Title of the Invention: Magnetic field coupling antenna module and magnetic field coupling antenna device
Abstract Title: Magnetic field coupling antenna module and magnetic field coupling device

A magnetic field coupling antenna module or device comprises a magnetic core 112 embedded in an insulating layer 110. Upper surface conductors 116 are formed on an upper surface of the insulating layer 110 and lower surface conductors 118 are formed on a lower surface of the insulating layer 110 whilst side surface conductors 120 and via holes 122, which electrically connect the upper surface conductors 116 with the lower surface conductors 118 to constitute a coil having a coil axis parallel to the upper surface of the insulating layer 110 whereby a magnetic field coupling antenna is formed. The module or device may include a capacitor 680 which is also embedded in the insulating layer 110. The magnetic core 112 may have various formations involving a plurality of magnetic core members. Plural coils may be formed and linked to surface electrodes via a capacitor. The antenna module or device is easily manufactured and provides a highly sensitive antenna with good impact resistant characteristics.
MAGNETIC FIELD COUPLING ANTENNA MODULE AND MAGNETIC FIELD COUPLING ANTENNA DEVICE

Technical Field

The present invention relates to a magnetic field coupling antenna module, a magnetic field coupling antenna device which are used in an RFID (Radio Frequency Identification) system which communicates with external devices using electromagnetic field signals, and manufacturing methods thereof.

Background Art

In recent years, in a RFID system which has been widely used, a mobile electronic device such as a cellular phone and a reader/writer each have information communication antennas and exchange data with each other. As an antenna of the RFID, a magnetic field coupling antenna having a configuration in which a coil is wound around a magnetic core is generally known. Especially for a magnetic field coupling antenna included in a mobile electronic device, there is a demand for a high impact-resistant characteristic so that an antenna characteristic is not changed even by drop impact, for example. As a cause of the change of the antenna characteristic due to externally-applied impact, damage of a magnetic core due to the impact can be taken as an example.
As a technique of preventing the antenna characteristic from being changed due to damage of a magnetic core, in Japanese Unexamined Patent Application Publication No. 2005-184094 (Patent Document 1), a magnetic field coupling antenna (hereinafter the magnetic field coupling antenna is simply referred to as an "antenna") having the following shape has been proposed. Figs. 15A and 15B show a configuration of the antenna disclosed in Patent Document 1. Fig. 15A is a top plan view, and Fig. 15B is a sectional view taken along a line A-A of Fig. 15.

In an antenna 1000 shown in Figs. 15A and 15B, a magnetic core member 1012 is sandwiched between two insulating layers 1010a and 1010b. The antenna 1000 has upper surface conductors 1016 disposed on an upper surface of the upper insulating layer 1010a, lower surface conductors 1018 disposed on a lower surface of the lower insulating layer 1010b, and connection conductors 1020 which connect the upper surface conductors 1016 to the lower surface conductors 1018. The upper surface conductors 1016, the lower surface conductors 1018, and the connection conductors 1020 are included in a coil 1014 which is wound around the insulating layers 1010a and 1010b. Note that the connection conductors 1020 are through holes extending from the upper surface of the insulating layer 1010a to the lower surface of the insulating layer 1010b. The upper surface
conductors 1016 are electrically connected to the lower surface conductors 1018 through plating layers formed on inner walls of the through holes.

With the configuration in which the magnetic core member 1012 is sandwiched between the upper and lower insulating layers 1010a and 1010b, impact applied to the entire antenna 1000 is not directly transmitted to the magnetic core member 1012. Therefore, the magnetic core member 1012 is not easily damaged and the antenna characteristic is not easily changed due to the damage of the magnetic core member 1012.

Summary of Invention

In the antenna 1000, the magnetic core member 1012 is formed by applying plating material including magnetic material on the lower insulating layer 1010b. Thereafter, the upper insulating layer 1010a is bonded to the insulating layer 1010b so as to cover the magnetic core member 1012.

An RFID antenna performs communication when an external magnetic flux passes through an axis of a coil to thereby induce voltage. In this case, since the magnetic core, that is, the magnetic core member of Patent Document 1 guides the magnetic flux so that the magnetic flux passes through the coil axis, the magnetic core member should have a predetermined thickness or more in order to realize high antenna sensitivity. However, there arises a problem in
that, in the method for forming the magnetic core member 1012 by applying plating material, very thin magnetic core member can be formed. Furthermore, there arises a problem in that if the thickness is intended to be increased, the plating material should be repeatedly applied.

Patent Document 1 also discloses a method using a plate-like magnetic core member 1012 in the antenna 1000. Specifically, insulating members are bonded to the plate-like magnetic core member 1012 so as to cover the magnetic core member 1012, and a cross-section shape the same as that of an assembly of the insulating layers 1010a and 1010b is formed using the plate-like magnetic core member 1012 and the insulating members. Then, the magnetic core member 1012 is sandwiched between the insulating layers 1010a and 1010b. According to this method, a process of bonding the insulating members should be additionally performed, and therefore, it is difficult to manufacture the antenna 1000 with ease.

Accordingly, preferred embodiments of the present invention provide a magnetic field coupling antenna which is easily manufactured and which has high antenna sensitivity while an impact-resistant characteristic is maintained.

The present invention is defined in the independent claims to which reference is now directed. Preferred features are set out in the dependent claims.
According to the present invention, there is provided a magnetic field coupling antenna module comprising a magnetic field coupling antenna comprising: an insulating layer; a magnetic core embedded in the insulating layer, wherein a lower surface of the magnetic core is not covered by the insulating layer; upper surface conductors formed on an upper surface of the insulating layer; lower surface conductors formed on a lower surface of the insulating layer, wherein the lower surface of the magnetic core is adjacent the lower surface conductors; and connection conductors which electrically connect the upper surface conductors to the lower surface conductors, wherein a coil which includes the upper surface conductors, the lower surface conductors, and the connection conductors and which has a coil axis parallel to the upper surface of the insulating layer is formed; the magnetic field coupling antenna module further comprising a capacitor embedded in the insulating layer, wherein the capacitor is disposed on the lower surface conductors.

In the magnetic field coupling antenna according to the present invention, the magnetic core may be provided in a plurality. A direction in which the plurality of magnetic cores are arranged is preferably perpendicular to the coil axis of the coil.

In the magnetic field coupling antenna according to the
present invention, an area of at least one of surfaces located opposite ends of the magnetic core in a direction of the coil axis is preferably larger than an area of an arbitrary cross section which is perpendicular to the coil axis of the magnetic core.

In the magnetic field coupling antenna according to the present invention, the magnetic core may be disposed on a side surface of the insulating layer located in the direction of the coil axis.

In the magnetic field coupling antenna according to the present invention, the coil may be divided into first and second coil portions in a state in which the coil has a non-winding portion in a middle of the coil.

In the magnetic field coupling antenna according to the present invention, at least portions of the connection conductors may be formed by through holes or via holes electrically connected to the upper surface conductor and/or the lower surface conductors of the insulating layer. Furthermore, at least portions of the connection conductors may be formed by patterns which have been formed on the side surface of the magnetic core in advance, and the pattern may be electrically connected to the through holes or the via holes.

Preferably, the capacitor may be disposed between the magnetic core and the connection conductors.
The capacitor may be disposed in the non-winding portion.

In the magnetic field coupling antenna module according to the present invention, a lower portion insulating layer may be further disposed on a lower surface of the insulating layer, and a lower surface electrode layer may be disposed on a lower surface of the lower portion insulating layer.

A magnetic field coupling antenna device according to the present invention includes a magnetic field coupling antenna module and an integrated circuit embedded in the insulating layer. An upper surface electrode layer may be disposed on a portion of the upper surface of the insulating layer where the upper surface conductors are not formed.

Advantages

According to embodiments of the present invention, since the magnetic core is embedded in the insulating layer, an impact resistant characteristic is improved. Furthermore, since the magnetic core having a predetermined thickness is embedded, manufacturing of a magnetic field coupling antenna is facilitated and high antenna sensitivity is achieved.

Brief Description of Drawings

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which: Fig. 1 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to a first embodiment of the
present invention.

Fig. 2A is a perspective view illustrating a method for manufacturing the magnetic field coupling antenna according to a first embodiment of the present invention.

Fig. 2B is a perspective view illustrating the method for manufacturing the magnetic field coupling antenna according to the first embodiment of the present invention.

Fig. 2C is a cross sectional view illustrating the method for manufacturing the magnetic field coupling antenna according to the first embodiment of the present invention.

Fig. 2D is a cross sectional view illustrating the method for manufacturing the magnetic field coupling antenna according to the first embodiment of the present invention.

Fig. 2E is a cross sectional view illustrating the method for manufacturing the magnetic field coupling antenna according to the first embodiment of the present invention.

Fig. 2F is a cross sectional view illustrating the method for manufacturing the magnetic field coupling antenna according to the first embodiment of the present invention.

Fig. 3 is a perspective view illustrating a modification example of the magnetic field coupling antenna according to the first embodiment of the present invention.

Fig. 4 is a diagram illustrating a configuration of a magnetic field coupling antenna according to a second embodiment of the present invention.
Fig. 5A is a perspective view illustrating a configuration of a magnetic field coupling antenna according to a third embodiment of the present invention.

Fig. 5B is a cross sectional view illustrating the configuration of the magnetic field coupling antenna according to the third embodiment of the present invention.

Fig. 6 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to a fourth embodiment of the present invention.

Fig. 7 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to a fifth embodiment of the present invention.

Fig. 8 is a schematic view illustrating a flow of a magnetic flux of the magnetic field coupling antenna according to the fifth embodiment of the present invention.

Fig. 9 is a perspective view illustrating a configuration of a magnetic field coupling antenna module according to a sixth embodiment of the present invention.

Fig. 10 is a perspective view illustrating a modification example of the magnetic field coupling antenna according to the sixth embodiment of the present invention.

Fig. 11 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to a seventh embodiment of the present invention.
Fig. 12A is a perspective view illustrating a configuration of a magnetic field coupling antenna according to an eighth embodiment of the present invention.

Fig. 12B is a cross sectional view illustrating the configuration of the magnetic field coupling antenna according to the eighth embodiment of the present invention.

Fig. 13A is a perspective view illustrating a modification example of the magnetic field coupling antenna according to the eighth embodiment of the present invention.

Fig. 13B is a cross sectional view illustrating the modification example of the magnetic field coupling antenna according to the eighth embodiment of the present invention.

Fig. 14 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to a ninth embodiment of the present invention.

Fig. 15A is a plan view illustrating a configuration of a conventional example.

Fig. 15B is a cross sectional view illustrating the configuration of the conventional example.

Reference Numerals

100, 200, 300, 400, 500, 600 magnetic field coupling antenna

601, 602 magnetic field coupling antenna module

703, 803, 903 magnetic field coupling antenna device

110 insulating layer
112 magnetic core
114 coil
116 upper surface conductor
118 lower surface conductor
120 side surface conductor
122 via hole

Description of Preferred Embodiments of the Invention

First Embodiment

A first embodiment of the present invention will be described with reference to Fig. 1. Fig. 1 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to the first embodiment. Hereinafter, the magnetic field coupling antenna is simply referred to as an "antenna".

An antenna 100 of the first embodiment includes an insulating layer 110 and a magnetic core 112 embedded in the insulating layer 110 in a state one surface of the magnetic core 112 is exposed from a lower surface of the insulating layer 110. The magnetic core 112 is embedded in the insulating layer 110 such that the magnetic core 112 is covered by the insulating layer 110 by pressuring the half-hardened insulating layer 110 onto the magnetic core 112. The embedded state includes the state in which part of the magnetic core 112 is exposed from the insulating layer 110 of this embodiment.
The insulating layer 110 is formed of a thermoset resin or a composite of a thermoset resin and an inorganic filler. A ferrite plate is suitably applicable to the magnetic core 112, and is formed in a rectangular parallelepiped. The magnetic core 112 is designed so as to have an optimum thickness for realizing desired antenna sensitivity. Furthermore, upper surface conductors 116 are disposed on an upper surface of the insulating layer 110, lower surface conductors 118 are disposed on a lower surface of the insulating layer 110, side surface conductors 120 are disposed on one side surface of the insulating layer 110, and via holes 122 are formed inside the insulating layer 110. The side surface conductors 120 and the via holes 122 constitute connection conductors which connect the upper surface conductors 116 to the lower surface conductors 118. Note that the via holes are formed as penetrating holes filled with material which extend from the upper surface to the lower surface of the insulating layer 110. Specifically, the upper surface conductors 116 and the lower surface conductors 118 are electrically connected to each other by the via holes simply filled with conductive paste or the via holes filled with conductive paste or non-conductive paste after plating layers are disposed on inner walls of the penetrating holes. The upper surface conductors 116, the lower surface conductors 118, and the side surface
conductors 120 and the via holes 122 which constitute the connection conductors form a coil 114 wound around the insulating layer 110 which has a coil axis in parallel to the upper surface of the insulating layer 110. Opposite ends of the coil 114 extend to another side surface of the insulating layer 110 so as to facilitate connection, and connection sections 126 are formed on the side surface.

Since the magnetic core 112 is embedded in the insulating layer 110, even when impact is applied due to dropping of the antenna 100, for example, the impact is not directly transmitted to the magnetic core 112, and therefore, the magnetic core 112 is not easily damaged. In this embodiment, although one surface of the magnetic core 112 is exposed from the lower surface of the insulating layer 110, the impact resistant characteristic is improved since the other three surfaces of the magnetic core 112 are covered with the insulating layer 110. Needless to say, when all the surfaces of the magnetic core 112 are covered with the insulating layer 110, the impact-resistant characteristic is further improved.

Furthermore, the embedding of the magnetic core 112 into the insulating layer 110 is not affected by a thickness of the magnetic core 112. That is, even when a magnetic core 110 having a large thickness is used, the magnetic core 110 can be embedded in the insulating layer 110 by a single
process of pressuring the half-hardened insulating layer 110 onto the magnetic core 110. Accordingly, by selecting a thickness of the magnetic core in accordance with desired antenna sensitivity, the antenna sensitivity can be easily improved.

Furthermore, the antenna 100 is a magnetic field coupling antenna in which voltage is induced in the coil 114 when a magnetic flux passes through the coil axis of the coil 114. The magnetic flux enters the magnetic core 112 from one of the side surfaces of the insulating layer 110 which are located in a direction of the coil axis to the magnetic core 112 and is emitted from the opposite side surface. When the flow of the magnetic flux is blocked, the magnetic flux passing through the coil axis of the coil 114 is reduced and the antenna sensitivity of the antenna 100 is deteriorated. Accordingly, it is preferable that an object which may block the flow of the magnetic flux is not disposed on both the side surfaces of the magnetic core 112 in the direction of the coil axis.

A method for manufacturing the antenna 100 will be described hereinafter with reference to Figs. 2A to 2F. Figs. 2A to 2F are perspective views illustrating a manufacturing process of the antenna 100.

Fig. 2A shows a process of forming the lower surface conductors. The lower surface conductors 118 are disposed
on a supporting plate or a substrate 130. The lower surface conductors 118 are formed by forming a plating layer on the supporting plate or the substrate 130 by electrolytic plating and performing etching on the plating layer, that is, by a known method. A case where a transferring plate formed of an SUS is used as the supporting plate will be described hereinafter.

Fig. 2B shows a process of mounting the magnetic core. The magnetic core 112 is mounted on the substrate 130 so as to overlap with the lower surface conductors 118. The magnetic core 112 is fixed on the substrate 130 by a pressure-sensitive adhesive sheet or an adhesive agent, for example.

Fig. 2C shows a process of forming the insulating layer, and shows a cross section which is perpendicular to the upper surface of the insulating layer 110. The insulating layer 110 having a copper foil 150 bonded thereto on the upper surface thereof in advance is prepared. The insulating layer 110 is formed of a thermoset resin or a composite of a thermoset resin and an inorganic filler, and is a half-hardened state (prepreg state). This insulating layer 110 is pressured on the composite obtained by the process of mounting the magnetic core from the magnetic core 112 side and heated. By this, the magnetic core 112 is embedded in the insulating layer 110. Since the lower
surface of the magnetic core 112 contacts the substrate 130, the lower surface of the magnetic core 112 is not covered with the insulating layer 110. Thereafter, the insulating layer 110 is further heated so as to be hardened.

Fig. 2D shows a process of forming the via holes, and shows a cross section which is perpendicular to the upper surface of the insulating layer 110. First, the copper foil 150 disposed on the upper surface of the insulating layer 110 is etched so that openings are formed at portions in which the via holes are to be formed. Then, laser beams are radiated through the openings from the upper surface of the insulating layer 110 so that penetrating holes are formed while the lower surface conductors 118 serve as bottom surfaces. Thereafter, a plating layer 140 is formed by nonelectrolytic plating or electrolytic plating on inner walls of the penetrating holes, and then, the penetrating holes are filled with nonconductive paste 142. The via holes 122 formed in this process are included in the connection conductors.

Fig. 2E shows a process of forming the upper surface conductors, and shows a cross section which is perpendicular to the upper surface of the insulating layer 110. A plating layer 152 is formed by the electrolytic plating on the copper foil 150 bonded on the insulating layer 110 in advance. The upper surface conductors 116 are formed by
simultaneously etching the plating layer 152 and the copper foil 150. The upper surface conductors 116 overlap with the via holes 122 and the magnetic core 112 when viewed from the upper surface of the insulating layer 110.

Fig. 2F shows a process of forming the side surface conductors. The side surface conductors 120 are formed by pattern printing on the side surface of the insulating layer 110. The side surface conductors 120 are electrically connected to the upper surface conductors 116 and the lower surface conductors 118. The side surface conductors 120 formed in this process are included in the connection conductors.

Through the foregoing processes, the upper surface conductors 116 and the lower surface conductors 118 are electrically connected to one another through the side surface conductors 120 and the via holes 122 whereby the coil 114 is formed around the insulating layer 110. Finally, the substrate 130 is separated from the lower surface conductors 118 and the insulating layer 110, and then, the antenna 100 is formed.

In this embodiment, the connection conductors include the side surface conductors 120 disposed on the side surface and the via holes 122 formed in the insulating layer 110. However, the present invention is not limited to this. Through holes may be used instead of the via holes 122.
Note that the term "through holes" are defined as penetrating holes which extend from the upper surface to the lower surface of the insulating layer 110 and which are not filled with material. The upper surface conductors 116 and the lower surface conductors 118 are electrically connected to one another by forming the plating layers on the inner walls of the penetrating holes. Furthermore, the connection conductors may be formed only by the side surface conductors or only by the via holes or the through holes.

Furthermore, in this embodiment, the coil 114 which is wound three times is formed as shown in Fig. 1. However, the present invention is not limited to this. By increasing the number of upper surface conductors 116, the lower surface conductors 118, the side surface conductors 120, and the via holes 122, the number of times the coil is wound increases with ease. By this, the coil having a high inductance value can be realized.

Furthermore, although the magnetic core 112 is formed in a rectangular parallelepiped in this embodiment, corners of the rectangular parallelepiped are preferably chamfered so as to be rounded. If the insulating layer 110 is further heated after the insulating layer 110 in which the magnetic core 112 has been embedded is hardened, moisture in the insulating layer 110 vaporizes and a volume of the moisture increases resulting in generation of stress in the
insulating layer 110. Since the stress is likely to be concentrated on the corners of the magnetic core 112 embedded in the insulating layer 110, it is possible that crack is generated with the corners as base points. Therefore, by chamfering the corners so that the corners are rounded, the stress can be dispersed and the crack is prevented from being generated.

Furthermore, it is effective that a hollow which penetrates from the upper surface to the lower surface of the magnetic core 112 is provided at the center portion of the magnetic core 112 so that the magnetic core 112 has a doughnut shape. By forming the magnetic core 112 in the doughnut shape, when the insulating layer 110 is pressured onto the magnetic core 112, the resin constituting the insulating layer 110 flows into the hollow formed at the center portion of the magnetic core 112. By this, since an area in which the magnetic core 112 contacts the insulating layer 110 increases, coupling strength between the magnetic core 112 and the insulating layer 110 is enhanced. Accordingly, the antenna 100 can be more reliably formed. Note that the hollow preferably has a size in a certain degree so that the hollow does not block the flow of the magnetic flux which passes through the inside of the magnetic core 112.
Modification

A modification example of the antenna 100 according to the first embodiment will be described hereinafter with reference to Fig. 3. Fig. 3 is a perspective view illustrating the modification example of the antenna according to the first embodiment.

In Fig. 3, a magnetic core 112 is embedded in an insulating layer 110. On one side surface of the magnetic core 112, patterns 160 are formed. Furthermore, via holes 123 are formed in the insulating layer 110 so as to extend from an upper surface of the insulating layer 110 to an upper surface of the 112. The via holes 123 and the patterns 160 are formed so as to overlap with each other when viewed from above, and are electrically connected to each other. Connection conductors include connection conductors 120a disposed on one side surface of the insulating layer 110, the via holes 123, and the patterns 160.

In the insulating layer 110, the magnetic core 112 in which the patterns 160 are formed on the side surface thereof in advance is embedded. After the magnetic core 112 is embedded in the insulating layer 110, the insulating layer 110 is hardened, and the via holes 123 are formed. Since the via holes 123 extend from the upper surface of the insulating layer 112 to the upper surface of the magnetic
core 112, the via holes 123 shown in Fig. 3 are shallower than the via holes 122 shown in Fig. 1.

In a case where bottomed holes are formed by laser beams and plating layers are disposed on inner walls of the bottomed holes, an aspect ratio which is a ratio of a diameter of each of the bottomed holes to a depth of the bottomed hole should be taken into consideration. In Fig. 1, since the via holes 120b are formed by setting the lower surface conductors 118 as bottom surfaces thereof, the diameters and the depths of the bottomed holes should be set taking aspect ratios into consideration. In general, when an aspect ratio is equal to or larger than 2, it is difficult to form plating layers extending to the bottom surfaces of the bottomed holes. Therefore, when the bottomed holes are deep, the diameters of the bottomed holes should be formed large in order to form the plating layers extending to the bottom surfaces of the bottomed holes.

As described above, since the shallow via holes 123 should be formed in this embodiment, the diameters of the bottomed holes may be formed small. Accordingly, the via holes 123 are formed in high density. Since the patterns 160 on the side surface of the magnetic core 112, upper surface conductors 116, the lower surface conductors 118, and side surface conductors 120 on one side surface of the insulating layer 110 can be formed in high density, the
number of times the coil 114 is wound can increase by increasing the number of the via holes 123.

Second Embodiment

A second embodiment of the present invention will be described with reference to Fig. 4. Fig. 4 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to the second embodiment. Components the same as those of the first embodiment are denoted by reference numerals the same as those of the first embodiment, and descriptions thereof are omitted. Hereinafter, the magnetic field coupling antenna is simply referred to as an "antenna".

In Fig. 4, an antenna 200 includes two magnetic cores 212a and 212b which are embedded in an insulating layer 110. The magnetic cores 212a and 212b are obtained by equally dividing the magnetic core of the first embodiment into two, and a total volume of the two magnetic cores 212a and 212b is the same as a volume of the magnetic core of the first embodiment. A direction in which the magnetic cores 212a and 212b are arranged is perpendicular to a direction of a coil axis of a coil 114, and a magnetic flux to pass through the coil axis of the coil 114 passes through an inside of one of the magnetic cores 212a and 212b. Therefore, a gap between the magnetic cores 212a and 212b does not block a flow of the magnetic flux which passes through the coil axis.
of the antenna 200.

By equally dividing the magnetic core used in the first embodiment into two, sizes of the magnetic cores can be reduced while antenna sensitivity is maintained. In a case where stress such as bending stress is applied to the antenna 200, the stress is transmitted to the magnetic cores 212a and 212b through the insulating layer 110. However, since the sizes of the magnetic cores 212a and 212b are small, damage such as cracking does not easily occur even when the stress is applied to the magnetic cores 212a and 212b.

By fixing the magnetic cores 212a and 212b on a supporting plate and pressuring and heating the half-hardened (prepreg) insulating layer 110, the magnetic cores 212a and 212b can be simultaneously embedded in the insulating layer 110. Accordingly, the antenna 200 having the two magnetic cores 212a and 212b embedded therein can be easily manufactured.

In this embodiment, the magnetic cores 212a and 212b are disposed such that the direction in which the magnetic cores 212a and 212b are arranged is perpendicular to the coil axis of the coil 114. However, the present invention is not limited to this embodiment, and the magnetic cores 212a and 212b may be arranged along the coil axis of the coil 114. Furthermore, three or more magnetic cores may be
embedded.

Third Embodiment

A third embodiment of the present invention will be described with reference to Figs. 5A and 5B. Fig. 5 shows a configuration of a magnetic field coupling antenna according to the third embodiment wherein Fig. 5A is a perspective view and Fig. 5B is a cross sectional view taken along a line A-A of Fig. 5A. Components the same as those of the first embodiment are denoted by reference numerals the same as those of the first embodiment, and descriptions thereof are omitted. In the following description, the magnetic field coupling antenna is simply referred to as an "antenna".

In Figs. 5A and 5B, three plate-like magnetic cores 312a, 312b, and 312c are embedded in an insulating layer 110. The three magnetic cores 312a, 312b, and 312c are arranged along a direction of a coil axis of a coil 114. Fig. 5B shows a cross section of the insulating layer 110 which is perpendicular to an upper surface of the insulating layer 110 and which is taken along the coil axis of the coil 114. In this cross section, among the magnetic cores 312a, 312b, and 312c, the two magnetic cores 312a and 312c positioned in opposite ends in the direction of the coil axis are higher than the magnetic core 312b positioned in the middle. That is, in the three magnetic cores 312a, 312b, and 312c, areas of surfaces positioned in the opposite ends in the direction
of the coil axis are larger than areas of arbitrary cross sections of the magnetic cores 312a, 312b, and 312c which are perpendicular to the coil axis. A magnetic flux enters one of the magnetic cores 312a and 312c which are positioned in the opposite ends in the direction of the coil axis from an outside of the antenna 300. Since the surfaces of the magnetic cores 312a and 312c which are positioned in the direction of the coil axis of the coil 114 have large areas, a large inlet of the magnetic flux is ensured and the magnetic flux easily enters one of the magnetic cores 312a and 312c. Furthermore, the magnetic flux is radiated from one of the magnetic cores 312a and 312c which is different from the magnetic core which accepted the magnetic flux. Similarly, since the areas of the surfaces positioned in the direction of the coil are large, a large outlet of the magnetic flux is ensured, and the magnetic flux is radiated more easily. With this configuration in which the magnetic flux is easily accepted and radiated, an amount of the magnetic flux which passes the coil axis of the coil 114 increases, and sensitivity of the antenna 300 is improved.

The three magnetic cores 312a, 312b, and 312c are fixed on a supporting plate and the half-hardened (prepreg) insulating layer 110 is pressured whereby the magnetic cores 312a, 312b, and 312c are simultaneously embedded in the insulating layer 110. Since this manufacturing method is
employed, the magnetic cores are not required to be formed in special shapes, and the configuration in which the magnetic flux is easily accepted and radiated can be employed.

Note that the magnetic cores having large areas are arranged in the opposite ends in the direction of the coil axis in this embodiment. However, the present invention is not limited to this embodiment. In a case where such a magnetic core is disposed on one of the opposite ends, a certain effect can be attained. Furthermore, also in a case where a single magnetic core is formed such that areas of surfaces thereof positioned opposite ends in a direction of a coil axis are larger than areas of arbitrary cross sections thereof which are perpendicular to the coil axis of the magnetic core, a magnetic flux is easily accepted and radiated, and accordingly, antenna sensitivity is improved. However, in this case, the magnetic core should be formed in a special shape.

Fourth Embodiment

A fourth embodiment of the present invention will be described with reference to Fig. 6. Fig. 6 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to the fourth embodiment. Components the same as those of the first embodiment are denoted by reference numerals the same as those of the first
embodiment, and descriptions thereof are omitted. In the following description, the magnetic field coupling antenna is simply referred to as an "antenna".

In Fig. 6, a magnetic core 412b is embedded in an insulating layer 110. Furthermore, other magnetic cores 412a and 412c are arranged on side surfaces of the insulating layer 110 positioned in a direction of a coil axis of a coil 114. The magnetic cores 412a and 412c are pressure-bonded to the half-hardened insulating layer 110 and the insulating layer 110 are hardened in the state in which the magnetic cores 412a and 412c are pressure-bonded thereto whereby the magnetic cores 412a and 412c can be arranged on the side surfaces of the insulating layer 110. The magnetic cores 412a and 412c are arranged so as to cover the entire side surfaces of the insulating layer 110.

Since the magnetic cores 412a and 412c are arranged in end portions in the direction of the coil axis of the coil 114 so as to cover the entire side surfaces of the insulating layer 110, the antenna 400 allows a magnetic flux to advance from the entire side surfaces positioned in the direction of the coil axis of the coil 114. Similarly, the magnetic flux can be radiated from the entire side surfaces. Accordingly, an amount of the magnetic flux which passes through the coil axis of the coil 114 becomes larger than that of the third embodiment, and consequently, antenna
sensitivity is improved. The magnetic cores 412a and 412c may be damaged since they are not covered with the insulating layer 110. However, since the magnetic core 412b positioned in the middle is covered with the insulating layer, even when the magnetic cores 412a and 412c are damaged, antenna sensitivity of a certain level can be realized.

In this embodiment, the magnetic cores 412a and 412c are pressure-bonded on the insulating layer 110 so as to be arranged on the side surfaces of the insulating layer 110. However, the magnetic cores 412a and 412c may be bonded on the side surfaces of the insulating layer 110 which has been hardened by adhesive agent.

Fifth Embodiment

A fifth embodiment of the present invention will be described with reference to Figs. 7 and 8. Fig. 7 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to the fifth embodiment. Fig. 8 is a schematic view illustrating paths of magnetic fluxes according to the fifth embodiment. Components the same as those of the first embodiment are denoted by reference numerals the same as those of the first embodiment, and descriptions thereof are omitted. In the following description, the magnetic field coupling antenna is simply referred to as an "antenna".
In Fig. 7, two magnetic cores 512a and 512b are embedded in an insulating layer 110. A coil 514 is wound in a state in which the coil 514 is divided into a first coil portion 515a and a second coil portion 515b. A gap between the first and second coil portions 515a and 515b corresponds to a non-winding portion 570 in which the coil is not wound. The first coil portion 515a is wound around the magnetic core 512a, and the second coil portion 515b is wound around the magnetic core 512b.

Furthermore, in the coil 514 including the first and second coil portions 515a and 515b, winding directions of the first and second coil portions 515a and 515b and a method for connecting the first and second coil portions 515a and 515b are set so that voltage is prevented from being induced by magnetic fluxes which pass coil axes of the first and second coil portions 515a and 515b in the same direction. More specifically, in Fig. 7, the number of winding of the first coil portion 515a and the number of winding of the second coil portion 515b are the same as each other but the winding directions are opposite to each other when viewed from the same direction. Furthermore, when viewed from the same direction, an end terminal of the first coil portion 515a and a starting terminal of the second coil portion 515b are connected to each other. When the first and second coil portions 515a and 515b are formed as
described above, and when the magnetic fluxes of the same
direction pass through the coil axes of the first and second
coil portions 515a and 515b, voltages in opposite directions
are induced in the first and second coil portions 515a and
515b. However, since the first and second coil portions
515a and 515b are connected to each other, the voltages in
the opposite directions are cancelled, and voltage is not
induced in the coil 514.

Henceforth, operation of an antenna 500 will be
described with reference to Fig. 8. Fig. 8 is a cross
sectional view taken along a line B-B of Fig. 7
schematically illustrating the paths of the magnetic fluxes.
As shown in Fig. 8, a magnetic flux $\phi$ which advances from a
direction of an upper surface of the antenna 500 enters the
non-winding portion 570 provided between the magnetic cores
512a and 512b. Thereafter, the magnetic flux is divided in
two directions and divided magnetic fluxes are guided to the
respective magnetic cores 512a and 512b embedded in the
insulating layer 110. In this way, the magnetic fluxes in
the opposite directions pass through the respective first
and second coil portions 515a and 515b. As described above,
since the winding directions of the first and second coil
portions 515a and 515b are different from each other,
voltages induced in the first and second coil portions 515a
and 515b are the same as each other due to the magnetic
fluxes in the opposite directions. Accordingly, a voltage obtained by adding the voltages induced in the first to second coil portions 515a and 515b is generated in the coil 514.

In a mobile electronic device which is required to be thin, the upper surface of the antenna 500 and a main surface of the mobile electronic device are arranged in parallel to each other. In general, the mobile electronic device is used in a state in which the main surface thereof faces a direction in which a magnetic flux approaches. That is, the upper surface of the antenna 500 faces the direction in which the magnetic flux approaches. Since the antenna 500 according to the fifth embodiment has a configuration in which the antenna 500 catches the magnetic flux on the upper surface thereof, in such a usage, the antenna 500 catches the magnetic flux more efficiently. Therefore, the antenna 500 contributes a thin mobile electronic device having high antenna sensitivity.

Sixth Embodiment

A sixth embodiment of the present invention will be described with reference to Fig. 9. Fig. 9 is a perspective view illustrating a configuration of a magnetic field coupling antenna module according to the sixth embodiment. Components the same as those of the first embodiment are denoted by reference numerals the same as those of the first
embodiment, and descriptions thereof are omitted. In the following description, the magnetic field coupling antenna module is simply referred to as an "antenna module".

In Fig. 9, an antenna module 601 is configured such that a magnetic core 112 and a capacitor 680 are embedded in an insulating layer 110. The capacitor 680 is located between one side surface of the insulating layer 110 and via holes 122 when viewed from an outside of a coil 114, that is, an upper surface of the insulating layer 110. The capacitor 680 and the coil 114 constitute a resonant circuit. When a resonant frequency of the resonant circuit matches a frequency of a magnetic flux caught by an antenna 600, considerably large voltage is induced.

In this embodiment, the capacitor 680 and the coil 114 which constitute the resonant circuit are integrally included in the antenna module 601. Accordingly, the resonant frequency is not changed after the antenna module 600 is manufactured, and high antenna sensitivity can be reliably realized.

The capacitor 680 and the magnetic core 112 are embedded in a half-hardened (prepreg) resin in a single process. Accordingly, the capacitor 680 can be easily embedded without an unnecessary process.

Furthermore, the capacitor 680 is embedded in the insulating layer 110 as an element. Accordingly, since the
capacitor having a different characteristic is embedded, shapes of upper surface conductors 116, lower surface conductors 118, side surface conductors 120, and the via holes 122 and positions on which they are disposed are not required to be changed, and a characteristic of the antenna module 601 can be easily changed. Moreover, by selecting a capacitor having a large capacity such as a laminated capacitor as the capacitor 680, the characteristic of the antenna module 601 can be considerably changed.

Modification Example

Fig. 10 shows an example of a modification of this embodiment. In Fig. 10, a capacitor 680 is located between a magnetic core 112 and via holes 122 when viewed from an upper surface of an insulating layer 110. Also in this modification example, the capacitor 680 and the magnetic core 112 are embedded in the insulating layer 110 in a single process, manufacturing is facilitated.

In this modification example, the capacitor 680 is surrounded by upper surface conductors 116, lower surface conductors 118, and the via holes 122. The upper surface conductors 116, the lower surface conductors 118, and the via holes 122 not only constitute a coil 114 but also function as a shield for the capacitor 680 so that the capacitor 680 is prevented from being affected by an external electromagnetic field. Accordingly, in an antenna
module 602, a resonant frequency of a resonant circuit including the coil 114 and the capacitor 680 is prevented from being changed, and more stable antenna sensitivity of the antenna module 602 can be attained.

Note that although the capacitor 680 is embedded in the insulating layer 110 in this embodiment, an electronic component to be embedded may be a component other than the capacitor. Furthermore, a plurality of capacitors 680 may be embedded in the insulating layer 110.

Seventh Embodiment

A seventh embodiment of the present invention will be described with reference to Fig. 11. Fig. 11 is a perspective view illustrating a configuration of a magnetic field coupling antenna according to the seventh embodiment. Components the same as those of the first embodiment are denoted by reference numerals the same as those of the first embodiment, and descriptions thereof are omitted. In the following description, the magnetic field coupling antenna device is simply referred to as an "antenna device".

In Fig. 11, an antenna device 703 is configured such that a magnetic core 112, a capacitor 780, and an integrated circuit element 782 are embedded in an insulating layer 110. The integrated circuit element 782 incorporates an RFID processing circuit.

Since the integrated circuit element 782 is also
embedded in the insulating layer 110, all elements required for an antenna 700 which includes the magnetic core 112 and a coil 114 and which functions as an RFID antenna are integrated. Accordingly, integrated implementation can be attained in a mobile electronic device.

Furthermore, the magnetic core 112, the coil 114, and the integrated circuit element 782 can be simultaneously embedded in the insulating layer 110 in a single process. Accordingly, the antenna device 703 is manufactured with ease.

Eighth Embodiment

An eighth embodiment of the present invention will be described with reference to Figs. 12A and 12B. Figs. 12A and 12B are diagrams illustrating a configuration of a magnetic field coupling antenna device according to the eighth embodiment. Fig. 12A is a perspective view and Fig. 12B is a cross sectional view taken along a line C-C of Fig. 12A. Components the same as those of the first embodiment are denoted by reference numerals the same as those of the first embodiment, and descriptions thereof are omitted. In the following description, the magnetic field coupling antenna device is simply referred to as an "antenna device".

In Figs. 12A and 12B, an antenna device 803 is configured such that a magnetic core 112, a capacitor 980, and an integrated circuit element 882 are embedded in an
insulating layer 110. The integrated circuit element 882 incorporates an RFID processing circuit. A lower portion insulating layer 811 is further disposed on a lower surface of the insulating layer 110, and a lower surface electrode layer 890 is disposed on a lower surface of the lower portion insulating layer 811.

A lower surface of the antenna device 803 is implemented on a master substrate of a mobile electronic device. In this embodiment, the lower surface electrode layer 890 is disposed on a lower surface of the antenna device 803. Therefore, an electromagnetic field of a circuit formed on the master substrate is shielded by the lower surface electrode layer 890, and therefore, the antenna device 803 is not affected by the circuit formed on the master substrate. Accordingly, an inductance value of a coil 114 included in the antenna device 803 and a resonant frequency of a resonant circuit including the capacitor 880 and the coil 114 are prevented from being changed.

Modification Example

An example of a modification of this embodiment will be described with reference to Figs. 13A and 13B. Figs. 13A and 13B are diagrams illustrating the modification example of the eighth embodiment. Fig. 13A is a perspective view, and Fig. 13B is a sectional view taken along a line D-D of Fig. 13A.
In Figs. 12A and 12B, an upper surface electrode layer 892 disposed on a portion of an upper surface of an insulating layer 110 in which upper surface conductors 116 are not disposed is added to the antenna device 800 shown in Figs. 12A and 12B. The upper surface electrode layer 892 is connected to a lower surface electrode layer 890 through via holes 894. Not only a lower surface but also an upper surface of the antenna device 800 are shielded so as not to be affected by an external electromagnetic field, and a stable characteristic of the antenna device 800 is attained. Note that the upper surface electrode layer 892 may be connected to an electrode serving as ground instead of the lower surface electrode layer 890.

In this embodiment, the lower portion insulating layer 811 and the lower surface electrode layer 890 are disposed on the lower surface of the antenna device 803 configured such that the magnetic core 112, the capacitor 880, and the integrated circuit element 882 are embedded in the insulating layer 110. However, the lower portion insulating layer 811 and the lower surface electrode layer 890 may be formed on a lower surface of an antenna module configured such that only a magnetic core and a capacitor is embedded in the insulating layer 110. Also in this case, the antenna module is not affected by an electromagnetic field of a circuit formed on a master substrate. Accordingly, an
inductance value of a coil and a resonant frequency of a resonant circuit including the capacitor and the coil are prevented from being changed.

Ninth Embodiment

A ninth embodiment of the present invention will be described with reference to Fig. 14. Fig. 14 is a perspective view illustrating a configuration of a magnetic field coupling antenna device according to the ninth embodiment. Components the same as those of the first embodiment are denoted by reference numerals the same as those of the first embodiment, and descriptions thereof are omitted. In the following description, the magnetic field coupling antenna device is simply referred to as an "antenna device".

In Fig. 14, an antenna device 903 is configured such that two magnetic cores 912a and 912b, a capacitor 980, and an integrated circuit element 982 are embedded in an insulating layer 110. The integrated circuit element 982 incorporates an RFID processing circuit.

A coil 914 is wound in a state in which the coil 914 is divided into first and second coil portions 915a and 915b. The first and second coil portions 915a and 915b have respective coil axes in parallel to an upper surface of the insulating layer 110. A gap between the first and second coil portions 915a and 915b corresponds to a non-winding
portion 970 in which the coil is not formed. The first coil portion 915a is wound around the magnetic core 912a, and the second coil portion 915b is wound around the magnetic core 912b. The first and second coil portions 915a and 915b are connected to each other so that voltage is not induced due to magnetic fluxes in the same direction which pass through the coil axes of the first and second coil portions 915a and 915b.

The capacitor 980 and the integrated circuit element 982 are disposed in the non-winding portion 970, that is, between the two magnetic cores 912a and 912b. By overlapping a region in which the non-winding portion 970 which catches the magnetic flux on the upper surface of the insulating layer 110 so that the coil 914 functions is formed and a region in which the capacitor 980 and the integrated circuit element 982 are disposed with each other, miniaturization of the entire antenna device 903 is realized. Note that, in this embodiment, although the capacitor 980 and the integrated circuit element 982 are disposed in the non-winding portion 970, the capacitor 980 and the integrated circuit element 982 do not block the magnetic flux.

In this embodiment, the two magnetic cores 912a and 912b are embedded in the insulating layer 110. However, a single magnetic core may be embedded.
Furthermore, in this embodiment, in the antenna device configured such that the magnetic cores 912a and 912b, the capacitor 980, and the integrated circuit element 982 are embedded in the insulating layer 110, the non-winding portion 970 is formed between the first and second coil portions 915a and 915b. However, an antenna module configured such that only magnetic cores and a capacitor are embedded in the non-winding portion 970 on the insulating layer 110 may be employed. Also in this case, by overlapping a region in which the non-winding portion is formed and a region in which the capacitor is arranged with each other, miniaturization of the antenna module is realized.

Embodiments of the present invention may be defined by any of the following numbered clauses:

1. A magnetic field coupling antenna comprising:
   an insulating layer;
   a magnetic core embedded in the insulating layer;
   upper surface conductors formed on an upper surface of the insulating layer;
   lower surface conductors formed on a lower surface of the insulating layer; and
   connection conductors which electrically connect the upper surface conductors to the lower surface conductors,
   wherein a coil which includes the upper surface
conductors, the lower surface conductors, and the connection conductors and which has a coil axis parallel to the upper surface of the insulating layer is formed.

2. The magnetic field coupling antenna according to clause 1, wherein the magnetic core is provided in a plurality.

3. The magnetic field coupling antenna according to clause 2, wherein a direction in which the plurality of magnetic cores are arranged is perpendicular to the coil axis of the coil.

4. The magnetic field coupling antenna according to any one of clauses 1 to 3, wherein an area of at least one of surfaces located opposite ends of the magnetic core in a direction of the coil axis is larger than an area of an arbitrary cross section which is perpendicular to the coil axis of the magnetic core.

5. The magnetic field coupling antenna according to any one of clauses 1 to 4, wherein the magnetic core is disposed on a side surface of the insulating layer located in the direction of the coil axis.

6. The magnetic field coupling antenna according to any one of clauses 1 to 5, wherein the coil is divided into first and second coil portions in a state in which the coil has a non-winding portion in a middle of the coil.

7. The magnetic field coupling antenna according to any one of clauses 1 to 6, wherein at least portions of the
connection conductors are formed by through holes or via holes electrically connected to the upper surface conductor and/or the lower surface conductors of the insulating layer.

8. The magnetic field coupling antenna according to clause 7, wherein at least portions of the connection conductors are formed by patterns which have been formed on the side surface of the magnetic core in advance, and the pattern is electrically connected to the through holes or the via holes.

9. A magnetic field coupling antenna module comprising:
   the magnetic field coupling antenna set forth in any one of clauses 1 to 8; and
   an electronic component embedded in the insulating layer.

10. The magnetic field coupling antenna module according to clause 9, wherein the electronic component is a capacitor.

11. The magnetic field coupling antenna module according to clause 9 or clause 10, wherein the electronic component is disposed between the magnetic core and the connection conductors when viewed from the upper surface of the insulating layer.

12. A magnetic field coupling antenna module comprising:
   the magnetic field coupling antenna set forth in clause 6; and
   a capacitor embedded in the insulating layer,
   wherein the capacitor is disposed in the non-winding
portion.

13. The magnetic field coupling antenna module according to any one of clauses 9 to 12, wherein a lower portion insulating layer is further disposed on a lower surface of the insulating layer, and a lower surface electrode layer is disposed on a lower surface of the lower portion insulating layer.

14. A magnetic field coupling antenna device comprising:
   the magnetic field coupling antenna module set forth in any one of clauses 9 to 13; and
   an integrated circuit embedded in the insulating layer.

15. The magnetic field coupling antenna device according to clause 14, wherein an upper surface electrode layer is disposed on a portion of the upper surface of the insulating layer where the upper surface conductors are not formed.

16. A method for manufacturing a magnetic field coupling antenna comprising:
   a step of forming lower surface conductors on a supporting plate or a substrate;
   a step of mounting a magnetic core on the supporting plate or the substrate;
   a step of embedding the magnetic core in the insulating layer by pressuring the insulating layer which is half-hardened onto the supporting plate or the substrate and the magnetic core;
a step of hardening the insulating layer in which the magnetic core is embedded;

a step of forming connection conductors electrically connected to the lower surface conductors on the insulating layer; and

a step of forming upper surface conductors electrically connected to the connection conductors on a surface facing a surface which contacts the lower surface conductors on the insulating layer.

17. A method for manufacturing a magnetic field coupling antenna module, the method comprising:

a step of forming lower surface conductors on a supporting plate or a substrate;

a step of mounting a magnetic core and a capacitor on the supporting plate or the substrate;

a step of embedding the magnetic core in the insulating layer by pressuring the insulating layer which is half-hardened onto the supporting plate or the substrate, the magnetic core, and the capacitor;

a step of hardening the insulating layer in which the magnetic core and the capacitor are embedded;

a step of forming connection conductors electrically connected to the lower surface conductors on the insulating layer; and

a step of forming upper surface conductors electrically
connected to the connection conductors on a surface facing a surface which contacts the lower surface conductors on the insulating layer.

18. A method for manufacturing a magnetic field coupling antenna device, the method comprising:

- a step of forming lower surface conductors on a supporting plate or a substrate;

- a step of mounting a magnetic core, a capacitor, and an integrated circuit element on the supporting plate or the substrate;

- a step of embedding the magnetic core in the insulating layer by pressuring the insulating layer which is half-hardened onto the supporting plate or the substrate, the magnetic core, the capacitor, and the integrated circuit element;

- a step of hardening the insulating layer in which the magnetic core, the capacitor, and the integrated circuit element are embedded;

- a step of forming connection conductors electrically connected to the lower surface conductors on the insulating layer; and

- a step of forming upper surface conductors electrically connected to the connection conductors on a surface facing a surface which contacts the lower surface conductors on the insulating layer.
CLAIMS

1. A magnetic field coupling antenna module comprising a magnetic field coupling antenna comprising:
   - an insulating layer;
   - a magnetic core embedded in the insulating layer, wherein a lower surface of the magnetic core is not covered by the insulating layer;
   - upper surface conductors formed on an upper surface of the insulating layer;
   - lower surface conductors formed on a lower surface of the insulating layer, wherein the lower surface of the magnetic core is adjacent the lower surface conductors; and connection conductors which electrically connect the upper surface conductors to the lower surface conductors,
   - wherein a coil which includes the upper surface conductors, the lower surface conductors, and the connection conductors and which has a coil axis parallel to the upper surface of the insulating layer is formed; the magnetic field coupling antenna module further comprising a capacitor embedded in the insulating layer, wherein the capacitor is disposed on the lower surface conductors.

2. The magnetic field coupling antenna module according to Claim 1, wherein the magnetic core comprises a plurality of magnetic cores.

3. The magnetic field coupling antenna module according to
Claim 2, wherein a direction in which the plurality of magnetic cores are arranged is perpendicular to the coil axis of the coil.

4. The magnetic field coupling antenna module according to any one of Claims 1 to 3, wherein an area of at least one of surfaces located opposite ends of the magnetic core in a direction of the coil axis is larger than an area of an arbitrary cross section which is perpendicular to the coil axis of the magnetic core.

5. The magnetic field coupling antenna module according to any one of Claims 1 to 4, wherein the magnetic core is disposed on a side surface of the insulating layer located in the direction of the coil axis.

6. The magnetic field coupling antenna module according to any one of Claims 1 to 5, wherein the coil is divided into first and second coil portions in a state in which the coil has a non-winding portion in a middle of the coil.

7. The magnetic field coupling antenna module according to any one of Claims 1 to 6, wherein at least portions of the connection conductors are formed by through holes or via holes electrically connected to the upper surface conductor and/or the lower surface conductors of the insulating layer.

8. The magnetic field coupling antenna module according to Claim 7, wherein at least portions of the connection conductors are formed by patterns which have been formed on
the side surface of the magnetic core in advance, and the
pattern is electrically connected to the through holes or
the via holes.

9. The magnetic field coupling antenna module according to
any preceding claim, wherein the capacitor is disposed
between the magnetic core and the connection conductors when
viewed from the upper surface of the insulating layer.

10. A magnetic field coupling antenna module according to
Claim 6, wherein the capacitor is disposed in the non-
winding portion.

11. The magnetic field coupling antenna module according
to any preceding claim, wherein a lower portion insulating
layer is further disposed on a lower surface of the
insulating layer, and a lower surface electrode layer is
disposed on a lower surface of the lower portion insulating
layer.

12. A magnetic field coupling antenna device comprising:
the magnetic field coupling antenna module according to
any preceding claim; and
an integrated circuit embedded in the insulating layer.

13. The magnetic field coupling antenna device according
to Claim 12, wherein an upper surface electrode layer is
disposed on a portion of the upper surface of the insulating
layer where the upper surface conductors are not formed.

14. A magnetic field coupling antenna module
substantially as described herein with reference to the accompanying drawings 1 to 14.

15. A magnetic field coupling antenna device substantially as described herein with reference to the accompanying drawings 1 to 14.
Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

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<td>WO 98/10389 A1 (SENSORMATIC) see figs.1 - 4 and page 3, lines 18 - 25.</td>
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:

Worldwide search of patent documents classified in the following areas of the IPC:

H01Q; H05K

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

EPODOC, WPI, TXTE
### International Classification:

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