(12) **UK Patent Application** (19) **GB** (11) **2 389 767** (13) **A**

(43) Date of A Publication **17.12.2003**

(21) Application No: **0226892.8**

(22) Date of Filing: **18.11.2002**

(30) Priority Data:
(31) **0213375** (32) **10.06.2002** (33) **GB**

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(51) INT CL^7:
H05B 6/36 // **H05B 6/12**

(52) UK CL (Edition V):
H5H HNR H2G1 H2G2X2
U1S S2400

(56) Documents Cited:
GB 2350766 A **EP 0921711 A1**
EP 0706304 A1 **EP 0599519 A1**
FR 002573947 A

(58) Field of Search:
UK CL (Edition V) **H5H**
INT CL^7 **H05B**
Other: **ONLINE:WPI,JAPIO,EPODOC**

(54) Abstract Title: **Apparatus for energy transfer by induction**

(57) The apparatus includes a primary induction unit including a planar surface for receiving a secondary element to which energy is to be transferred. The primary induction unit comprises an array of primary transformer windings to provide a substantially uniform magnetic flux distribution over said planar surface.
The winding connections of the array may be serial, parallel or both and multiple overlapping layers may be used. The individual spiral windings may be circular, square or hexagonal.

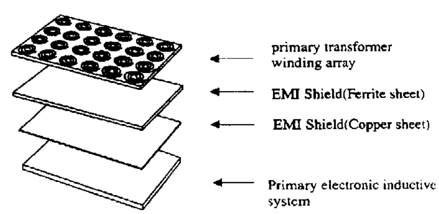

FIG.4(a)

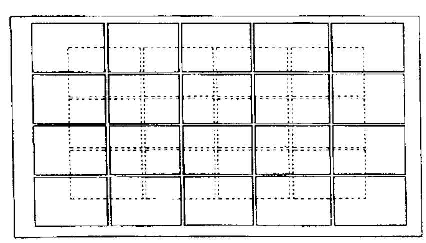

FIG.12

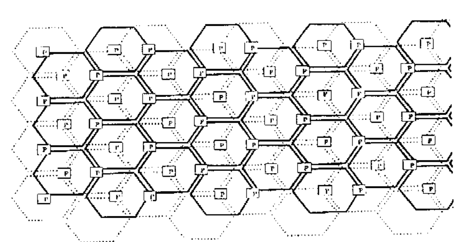

FIG.21

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

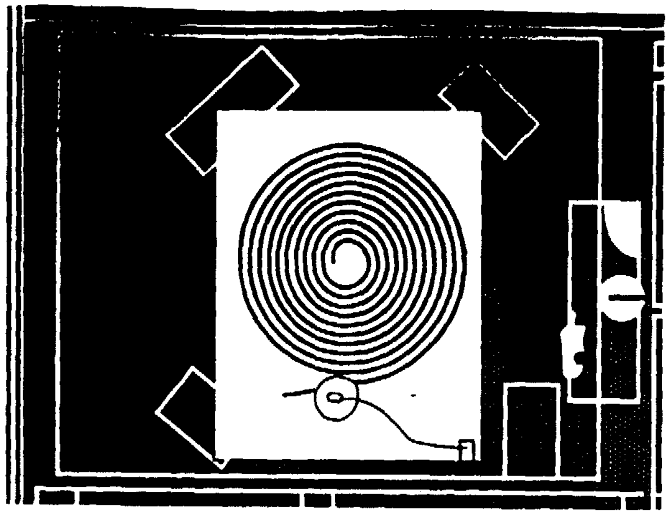

FIG.1(a)

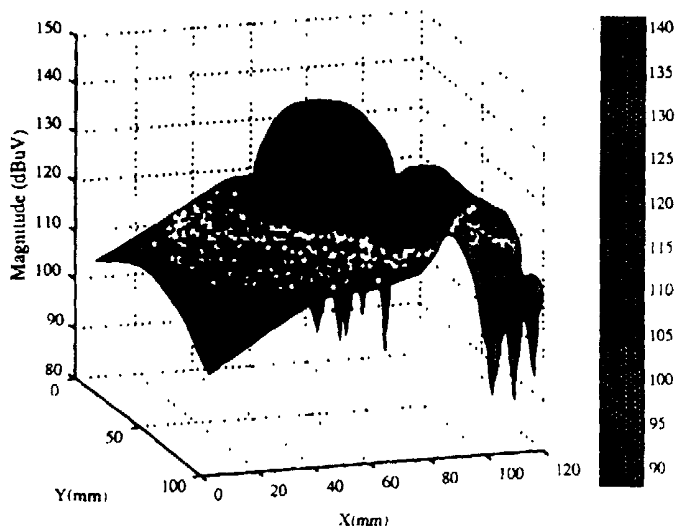

FIG.1(b)

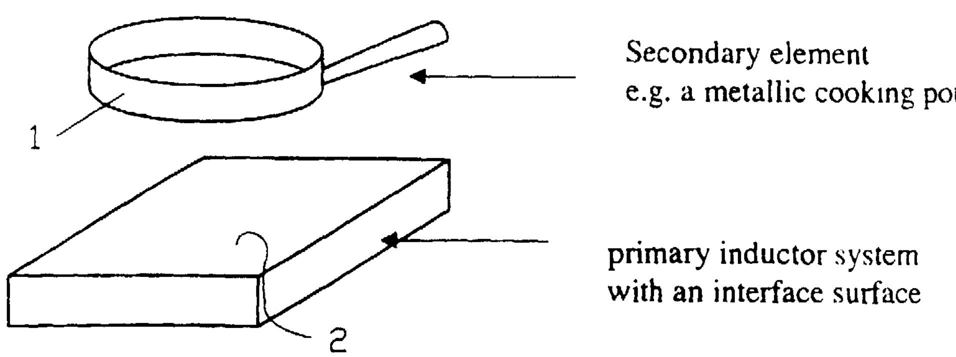

FIG.2

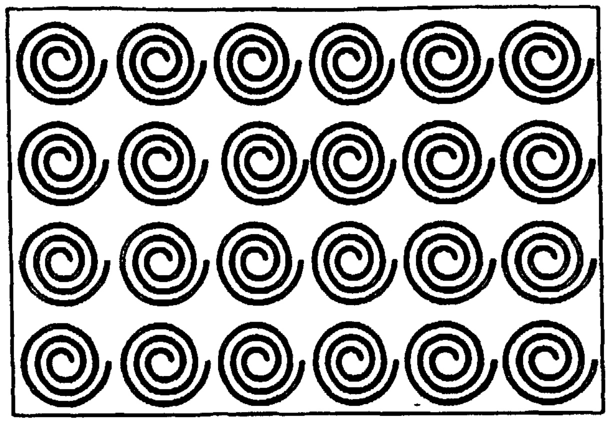

FIG.3

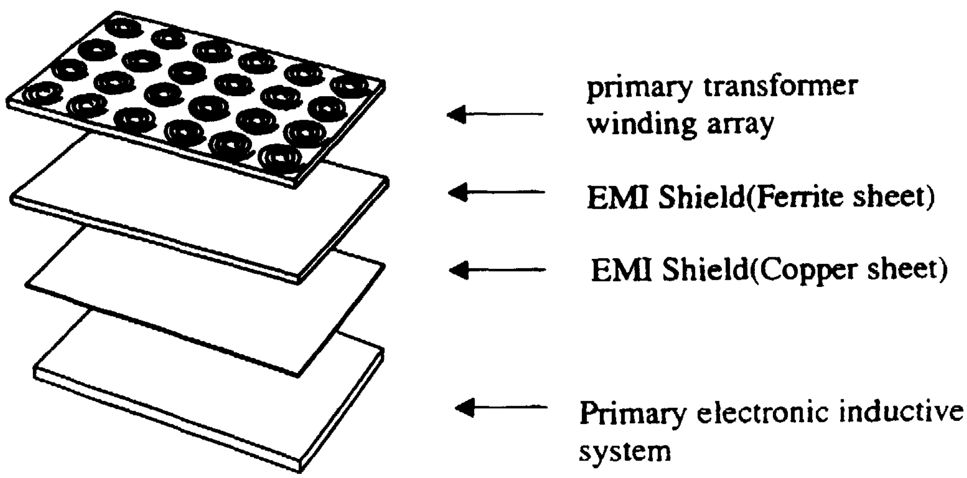

FIG.4(a)

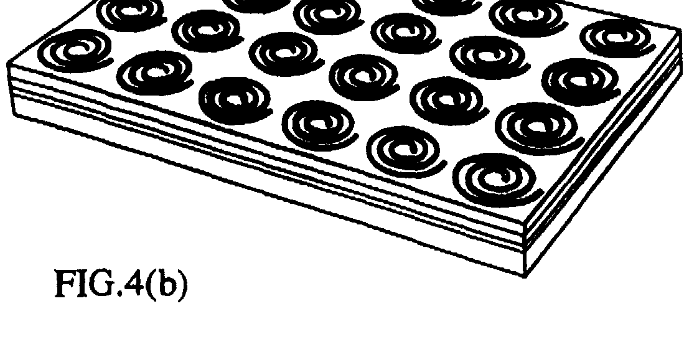

FIG.4(b)

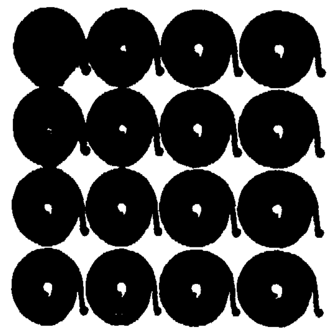

FIG.5(a)

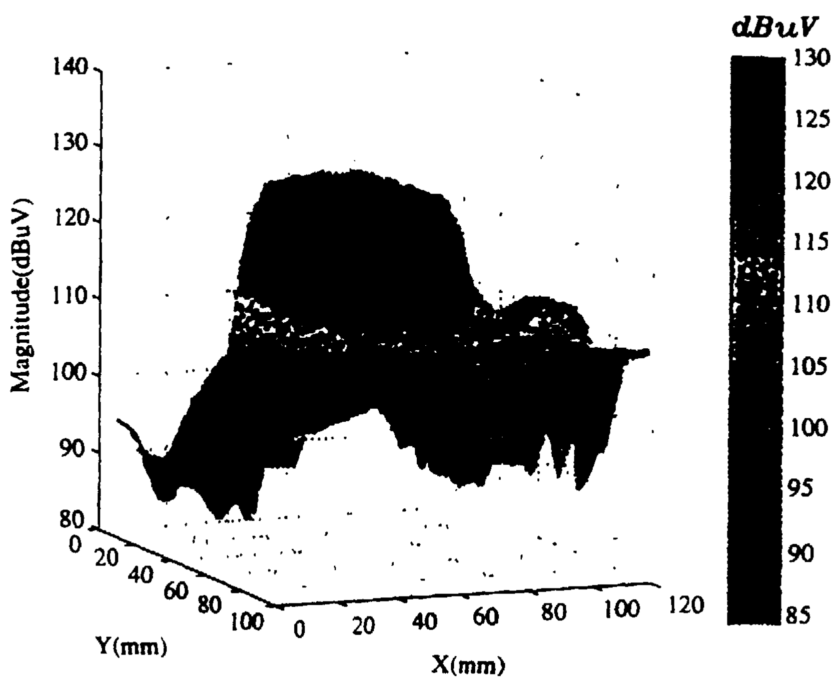
dBuV
130
125
120
115
110
105
100
95
90
85
140
130
120
110
100
90
80
Magnitude(dBuV)
0
20
40
60
80
100
Y(mm)
0
20
40
60
80
100
120
X(mm)

FIG.5(b)

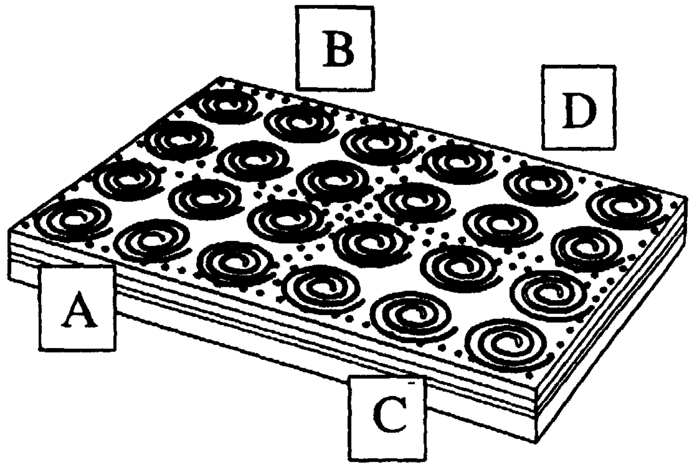
B
D
A
C

Fig.6(a)

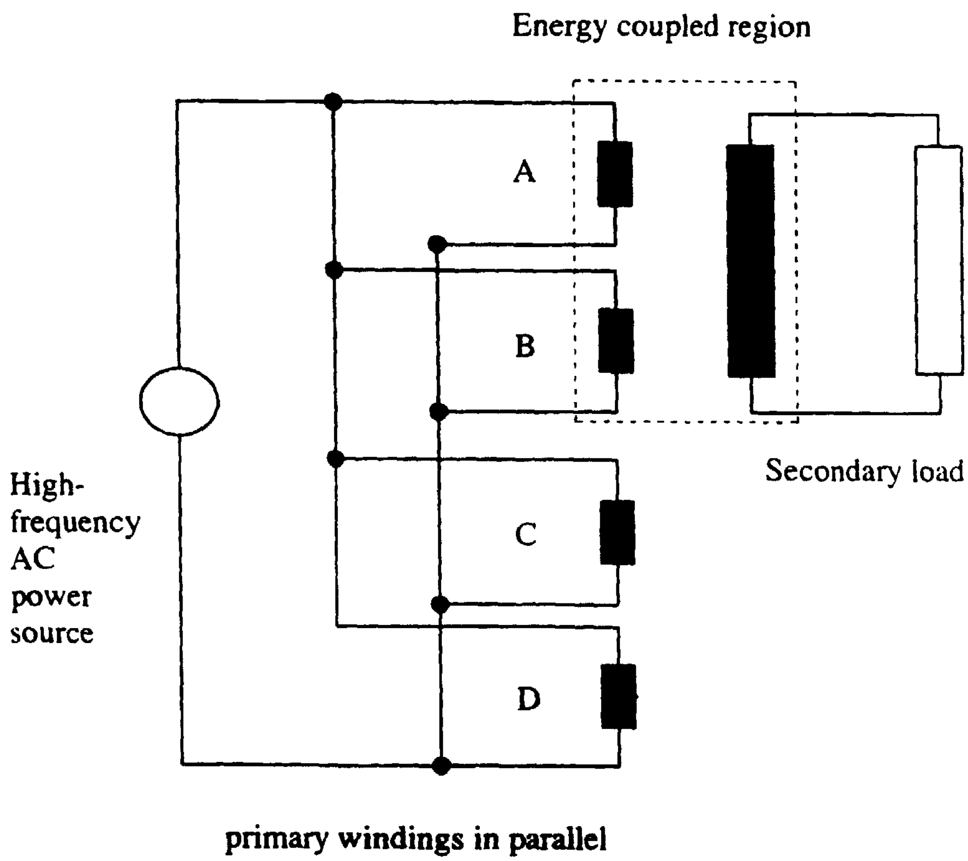
Energy coupled region
A
B
C
D
Secondary load
High-
frequency
AC
power
source
primary windings in parallel

Fig.6(b)

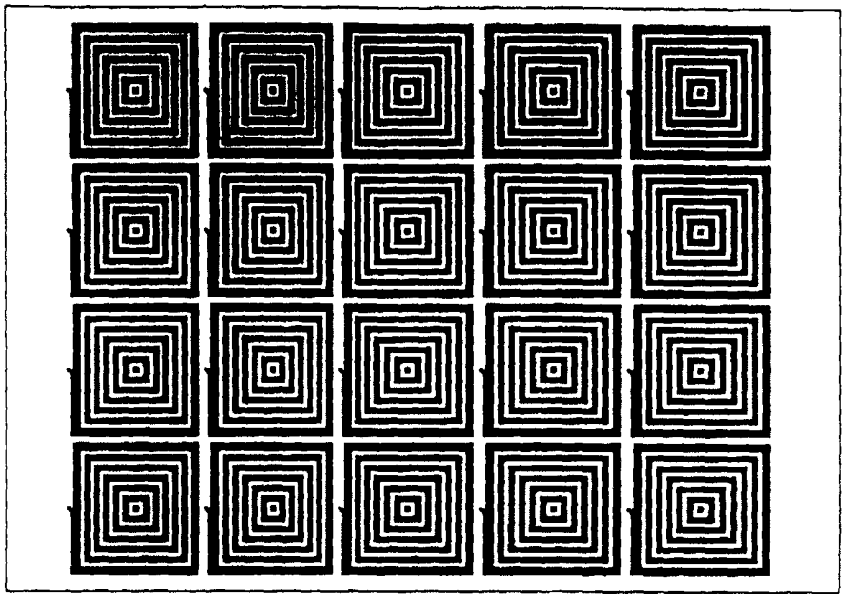

FIG.7

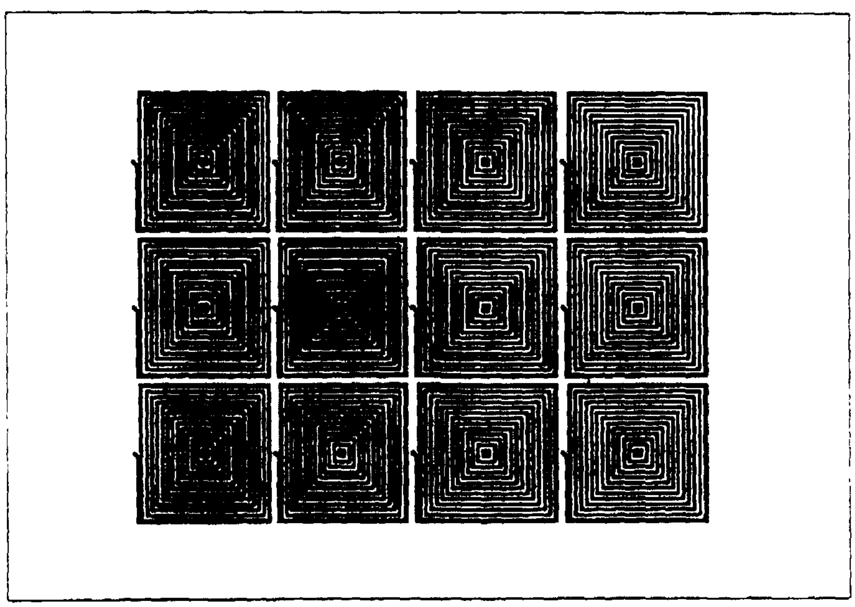

FIG.8

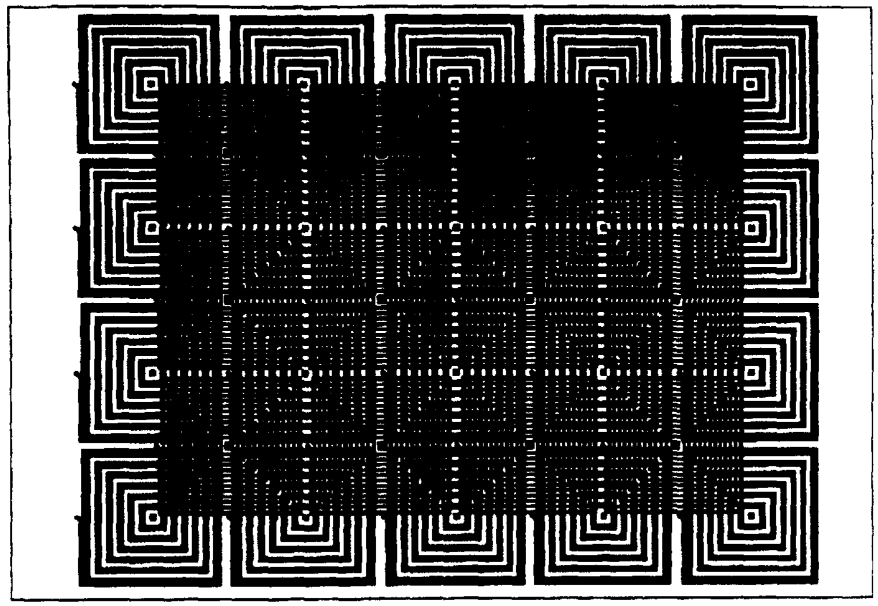

FIG.9

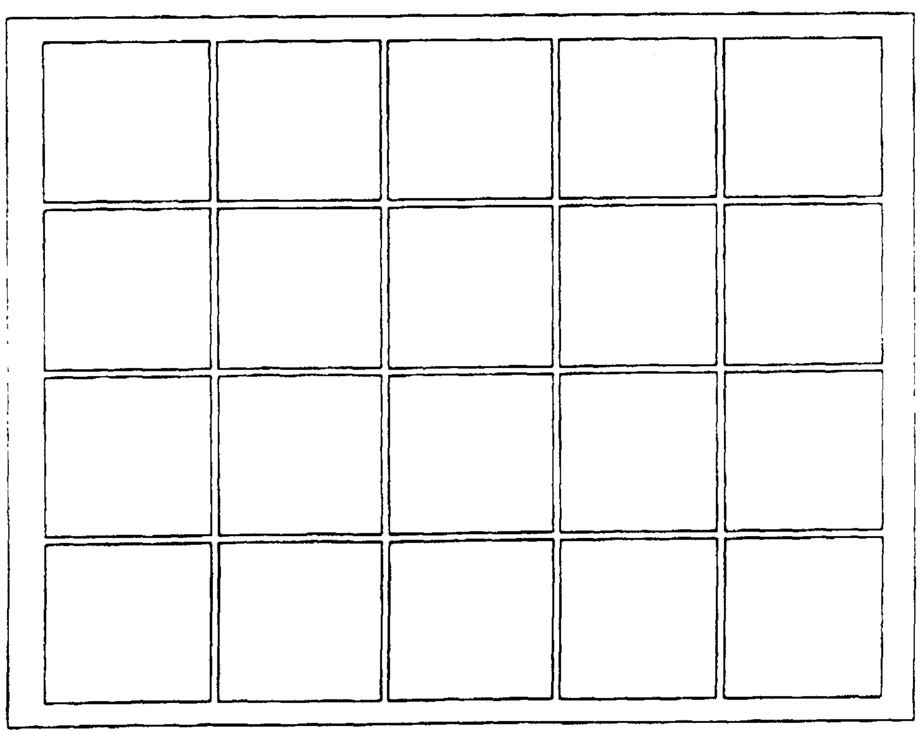

FIG.10

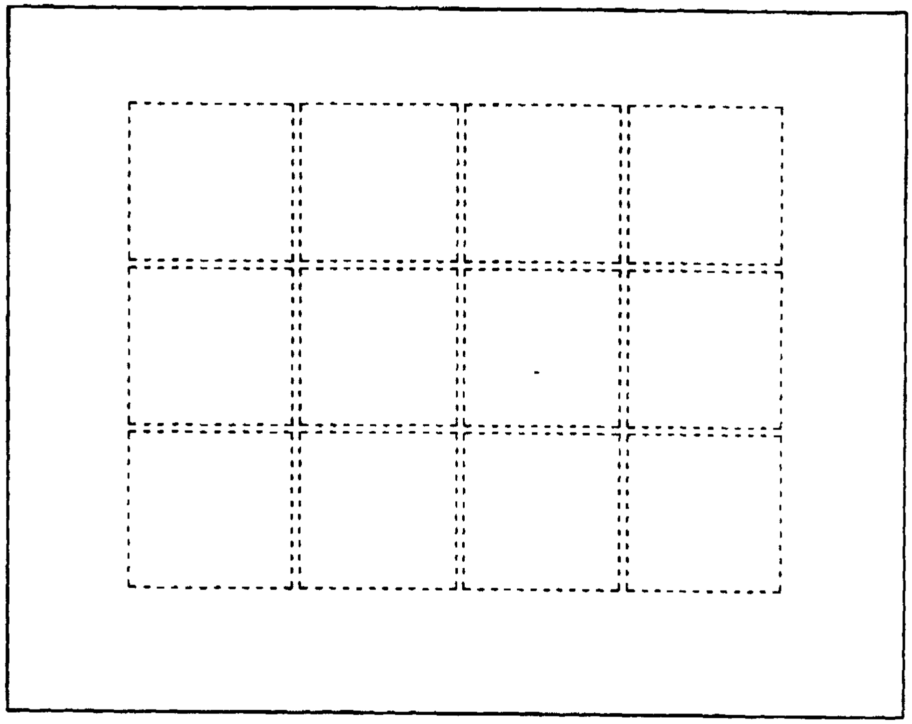

FIG.11

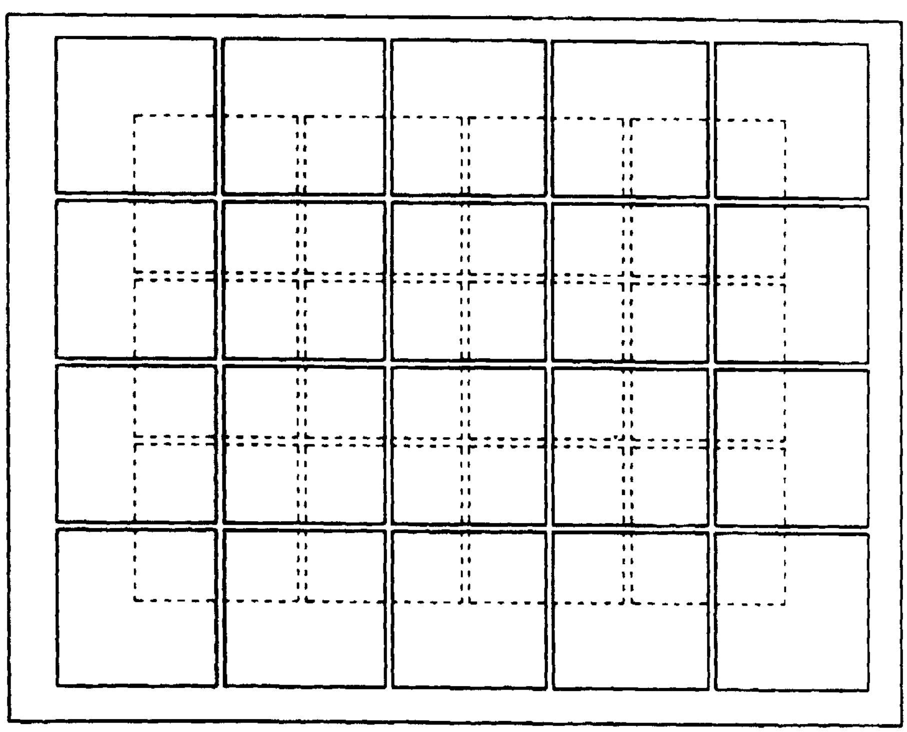

FIG.12

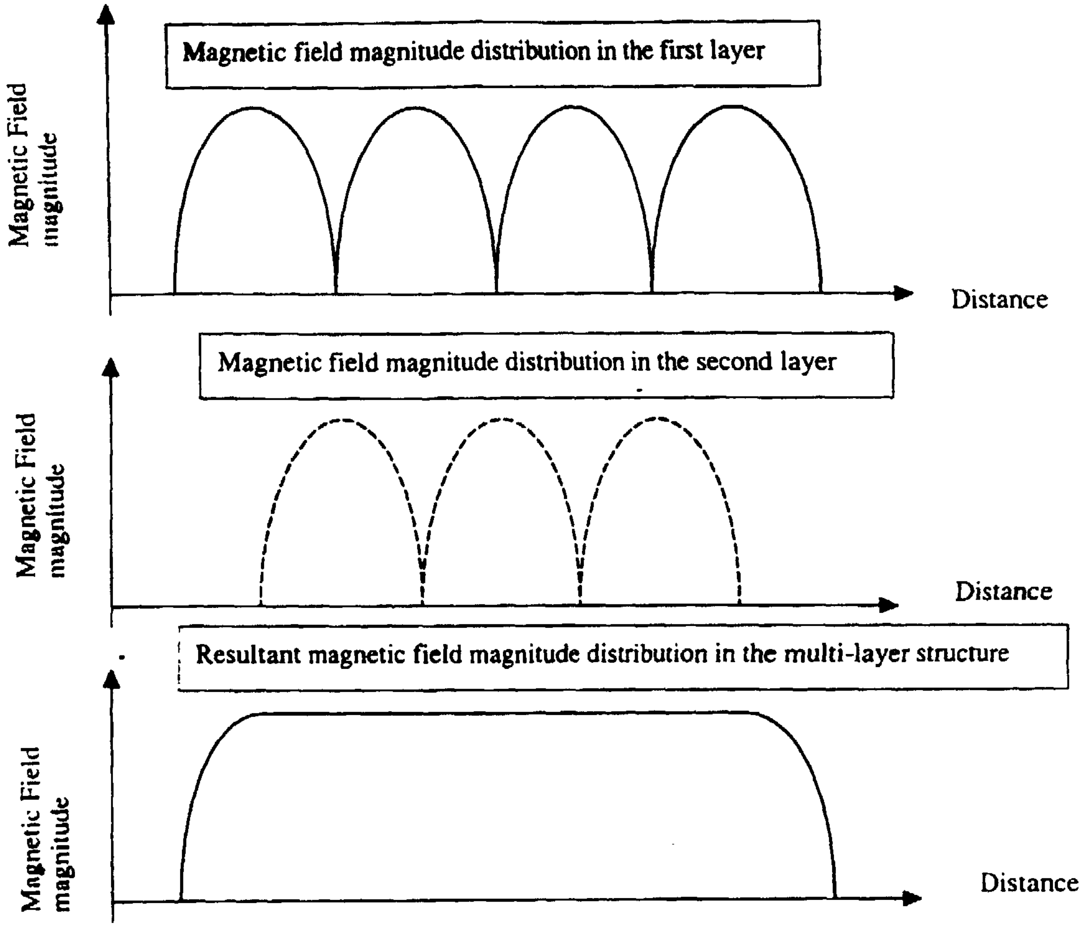

FIG.13

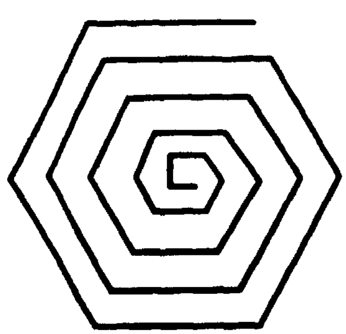

FIG.14

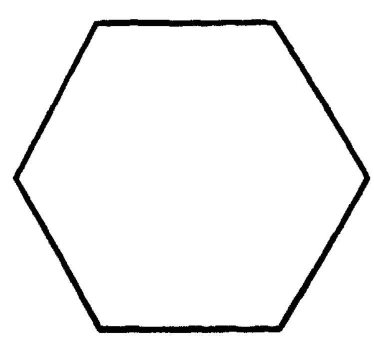

FIG.15

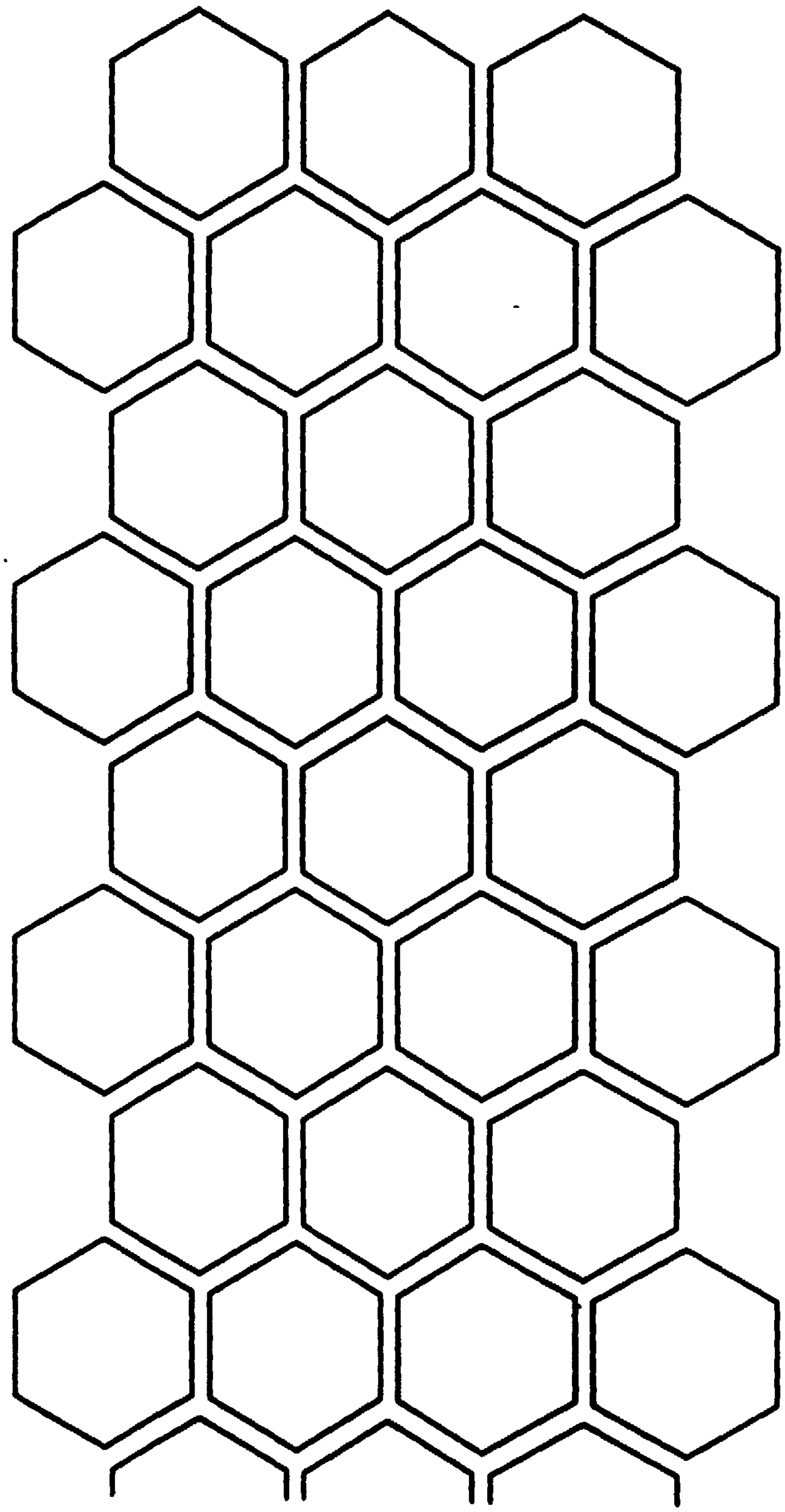

FIG.16

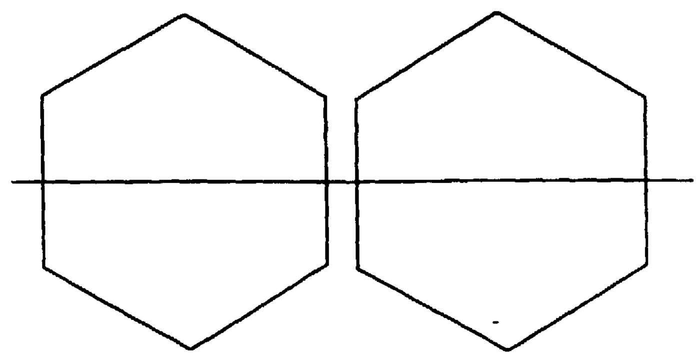

FIG.17

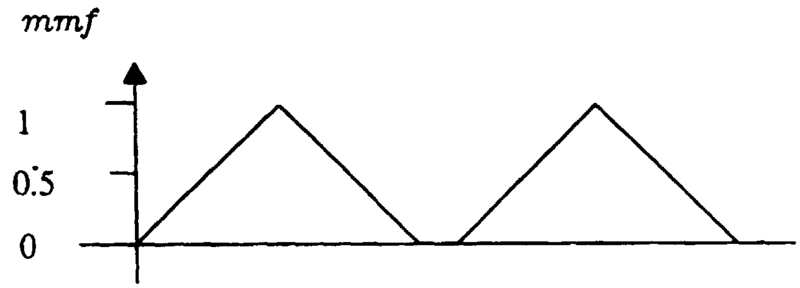

FIG.18

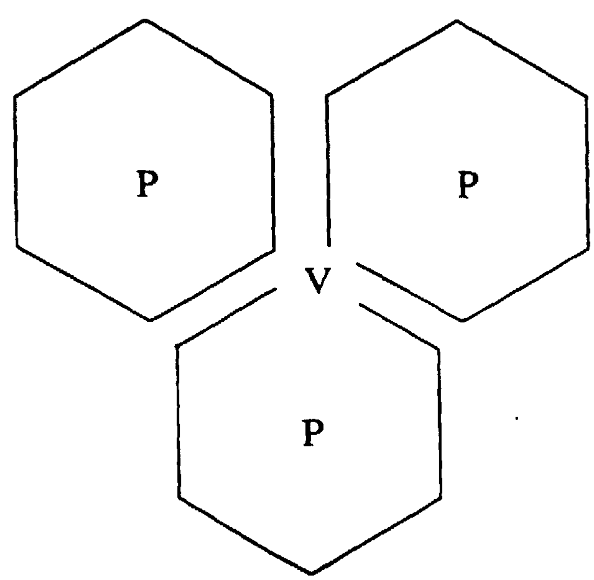

FIG.19

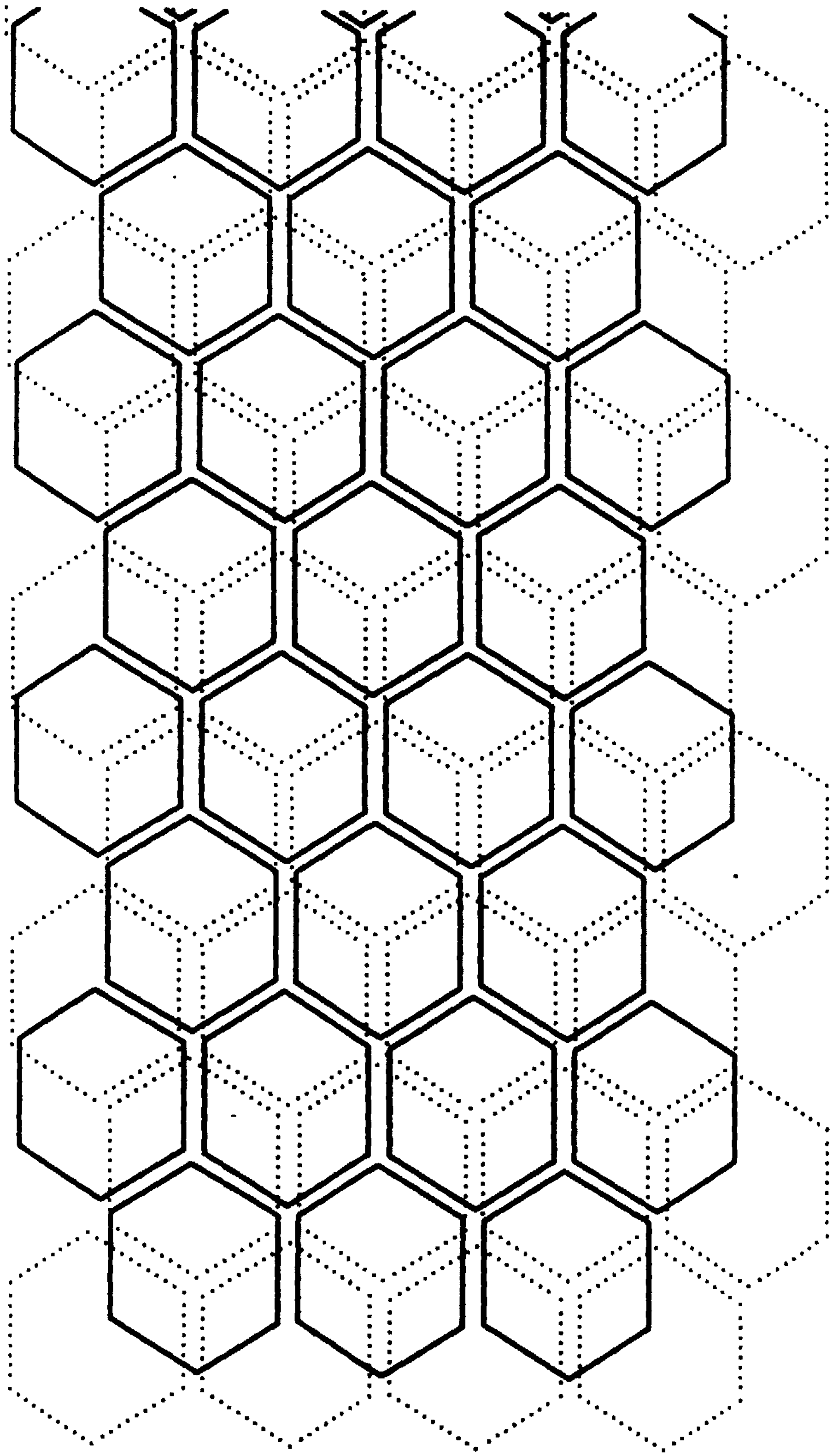

FIG.20

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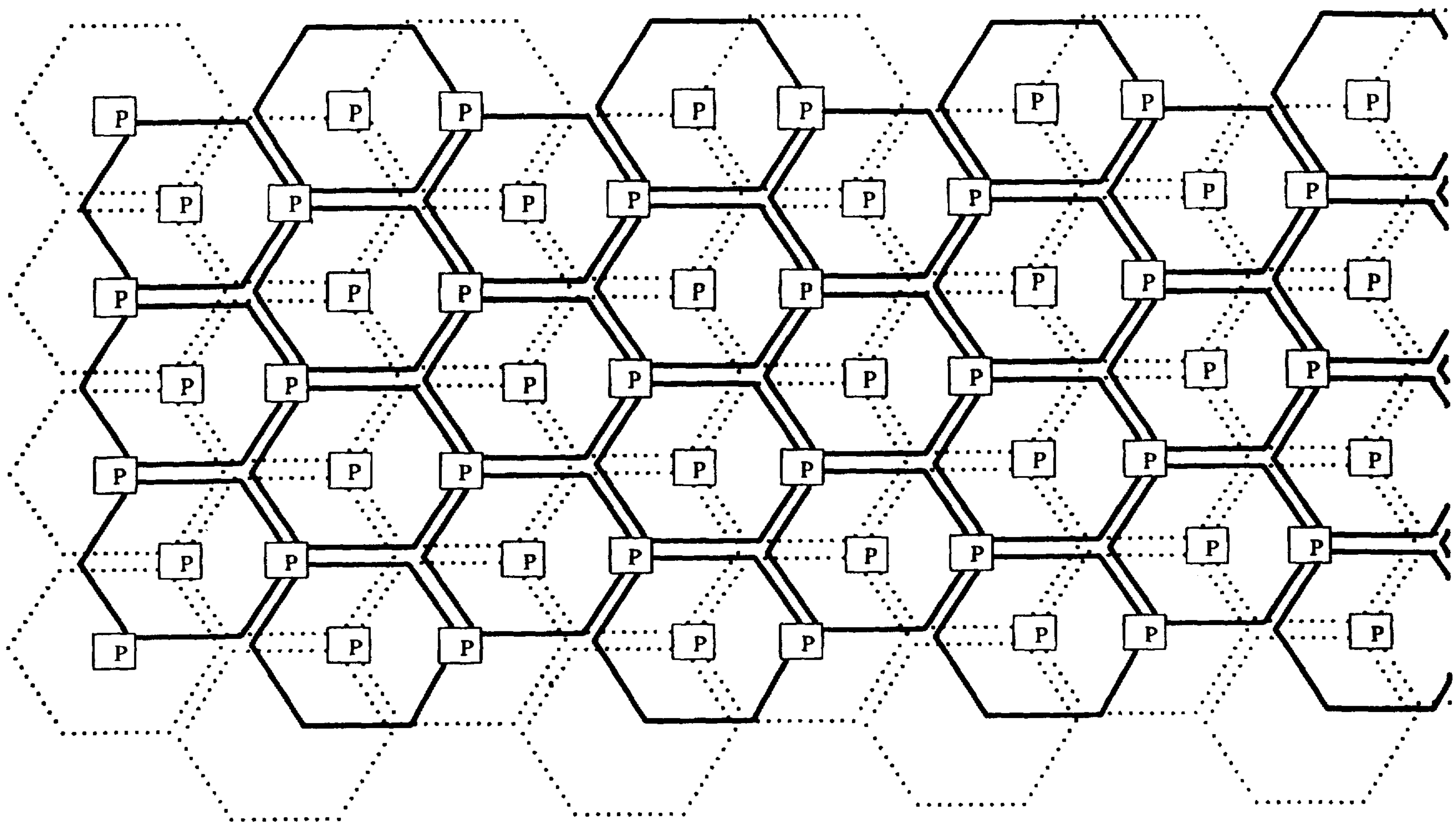

FIG.21

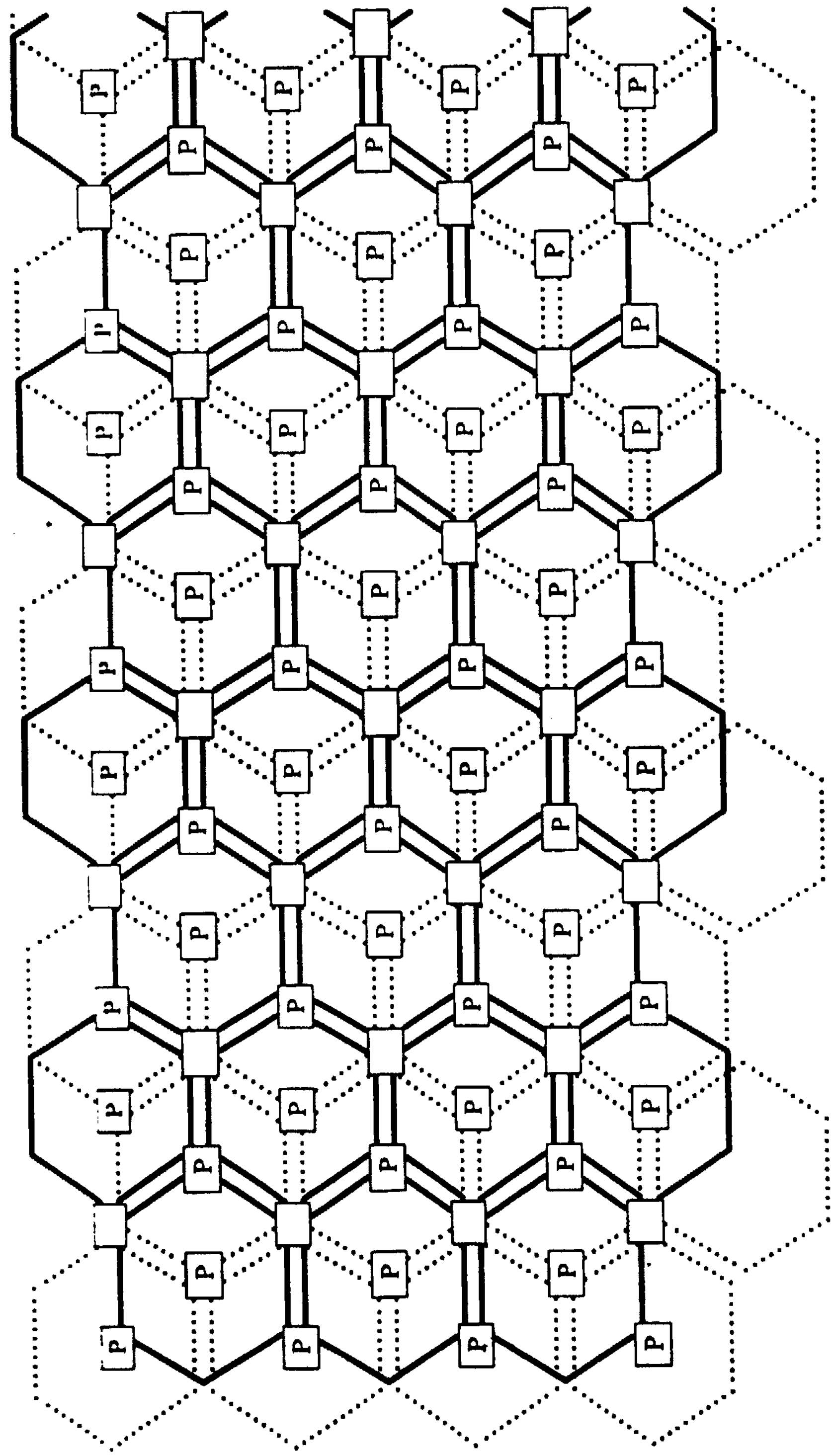

FIG.22

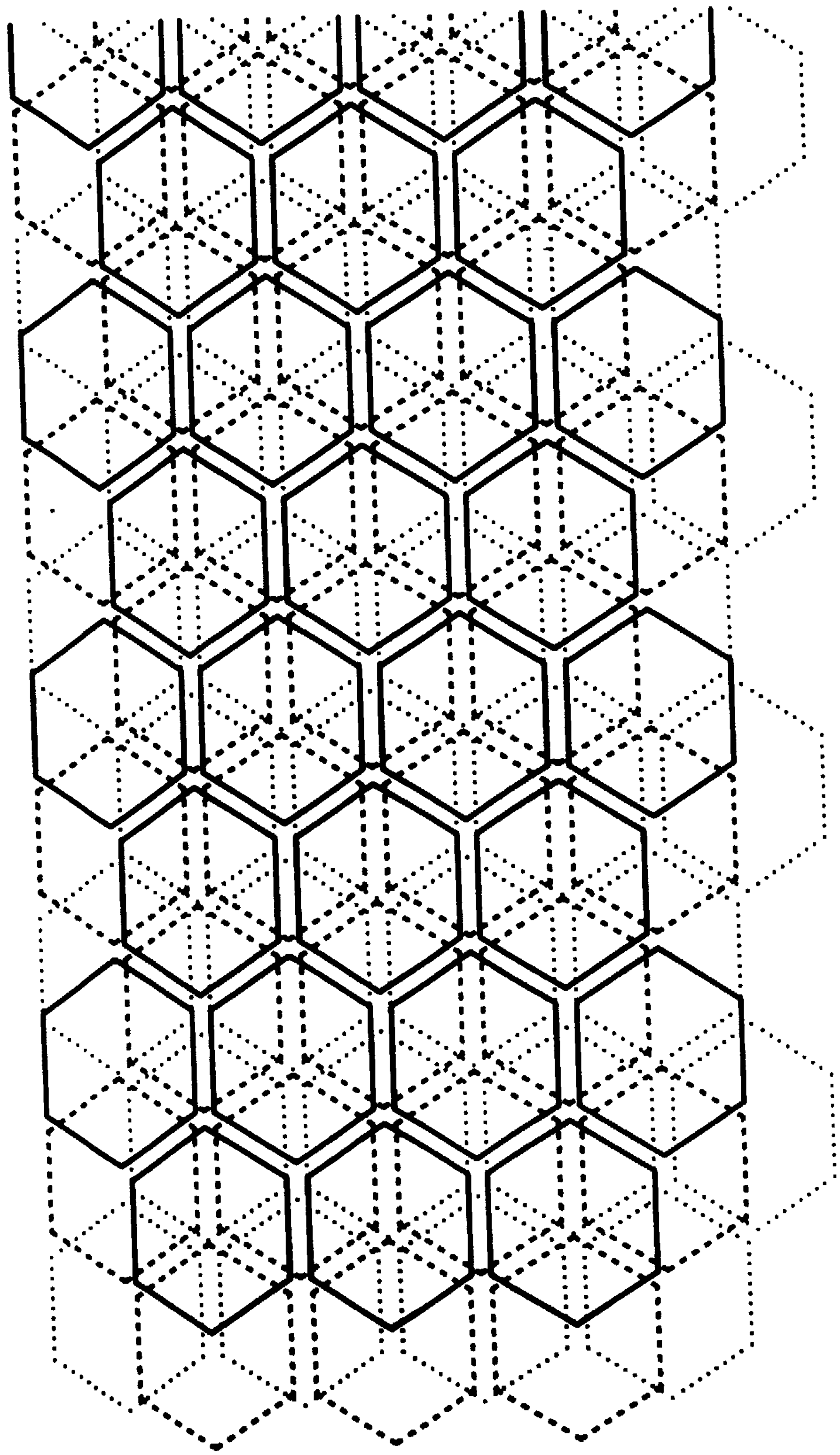

FIG.23

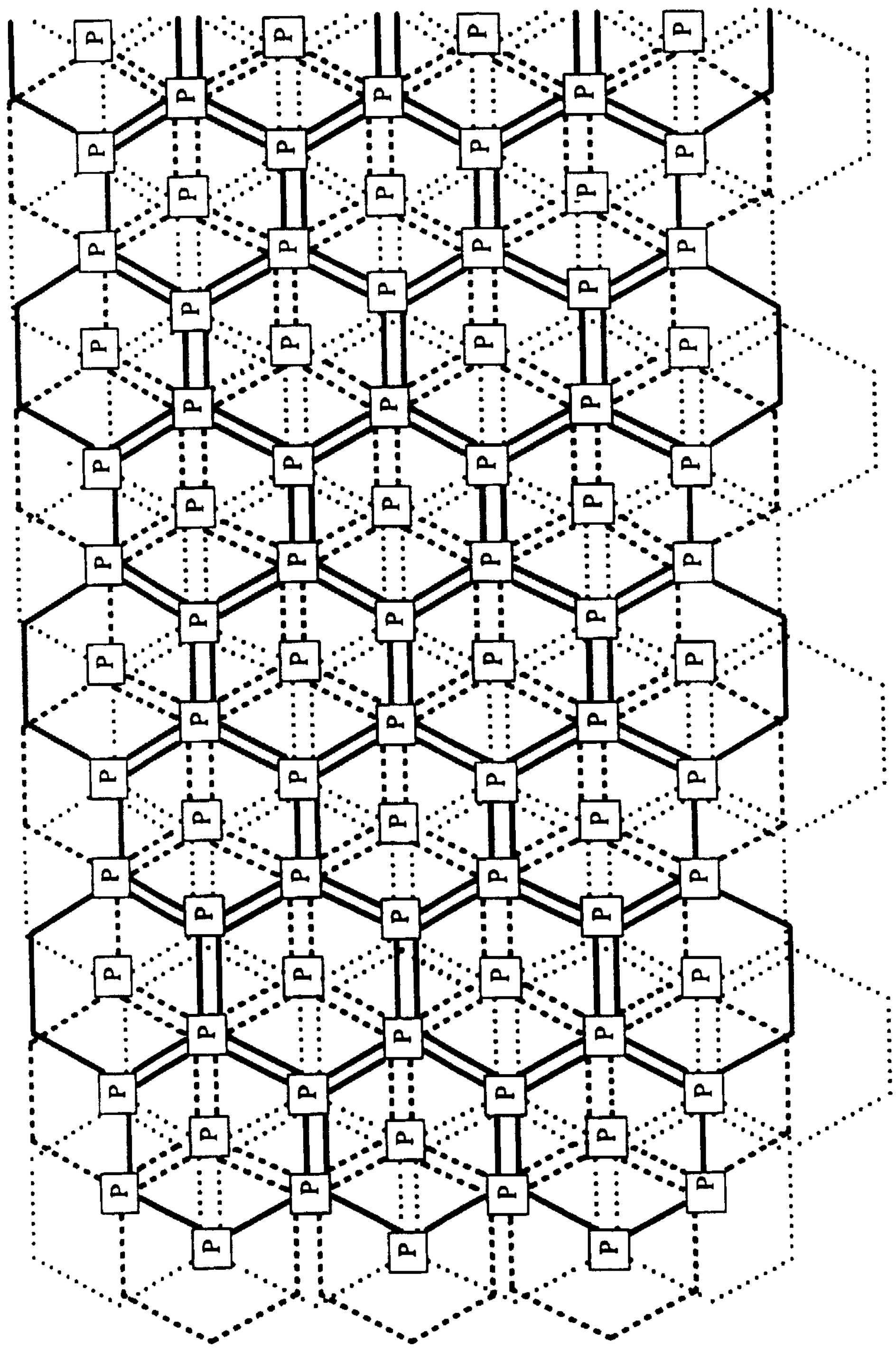

FIG.24

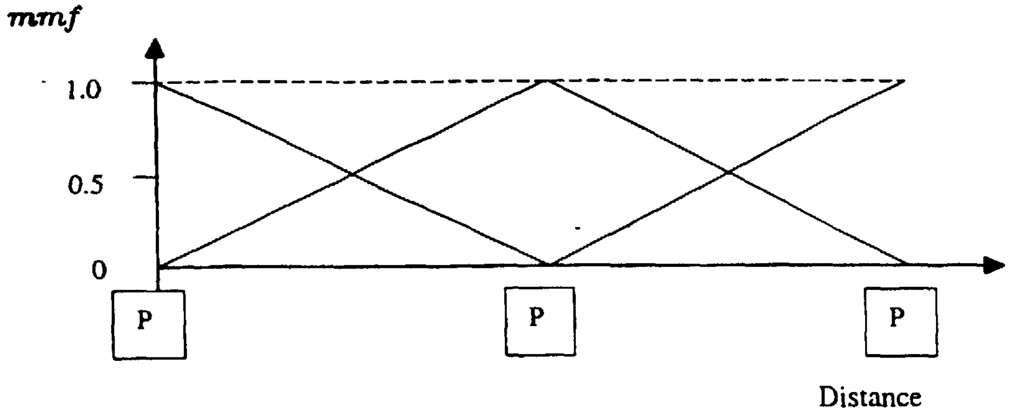

FIG.25

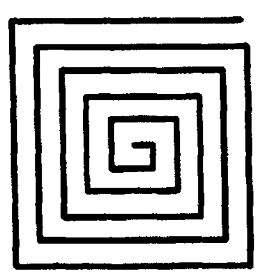

FIG.26

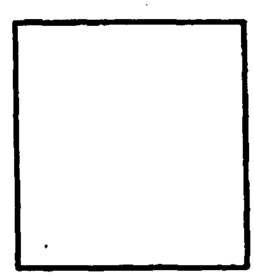

FIG.27

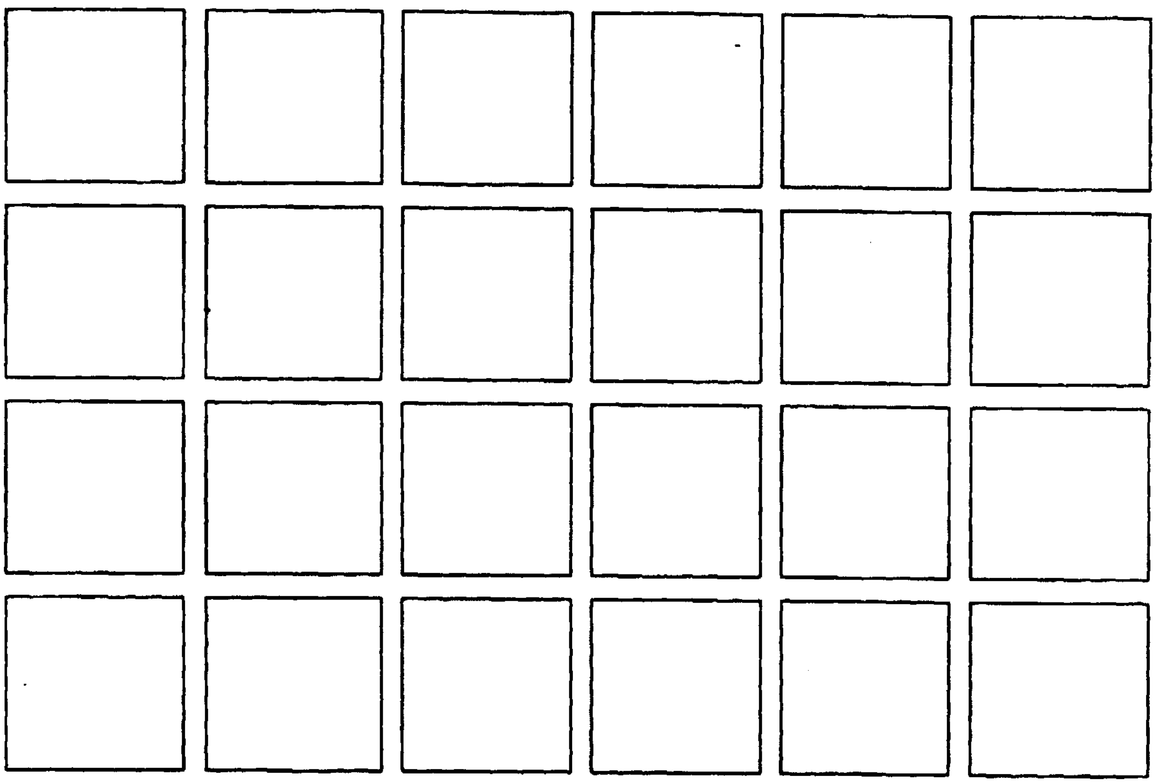

FIG.28

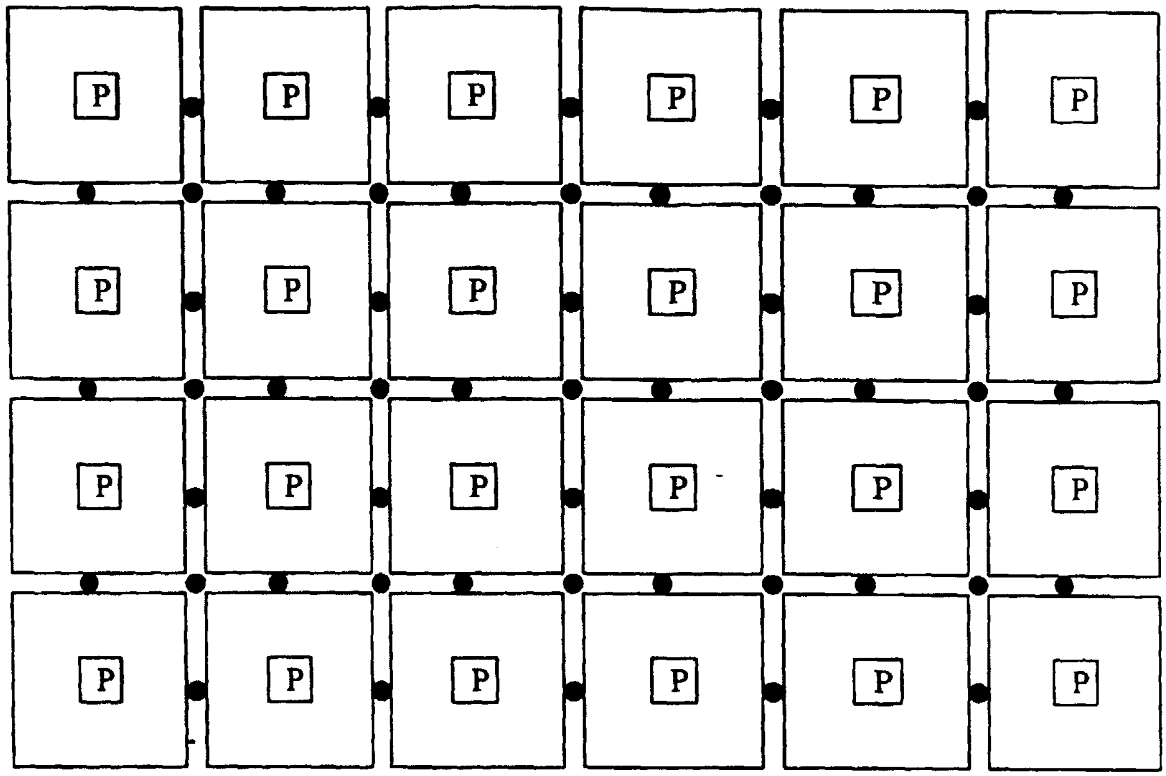

FIG.29

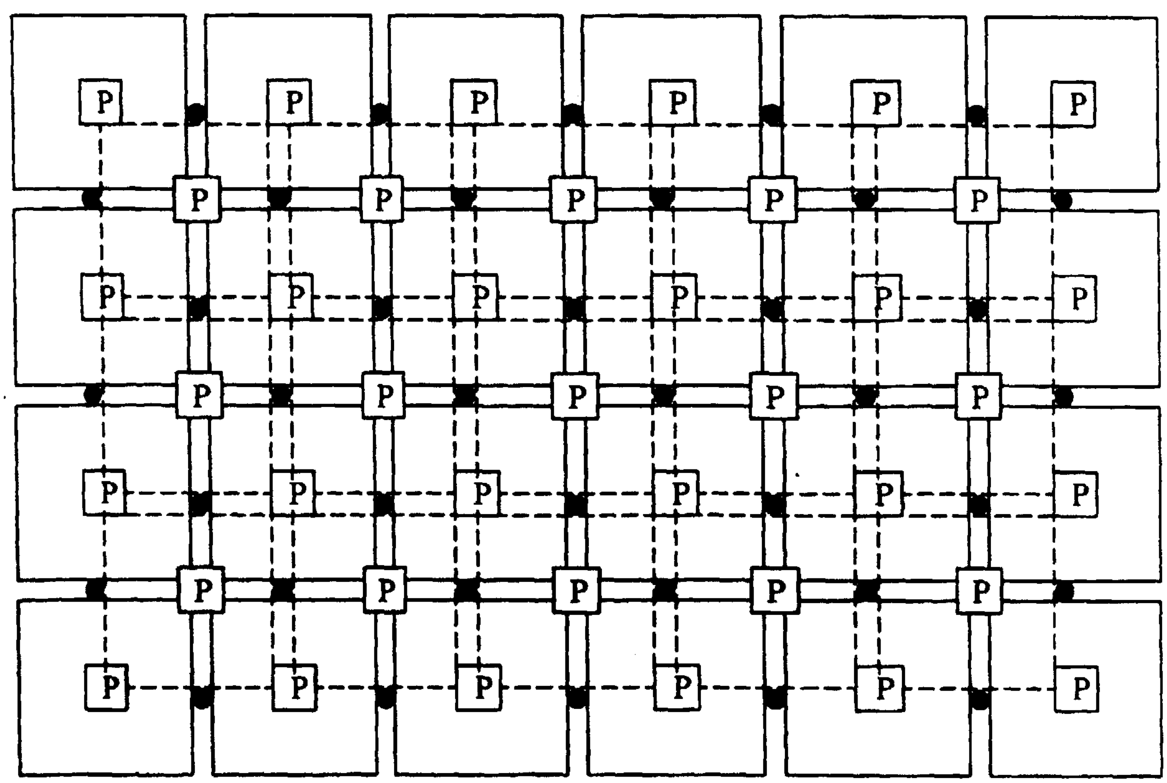

FIG.30

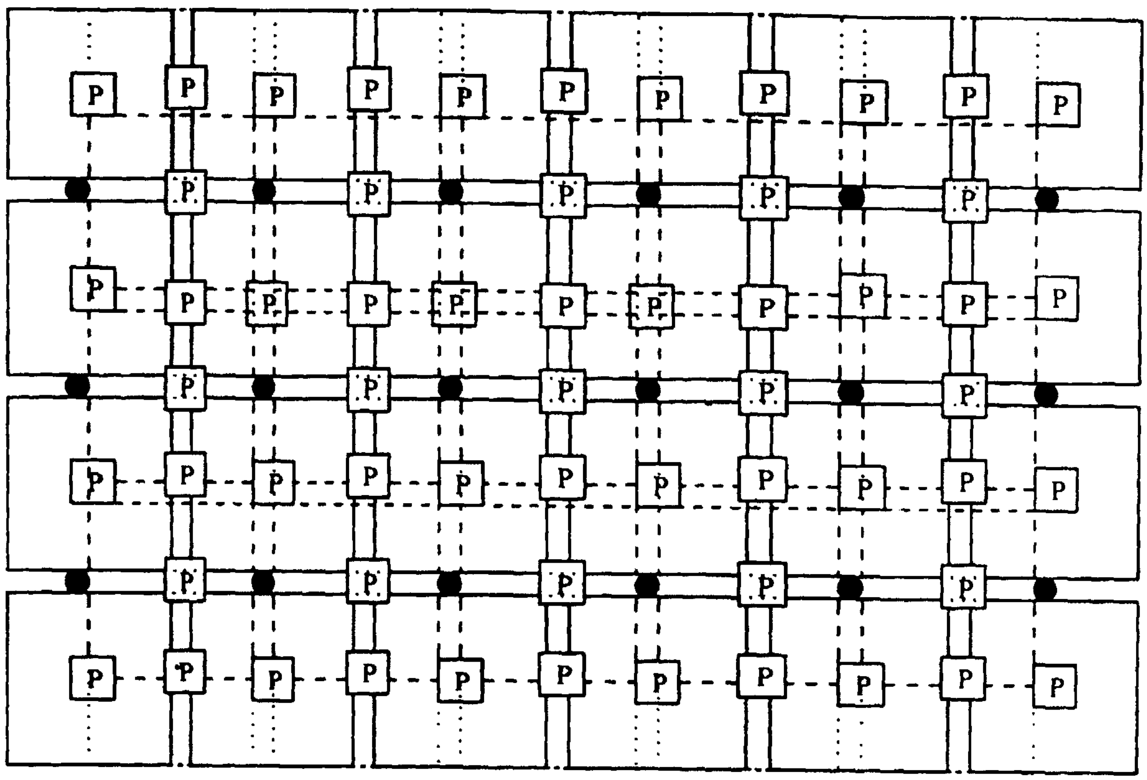

FIG.31

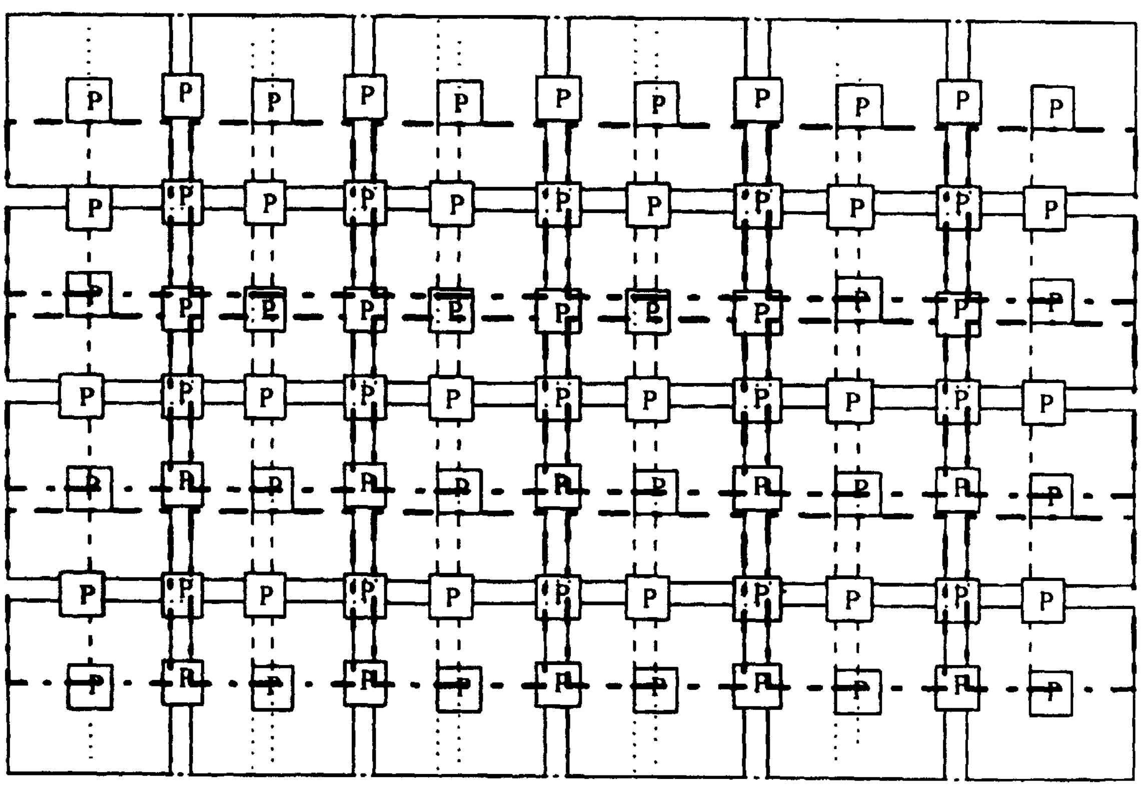

FIG.32

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APPARATUS FOR ENERGY TRANSFER BY INDUCTION

FIELD OF THE INVENTION

This invention relates to an apparatus for the transfer of energy by electrical induction, and in particular to an induction heating apparatus, for example an induction cooking apparatus.

BACKGROUND OF THE INVENTION

Induction heating equipment such as an induction cooker usually uses a single spiral winding as the primary transformer winding. When excited by a high-frequency ac voltage generated by a power electronic circuit, a high-frequency ac magnetic flux is created in the spiral winding. This magnetic flux points in a direction perpendicular to the plane of the spiral winding. Protected by a layer of electrical insulator, the ac excited spiral winding provides an induction surface. When a secondary element such as a metallic cooking pot is placed on top of the electrically insulated surface of the spiral primary winding, current will be induced in the secondary metallic material by induction due to the ac magnetic flux created in the spiral primary winding. The conduction loss due to the induced current in the secondary element causes heating of the secondary element.

PRIOR ART

Similar induction heating equipment using a single spiral winding for drying printing materials has been proposed by Elgee et al in US patent 6,349,671. Ulrich et al proposed an induction heating system using a flexible coil in US patent 6,346,690 and US patent 6,229,126. The flexible coil is wound in a concentric manner and is fed by a power supply. There are limitations in using a single spiral winding as the inductive element. First, the magnetic field distribution is not uniform. The magnetic flux (ϕ) is proportional to the product of the current (i) in and the number of turns (N) of the winding. For a spiral winding, the number of turns is highest in the centre of the spiral winding and lowest in the edge of the spiral winding. This means that the magnitude of the magnetic field is highest in the centre and decreases from the centre. Fig.1(a) shows a typical single spiral winding. If excited with an ac power source at high frequency (say over 10kHz), an ac magnetic flux is generated. Fig.1(b) shows the measured magnitude plot of the magnetic field distribution of the single spiral winding in Fig.1(a). It can be seen that the magnitude of the magnetic field is highest in the centre of the spiral winding and this magnitude decreases with increasing distance from the centre.

If the secondary element is not placed in the central area of the inductive surface, the magnetic flux it experiences is small and therefore the current induced in it is also small. Consequently, the heating effect is far from satisfactory. This non-uniform magnetic field distribution and its associated non-uniform heating problem limit the performance of many commercial induction heating systems.

SUMMARY OF THE INVENTION

According to the present invention there is provided apparatus for the transfer of energy by electrical induction comprising a primary induction unit formed with a planar surface for receiving at least one secondary element to which energy is to be transferred, wherein said primary induction unit comprises an array of primary transformer windings so as to provide a substantially uniform magnetic flux distribution over said planar surface.

In a preferred embodiment, the primary windings are connected in groups to define a plurality of energy transfer areas whereby energy may be transferred to a plurality of secondary elements provided simultaneously on said planar surface. The primary windings may be connected in series and/or in parallel. The windings may be circular, rectangular, square or polygonal spirals.

Preferably multiple layers of such arrays may be provided, with the array in one layer being offset relative to the array in another layer such that regions of one layer that generate maximum flux coincide with regions of another later that generate minimum flux.

The present invention is particularly well suited in a preferred embodiment for realisation as an induction heating apparatus, and the primary induction unit may be an induction cooker, with the secondary element(s) being one or more metallic cooking utensils.

Viewed from another broad aspect the present invention provides apparatus for the transfer of energy by electrical induction comprising a primary induction unit formed with a planar surface for receiving at least one secondary element to which energy is to be transferred, wherein said at least one secondary element may be located anywhere on said planar surface and energy is only transferred from said primary induction unit in the area of said surface where the said at least secondary element is located.

Viewed from another broad aspect the present invention provides apparatus for generating substantially uniform magnetic flux over a surface, comprising at least two layers each being formed with an array of primary electrical windings, wherein the array of a first said layer is offset relative to the array of a second said layer such that regions of said first layer that generate maximum magnetic flux coincide with regions of said second layer that generate minimum magnetic flux.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention will now be described by way of example and with reference to the accompanying drawings, in which:-

Figs.1(a) and (b) show (a) a conventional single spiral winding, and (b) the resulting magnetic field distribution,

Fig.2 illustrates a typical inductive cooking apparatus,

Fig.3 illustrates an array of primary windings according to an embodiment of the invention,

Fig.4 shows the structure of a primary inductive unit according to an embodiment of the invention in (a) exploded view and (b) perspective view,

Figs.5(a) and (b) show an array of primary windings according to an embodiment of the invention, and (b) the magnetic field generated thereby,

Figs.6(a) and (b) show (a) an embodiment of the invention having groups of windings, and (b) an equivalent circuit,

Fig.7 shows a first layer of a 4x5 winding array for use in a multi-layer embodiment,

Fig.8 shows a second layer of a 3x4 winding array for use in conjunction with the layer of Fig.7 in a multi-layer embodiment,

Fig.9 shows the layers of Fig.7 and Fig.8 in the two-layer structure,

Fig.10 is simplified version of Fig.7,

Fig.11 is a simplified version of Fig.8,

Fig.12 is a simplified version of Fig.9,

Fig.13 is a plot showing the smoothing effect of the two-layer structure,

Fig.14 shows a hexagonal spiral winding,

Fig.15 is a simplified form of Fig.14,

Fig.16 shows a single-layer of hexagonal spiral windings,

Fig.17 shows two adjacent hexagonal spiral windings,

Fig.18 shows the mmf distribution of the adjacent windings of Fig.17,

Fig.19 shows three adjacent hexagonal spiral windings and the peaks and minima of the flux distribution,

Fig.20 shows two overlapped layers of hexagonal spiral windings,

Fig.21 shows the location of the peak flux in the structure of Fig.20,

Fig.22 corresponds to Fig.21 but also shows the location of the flux minima,

Fig.23 shows an embodiment of the invention formed with three overlapped layers,

Fig.24 corresponds to Fig.23 but shows the location of the flux peaks,

Fig.25 is a plot showing the uniformity of the flux distribution along a line,

Fig.26 shows a square spiral winding,

Fig.27 is a simplified version of Fig.26,

Fig.28 shows a first layer of square spiral windings,

Fig.29 corresponds to Fig.28 but shows the location of the flux maxima and minima,

Fig.30 shows two overlapped layers of square spiral windings including the location of the flux maxima and minima,

Fig.31 shows three overlapped layers of square spiral windings including the location of the flux maxima and minima, and

Fig.32 shows four overlapped layers of square spiral windings including the location of the flux maxima and minima.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

This invention relates to a new induction system for the transfer of energy, and in particular to induction heaters and induction cookers. As shown in Fig.2, the induction system consists of two units, namely (1) a power delivering inductive circuit that contains the primary circuit of an array of planar isolation transformer windings and (2) a secondary element that couples energy from the primary inductive circuit. In the context of an induction cooker, the secondary element may be a metallic pan 1, while the first element is the induction heating surface 2 on which the pan is to be placed.

In a preferred embodiment of the invention, a plurality of primary transformer windings are located in the primary inductive circuit, and preferably in the form of an array as shown in Fig.3 The windings may be circular, rectangular, hexagonal, square or any polygonal shape. The windings may be connected in series, or in parallel or in a combination of both. By providing an array of windings a more uniform magnetic flux distribution can be provided, and the possibility of a localized charging zone mechanism is enabled as will be discussed further below. It will be understood that only the area of the induction surface covered by the secondary element will be activated, while most of the non-covered area radiates virtually no energy.

As shown in Fig.4, the primary transformer circuit unit transmits electrical energy at high frequency through a flat inductive surface that contains an array of primary transformer windings. The inductive surface can be of circular, square, rectangular, hexagonal or any polygonal shape depending on the requirement of the applications. In Fig.4, a rectangular inductive surface is used as an example. The primary transformer windings can be of circular, square, rectangular, hexagonal or any polygonal shape. If utilization of space is needed, these windings can be wound into hexagonal shape. These windings can be wound in a concentric or spiral manner. For low power applications, they can be printed on a circuit board.

An important aspect of the present invention the primary transformer windings are arranged in the form of an array. These windings can be connected in series or in parallel or a combination of both. The advantage of using an array of primary transformer windings is to generate a more uniform magnetic field than a single winding. This uniform magnetic field distribution is illustrated in a practical example of a 4x4 winding array as shown in Fig.5(a). When connected in series (of the same polarity) and excited with a high-frequency ac voltage, this 4x4 winding array generates a magnetic field that is almost uniform as shown in Fig.5(b). Each winding generates its own magnetic field. When arranged in an array manner, the overall magnetic field is much more uniform than the field generated by a single winding. This can be clearly seen by comparing the magnitude plots of Fig.1(b) and Fig.5(b).

Besides using the series connection, the primary transformer windings can be connected in parallel or a combination of series and parallel. Fig.6(a) shows an example with an array of primary windings forming four groups in four zones A,B,C and D. This means that the proposed induction has more than one primary transformer winding connected in parallel to the power inverter of the primary induction circuit. If the secondary element is placed on Zones A and B, the equivalent circuit of the proposed system is shown in Fig.6(b). As the secondary element is close to the primary windings in Zones A and B (but not C and D), only the primary windings A and B sense the secondary load. Primary windings C and D have virtually no load and therefore their secondary circuits are essentially open circuits. This means that only the overlapped area between the induction surface and the secondary element has energy transfer. This localized activation principle is an important feature of this invention.

In a preferred embodiment, the present invention features a primary induction circuit that has (1) a switched mode power electronic circuit, (2) a transformer that consists of a primary winding or a group of primary windings connected in series or in parallel or a combination of both, (3) an optional EMI shield (which may be a combination of a ferrite sheet and a copper sheet) and (4) a flat interface surface on which the secondary element or elements can be placed and can couple energy from the primary induction circuit. The schematic of the primary induction system is shown in Figs4(a) and (b).

The induction system can be powered by AC or DC power sources. If the power supply is the AC mains, the switched mode power electronic circuit should perform a low-frequency (50 or 60Hz) AC to DC power conversion and then DC to high-frequency (typically in the range from 20kHz to 10MHz) AC power conversion. This high-frequency AC voltage will feed the primary winding or windings of the primary induction circuit. If the power supply is a DC voltage source (e.g. a battery), the switched mode power supply should perform a DC to high-frequency AC power conversion. The high-frequency voltage is fed to the primary winding or windings of the transformer.

The induction system is able to induce current in the secondary element or elements. For induction heating systems, the heat distribution should be as uniform as possible. In addition, only the overlapped area of the primary induction surface and the secondary element provides energy transfer. In order to achieve these functions, the AC magnetic flux experienced by the secondary element should be as even as possible. A standard spiral winding as shown in Fig.1(a) is not suitable to meet this requirement because its flux distribution is not uniform as shown in Fig.1(b) when the winding is excited by an AC power source. The reason for such non-uniform magnetic flux distribution is that the number of turns in the central region of the single spiral winding is largest. As the magnetic flux or magnetomotive force (mmf) is proportional to the product of the number of turn and the current in the winding, the magnitude of the magnetic flux or mmf is highest in the centre of the winding.

An improved method proposed in this invention is to ensure that the magnetic flux distribution experienced by secondary element is as uniform as possible. This method can be realized by using a "distributed" primary transformer winding array structure as shown in Fig.3. This planar winding array consists of many spiral windings. These spiral windings can have hexagonal, circular, square or rectangular patterns. These transformer windings can be connected in series, in parallel or a combination of both to the high-frequency AC voltage generated in the power supply in the primary charger circuit.

Fig.5(a) shows a practical example with the transformer winding array connected in series so that all the fluxes created in the windings point to the same direction. Fig.5(b) shows the measured flux distribution of one planar transformer when the windings in the transformer array are connected in series. This measurement confirms the uniform magnetic flux distribution of the array structure. Comparison of Fig.1(b) and Fig.5(b) confirms the improvement of the uniform magnetic field distribution using the transformer array structure. In addition, the transformer array structure enables the possibility of creating a multiple primary transformer windings structure which allows for a new localized energy transfer mechanism as explained below.

The primary transformer windings can also have a combination of series and parallel connections if desired. Such an arrangement allows the induction surface to provide various induction regions to cater for different sizes of the secondary elements. Fig.6(a) illustrates this localized induction zone principle. Assume that the transformer array is divided into 4 zones (A, B, C and D). The transformer windings within each zone are connected in series to form one primary winding group with distributed magnetic flux feature. There will be four primary windings in the equivalent circuit as shown in Fig.6(b). If the secondary element is placed on Zones A and B, the equivalent electrical circuit is shown in Fig.6(b). Only the parallel primary transformer winding groups for Zones A and B are loaded because they can sense a nearby secondary element that can couple energy from the primary windings. Therefore, they will generate magnetic flux in Zones A and B. Primary transformer windings C and D are not loaded because they have no secondary element close to them. Their equivalent secondary circuits are simply an open-circuit (Fig.6(b)). As a result, power transfer between the primary induction circuit and the secondary element takes place basically through the coupled regions (areas) of the induction interface surface covered by the secondary element. The non-covered area of the induction surface will transfer very limited energy. This special design avoids unnecessary or excessive electromagnetic interference.

In the present invention, at least in preferred forms, there is proposed a new induction system that overcomes the non-uniform magnetic flux problem arising from using a single spiral winding. More importantly, the proposed induction system, based on a winding array structure, can generate a near-uniform magnetic field over the needed areas on the inductive surface and thus provide a near-uniform heating effect in the secondary element. Based on a multiple primary transformer winding concepts, the invention also operates on a new localized energized zone principle so that energy is coupled to the secondary element primarily through the overlapped area of the inductive and the secondary element. That is to say, energy is only transferred when a secondary winding or element is placed over one or more of the primary windings, and energy is only transferred from those primary windings that couple to the secondary winding or element, mainly the primary winding or windings directly beneath the secondary winding or element, and possibly also (though to a lesser extent) any nearby primary windings that are close enough to couple to the secondary winding or element to a significant extent.

In the embodiments described above a single layer of transformer arrays is provided. However, in order to generate a more uniform magnetic field distribution, multi-layer transformer arrays can be used. The following embodiments describe how multiple layers of transformer arrays may be used that can provide a very uniform magnetic field distribution on the energy transfer surface.

Fig.7 shows a 4x5 primary planar transformer winding array which consists of square-spiral winding patterns. This can be fabricated on one layer of a printed circuit board structure for low power applications, though for high power applications it should be an actual winding. It should be noted that, for an individual winding pattern in the array, the magnitude of the magnetic flux is highest in the center of the spiral winding. The magnitude of the magnetic flux is smallest in the small gap between adjacent winding patterns.

A second layer with a 3x4 transformer winding array is shown in Fig.8. The individual winding patterns in both layers are identical. As shown in Fig.9, by having the two layers of arrays arranged in such a manner that the center (region of maximum magnetic flux magnitude) of a winding pattern on one layer is placed on the gap (region of minimum magnetic flux magnitude) between adjacent winding patterns on the other layer, the variation of the magnetic field magnitude can be minimized and the magnetic flux magnitude can therefore be made as even as possible over the overlapped surface. The essence of the multi-layer transformer arrays is to have a displacement between the individual winding patterns of the two layers so that the regions of the maximum magnetic field magnitude of one layer is "evened out" by the regions of the minimum magnetic field magnitude.

In order to examine the 'uniform magnetic field magnitude' feature of the proposed overlapped multi-layer transformer arrays, this 'magnitude smoothing' concept is illustrated in simplified diagrams in Fig.10 to 12. Fig.10 is a simplified version of Fig.7. Each solid square in Fig.10 represents a square-spiral winding pattern in the first layer (Fig.7). Fig.11 is a simplified version of the Fig.8. Each dotted square represents a square-spiral winding pattern in the second layer (Fig.8). The simplified version of the multi-layer array structure is shown in Fig.12. From Fig.12, it can be seen that the overlapped array structure (with correct displacement between the two layers) divides each square-spiral winding pattern into four smaller sub-regions. The important feature is that the four sub-regions are identical in terms of winding structure. Despite that fact that the distribution of the magnetic field magnitude on the surface of each individual square-spiral winding is not uniform, the distribution of the resultant magnitude field magnitude on the surface of each sub-region is more or less identical because of the overlapped multi-layer winding structure. The concept of the generating uniform magnetic field magnitude over the energy transfer surface is illustrated in Fig.13.

In this example, a multi-layer transformer winding array structure that can provide a uniform magnetic field magnitude distribution is described. This example is based on square-spiral winding patterns. In principle, winding patterns of other shapes can also be applied as long as the resultant magnetic field magnitude distribution is as uniform as possible.

The use of two layers of transformer arrays can reduce the variation in the magnetic flux over the energy transfer surface. However, there may still be some variations and the use of a three or four layer structure may provide a still more uniform flux distribution as described in the following embodiments.

The following embodiment is a structure comprising three layers of planar winding arrays. This winding structure can generate magnetomotive force (*mmf*) of substantially even magnitude over the energy transfer surface. Each winding array consists of a plurality spiral windings each of which are of an hexagonal shape. A spiral winding arranged in a hexagonal shape is shown in Fig.14. For simplicity, it will be represented as a hexagon as shown in Fig.15. A plurality of hexagonal spiral windings can be arranged as an array as shown in Fig.16. These windings can be connected in parallel, in series or a combination of both to the electronic driving circuit. If a current passes through each spiral winding pattern, a magnetomotive force (*mmf*), which is equal to the product of the number of turns (*N*) and current (*I*) (i.e. *NI*), is generated. Fig.17 shows two spiral winding patterns adjacent to each other and the per-unit *mmf* plot over the distance (dotted line) can be linearized as shown in Fig.18. It can be seen that the *mmf* distribution over the distance is not uniform. The maximum *mmf* occurs in the center of the hexagonal pattern and the minimum *mmf* occurs in the edge of the pattern.

Fig.19 shows three adjacent windings. The maximum *mmf* region is labeled by a symbol 'P' (which stands for Peak *mmf*). The minimum *mmf* region at the junction of 2 patterns is labeled as 'V' (which stands for Valley of the *mmf* distribution). In order to generate a uniform *mmf* distribution over the planar energy transfer surface, two more layers of winding arrays should be added. This principle is explained firstly by adding a second layer of winding array to the first one as shown in Fig.20. The second layer is placed on the first one in such a way that the peak *mmf* positions (P) of the patterns of one layer are placed directly over the valley positions (V) of the patterns in the other layer. Fig.21 highlights the peak positions of the patterns that are directly over the valley positions of the other layer for the two overlapped layers in Fig.20.

It can be observed from Fig.21, however, that the use of two layers of winding arrays, while presenting an improvement over a single layer, does not offer the optimal solution for generating uniform *mmf* over the inductive energy transfer surface. For each hexagonal pattern in the two-layer structure, the peak positions occupy the central position and three (out of six) vertices of each hexagon. The remaining three vertices are valley positions (V) that need to be filled by a third layer of winding arrays. These valley positions are shown in Fig.22 as empty squares.

Careful examination of Fig.22 shows that there are six peak positions (P) surrounding each valley position. Therefore, a third layer of a hexagonal winding array can be used to fill up all these remaining valley positions. By placing the central positions (peak *mmf* positions) of the hexagonal winding patterns of the third layer of the winding array over the remaining valley positions of the two-layer structure, an optimal three-layer structure is formed as shown in Fig.23. Fig.24 highlights the peak *mmf* positions of the three-layer structure. It can be observed that all central positions and vertices of all hexagonal patterns have peak *mmf*.

In order to confirm that the *mmf* over the surface has uniform *mmf* distribution, any distance between any two adjacent peak *mmf* positions can be considered as illustrated in Fig.25. If the winding patterns are excited in the same manner and polarity so that the *mmf* generated by each layer of the winding array are always in the same direction at any moment, the resultant *mmf* is simply the sum of the *mmf* generated by each layer. Fig.25 shows that the resultant *mmf* over the distance between any two adjacent peak positions in Fig.25 is equal to 1.0 per unit. This confirms that the proposed three-layer winding array structure can be used to generate highly uniform *mmf* over the inductive energy transfer surface. When used as a contactless, inductive energy transfer surface, this uniform *mmf* distribution feature ensures that, for a given airgap, a secondary coupling winding can always couple the same amount of magnetic flux regardless of the position of the secondary element.

In another embodiment, the three-layer winding array structure can be constructed as a four-layer, with one of the four layers accommodating the return paths of the spiral windings to the electronic driving circuit.

A further embodiment is based again on square spiral winding patterns. In this embodiment four layers of square-spiral winding arrays are used to generate highly uniform *mmf* over the surface. As in the hexagonal embodiment described above, for convenience of illustration each square-spiral winding pattern (Fig.26) is simplified as a square symbol (Fig.27) in the following description.

Fig.28 shows the first layer of the square-spiral winding array. The *mmf* in the central region of each square pattern is highest. These regions are highlighted as 'Peak' or (P) in Fig.29The regions of the minimum *mmf* (i.e. the valleys) occurs along the edges of the square patterns. These regions are highlighted with dots (•) in Fig.29.

In order to reduce the *mmf* ripples on the surface, the peak (P) positions of a second layer of square-spiral winding array can placed over some of the valley positions (•) as shown in Fig.30. When a third layer of square-spiral winding array is added to the structure in Fig.30, the resultant layout is shown in Fig.31. It can now be observed that one more layer of the square-spiral windings is needed to fill up all the valleys with peaks as shown in Fig.32.

CLAIMS

1. Apparatus for the transfer of energy by electrical induction comprising a primary induction unit formed with a planar surface for receiving at least one secondary element to which energy is to be transferred, wherein said primary induction unit comprises an array of primary transformer windings so as to provide a substantially uniform magnetic flux distribution over said planar surface.

2. Apparatus as claimed in claim 1 comprising at least two planar arrays of primary windings wherein one said planar array overlies the other said array.

3. Apparatus as claimed in claim 2 wherein a first said array is offset relative to a second said array such that regions of said first array that generate maximum magnetic flux coincide with regions of said second array that generate minimum magnetic flux.

4. Apparatus as claimed in claim 3 comprising three layers of hexagonal windings.

5. Apparatus as claimed in claim 3 comprising four layers of square windings.

6. Apparatus as claimed in claim 1 wherein said primary windings are connected in groups to define a plurality of energy transfer areas whereby energy may be transferred to a plurality of secondary elements provided simultaneously on said planar surface.

7. Apparatus as claimed in claim 1 wherein said primary windings are connected in series and/or in parallel.

8. Apparatus as claimed in claim 1 wherein said windings are hexagonal, circular, rectangular, square or polygonal spirals.

9. Apparatus as claimed in claim 1 wherein said apparatus is an induction heating apparatus.

10. Apparatus as claimed in claim 9 wherein said primary induction unit is an induction cooker, and wherein said secondary element(s) is/are a metallic cooking utensil.

11. Apparatus for the transfer of energy by electrical induction comprising a primary induction unit formed with a planar surface for receiving at least one secondary element to which energy is to be transferred, wherein said at least one secondary element may be located anywhere on said planar surface and energy is only transferred from said primary induction unit in the area of said surface where the said at least secondary element is located.

12. Apparatus for generating substantially uniform magnetic flux over a surface, comprising at least two layers each being formed with an array of primary electrical windings, wherein the array of a first said layer is offset relative to the array of a second said layer such that regions of said first layer that generate maximum magnetic flux coincide with regions of said second layer that generate minimum magnetic flux.

13. Apparatus as claimed in claim 12 comprising three layers of hexagonal windings.

14. Apparatus as claimed in claim 13 comprising four layers of square windings.

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Application No: GB 0226892.8
Claims searched: 1-10,12

Examiner: John Cockitt
Date of search: 12 February 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1at least	GB2350766A	JAEGER - coil array
X	1at least	EP0706304A1	WUEST - coil array powered for uniform heating
X	1at least	FR02573947A	CEM - offset grid
X	1at least	EP0599519A1	METCAL - array of coils - field cancellation
X	1at least	EP0921711A1	THERMA - array of coils

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Field of Search:

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H05B

The following online and other databases have been used in the preparation of this search report:

ONLINE: EPODOC, WPI, JAPIO