

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“E” earlier application or patent but published on or after the international filing date	“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	“&” document member of the same patent family
“O” document referring to an oral disclosure, use, exhibition or other means	
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 02 June 2014	Date of mailing of the international search report 16 JUN 2014
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774