A coil antenna comprises a conductive coil 11 formed on a substrate 10 and a planar magnetic material core 1, where the interval between coil members PA extending parallel to an axis of the core 1 is smaller than coil members CA extending orthogonally to the said magnetic core axis. The coil conductor 11 may be formed in multiple layers and the coil members PA which are parallel to the said core axis may be arranged superposed on one another. The coil conductor 11 may form a rectangular shaped spiral pattern around an opening CW in a flexible substrate 10. The planar magnetic core 1 may be arranged to extend through the said opening CW in the substrate. Alternatively, the flexible substrate 10 and coil conductor pattern 11 may be folded to wrap the magnetic core 1. The compact coil antenna is intended to provide a higher degree of coupling with a target antenna even when it is located close to a conductive plate.
GB 2470299 A continuation

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[FIG. 4]

COUPLING COEFFICIENT

0 0.01 0.02 0.03

0% 10% 20% 30% 40%

L/M
COIL ANTENNA

[Technical Field]

[0001]

The present invention relates to a coil antenna used in, for example, a Radio Frequency Identification (RFID) system that communicates with an external device by using electromagnetic field signals.

[Background Art]

[0002]


Fig. 1 is a top view illustrating the structure of an antenna coil described in Patent Document 1. An antenna coil 30 illustrated in Fig. 1 includes an air core coil 32 and a planar magnetic core member 33. The air core coil 32 is configured by spirally winding conductors 31 (31a, 31b, 31e, and 31d) in a plane on a film 32a. The magnetic core member 33 is inserted into the air core coil 32 so as to be substantially parallel to a plane of the air core coil 32. The air core coil 32 has an aperture 32d and the magnetic
core member 33 is inserted into the aperture 32d. A first
terminal 31a is connected to a connecting conductor 31e via
a through hole 32b, and a second terminal 31b is connected
to the connecting conductor 31e via a through hole 32c. And,
the magnetic-material antenna is arranged on a conductive
plate 34.

[0003]

In an antenna coil disclosed in Patent Document 2, an
antenna magnetic core, which is a planar body, is arranged
so as to configure substantially the same plane as the
antenna coil while passing through an air core unit of the
antenna coil.

[0004]

In a coil antenna disclosed in Patent Document 3,
multiple coils wound on a plane are arranged in multiple
layers around the same central axis, the coils on the
respective layers are connected in series to each other, and
a member of a high permeability is provided between the
coils on the respective layers.

[0005]

[Summary of the Invention]

[0006]

In general, the characteristics as a coil antenna are
improved and its communication performance is also improved
as the number of turns of the coil is increased, the loss of

- 2 -
the coil is decreased, and the width of the magnetic core is increased, as long as an inductance necessary for the resonance at a predetermined resonant frequency is achieved. However, there are the following problems in the coil antennas disclosed in Patent Documents 1 to 3.

[0007]

The antenna coils disclosed in Patent Documents 1 and 2 has the problems in that it is necessary to decrease the width of the magnetic-material core in order to increase the number of turns of the coil, it is not possible to increase the number of turns of the coil when the width of the magnetic-material core is increased, and the loss of the coil is increased when the line width of the coil conductor is decreased to increase the number of turns.

[0008]

In addition, the antenna coil disclosed in Patent Document 1 has a structure in which the antenna coil is coupled to the magnetic flux parallel to the rear conductive plate 34, as illustrated in Fig. 1. Accordingly, when the antenna coil is mounted in, for example, a mobile phone terminal, there is a problem in that the mobile phone terminal cannot be used with being held over the surface of a reader-writer in parallel if the antenna coil is installed in parallel with a circuit board in the casing of the mobile phone terminal.
[0009]
In the coil antenna disclosed in Patent Document 3, since the member of a high permeability (a magnetic-material core) is vertically directed, the communication is disabled if the coil antenna is placed on a conductor plate.

[0010]
Accordingly, we have appreciated that it would be desirable to provide a compact coil antenna that operates even if the coil antenna is arranged closely to its conductor plate and that has a higher degree of coupling with a target antenna.

[0011]
According to the present invention there is provided a coil antenna comprising a flexible substrate having a coil conductor formed thereon and a planar magnetic-material core, wherein, of the coil conductor, the arrangement interval in a part that is parallel to the axis of the magnetic-material core is shorter than the arrangement interval in a part that is orthogonal to the axis of the magnetic-material core.

[0012]
Preferably the coil conductor is composed of multiple layers, and the parts of the respective layers of the coil conductor, which are parallel to the axis of the magnetic-material core, are arranged so as to be superposed on one another.
[0013]

Preferably, the coil conductor is formed in a spiral form around a coil conductor opening, the flexible substrate has an aperture at a position corresponding to the coil conductor opening of the coil conductor, and the magnetic-material core passes through the aperture.

[0014]

Preferably, the coil conductor is formed in a rectangular spiral form including two parts that are parallel to the axis of the magnetic-material core and two parts that are orthogonal to the axis of the magnetic-material core, and part of either of the two parts of the coil conductor, which are orthogonal to the axis of the magnetic-material core, is covered with the magnetic-material core.

[0015]

Preferably, the coil conductor is formed in a spiral form around a coil conductor opening, and the flexible substrate is folded in the coil conductor opening of the coil conductor to be arranged so as to wrap the magnetic-material core.

[Advantages]

[0016]

Embodiments of the present invention may have the following advantages:
The coil antenna operates and is able to communicate even if the coil antenna is arranged closely to a conductor plate.

[0017]

Since the width of the magnetic-material core can be increased with the same antenna size, the amount of magnetic flux through the magnetic-material core is increased to improve the communication performance.

[0018]

Since the line width of the coil can be increased with the same antenna size, the loss of the coil is reduced to improve the communication performance.

[0019]

Increasing the pitch of the coil pattern allows the coupling coefficient with a target antenna coil to be increased, thus improving the communication performance.

[0020]

[Brief Description of the Drawings]

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

[0021]

Fig. 1 is a top view illustrating the structure of a coil antenna described in Patent Document 1.
Fig. 2 includes diagrams illustrating the structure of a coil antenna according to a first embodiment: Fig. 2(A) is a top view of a flexible substrate 101, Fig. 2(B) illustrates the shape of an upper coil conductor part 11S of a coil conductor 11, Fig. 2(C) illustrates the shape of a lower coil conductor part 11U of the coil conductor 11, and Fig. 2(D) illustrates a state in which the upper coil conductor part 11S is over the lower coil conductor part 11U.

Fig. 3(A) is a top view of a coil antenna 201 embodying the invention and Fig. 3(B) is a front view of the coil antenna 201.

Fig. 4 illustrates the relationship between a coil length L and the coupling coefficient.

Fig. 5(A) is a top view of a coil antenna 202 according to a second embodiment and Fig. 5(B) is a front view of the entire antenna apparatus including the coil antenna 202.

Fig. 6(A) is a top view of a coil antenna 203 according to a third embodiment, Fig. 6(B) is a bottom view of the coil antenna 203, and Fig. 6(C) is a front view of the entire antenna apparatus including the coil antenna 203.

Detailed description of embodiments of the invention

[0022]

<<First Embodiment>>

Fig. 2 includes diagrams illustrating the structure of a coil antenna according to a first embodiment.
Fig. 2(A) is a top view of a flexible substrate 101, which is one component of the coil antenna. The flexible substrate 101 includes a base 10 and a coil conductor 11. The coil conductor 11 is formed on the top face of the base 10.

[0023]

Fig. 2(B) illustrates the shape of an upper coil conductor part 11S of the coil conductor 11. Fig. 2(C) illustrates the shape of a lower coil conductor part 11U of the coil conductor 11. Fig. 2(D) illustrates a state in which the upper coil conductor part 11S is over the lower coil conductor part 11U.

[0024]

Each of the lower coil conductor part 11U and the upper coil conductor part 11S has a substantially rectangular and spiral shape, and an insulating layer exists between the lower coil conductor part 11U and the upper coil conductor part 11S. However, the inner end of the lower coil conductor part 11U conducts to the inner end of the upper coil conductor part 11S to be connected in series to the inner end of the upper coil conductor part 11S. In the above manner, the coil conductor 11 is formed in a spiral shape around a coil conductor opening CW.

[0025]

A terminal electrode 12 connecting to the outer end of
the upper coil conductor part 11S is provided on the flexible substrate 101. In addition, a terminal electrode 13 connecting to the outer end of the lower coil conductor part 11U is provided on the flexible substrate 101.

[0026]

The lower coil conductor part 11U and the upper coil conductor part 11S may be formed on both faces of the base of the flexible substrate, instead of being formed on one side of the base of the flexible substrate with the upper coil conductor part 11S being over the lower coil conductor part 11U.

As illustrated in Fig. 2(A), an aperture (slit) S is formed at a position corresponding to the coil conductor opening CW in the base 10 of the flexible substrate 101.

[0027]

Fig. 3(A) is a top view of a coil antenna 201. Fig. 3(B) is a front view of the coil antenna 201.

A magnetic-material core 1 formed of a rectangular planar ferrite sheet passes through the aperture S of the flexible substrate 101 to compose the coil antenna 201. An antenna apparatus is configured by arranging the coil antenna 201 closely to a planar conductor 2. The planar conductor 2 is, for example, a circuit board on which the coil antenna 201 is installed. The coil antenna 201 is arranged such that the face on which the terminal electrodes
12 and 13 illustrated in Fig. 3(A) are formed opposes the planar conductor (circuit board) 2.

[0028]

As illustrated in Fig. 2(A), in the lower coil conductor part 11U and the upper coil conductor part 11S, the arrangement interval in parallel-to-axis parts PA that are parallel to the direction of the axis of the magnetic-material core 1 (the lateral direction in the figure) (the direction of the magnetic path) is shorter than the arrangement interval in orthogonal-to-axis parts CA that are orthogonal to the axis of the magnetic-material core 1. In addition, in this example, the parallel-to-axis parts PA of the upper coil conductor part 11S are arranged so as to be over the parallel-to-axis parts PA of the lower coil conductor part 11U.

[0029]

Accordingly, the width of the magnetic-material core can be increased with the same antenna size and the line width of the coil can be increased with the same antenna size, thus further increasing the pitch of the coil pattern.

[0030]

Here, the results of simulation of the resistance representing the loss of the coil and the coupling coefficient representing the level of the communication performance (the coupling coefficient with a target coil
antenna) are shown. Simulation conditions are as follows:

[0031]

<Each Coil Antenna>

(1) Coil antenna having a first structure in related art

A coil antenna having a large line width of the coil conductor and a small width of the magnetic core, in which coils parallel to the length of the magnetic core are not superposed on one another.

Size of the magnetic-material core 14 mm × 15 mm × 0.2 mm

Line width of the coil conductor 0.1 mm

(2) Coil antenna having a second structure in the related art

A coil antenna having a small line width of the coil conductor and a large width of the magnetic core, in which coils parallel to the length of the magnetic core are not superposed on one another.

Size of the magnetic-material core 17 mm × 15 mm × 0.2 mm

Line width of the coil conductor 0.1 mm

(3) Coil antenna embodying the present invention

A coil antenna having a large line width of the coil conductor and a large width of the magnetic core, in which coils parallel to the length of the magnetic-material core
are superposed on one another.

Size of the magnetic-material core \(17 \text{ mm} \times 15 \text{ mm} \times 0.2 \text{ mm}\)

Line width of the coil conductor \(0.3 \text{ mm}\)

<Common items>

Size of the target coil antenna \(100 \text{ mm} \times 100 \text{ mm}\)

Distance from the target coil antenna \(30 \text{ mm}\)

Size of the coil conductor of each coil antenna \(20 \text{ mm} \times 15 \text{ mm}\)

The number of turns of the coil conductor of each coil antenna \(6\)

The relationship between the resistance representing the loss of the coil and the coupling coefficient representing the level of the communication performance is as follows:

\[
\begin{array}{c|c|c}
\text{Coil antenna} & \text{Resistance [Ω]} & \text{Coupling coefficient} \\
\hline
1 & 1.59 & 2.11% \\
2 & 2.00 & 2.29% \\
3 & 1.62 & 2.33% \\
\end{array}
\]

In the above manner, it is possible to compose the coil antenna having a high coupling coefficient with the target antenna and a low resistance.

[0033]

Next, the relationship between a coil length \(L\) (the dimension of the coil in the direction of the axis of the
coil in a range in which the coil is wound around the magnetic-material core) and the coupling coefficient is illustrated in Fig. 4. The same simulation conditions as the ones described above are used in this case.

As apparent from Fig. 4, the coupling coefficient reaches the maximum value when the ratio of the length L of the coil with respect to the length M of the magnetic-material core 1 in the direction of the axis exceeds 25%. Accordingly, it is possible to achieve the best communication performance.

[0034]

<<Second Embodiment>>

Fig. 5(A) is a top view of a coil antenna 202 according to a second embodiment. Fig. 5(B) is a front view of the entire antenna apparatus including the coil antenna 202.

A flexible substrate 102 includes the base 10 and the coil conductor 11. The coil conductor 11 is formed on the top face of the base 10.

[0035]

The coil conductor 11 includes the lower coil conductor part and the upper coil conductor part each having a substantially rectangular and spiral shape, as in the first embodiment. The coil antenna 202 differs from the coil antenna in the first embodiment in that the flexible substrate 102 is arranged so as to be over the magnetic-
material core 1.

[0036]

The coil conductor 11 includes the parallel-to-axis parts PA that are parallel to the axis of the magnetic-material core 1 and the orthogonal-to-axis parts CA that are orthogonal to the axis of the magnetic-material core 1. The arrangement interval in the parallel-to-axis parts PA is shorter than the arrangement interval in the orthogonal-to-axis parts CA.

Part of either of the two parallel-to-axis parts PA of the coil conductor 11 is covered with the magnetic-material core 1.

[0037]

Also with the above structure, it is possible to compose the coil antenna having a high coupling coefficient with a target antenna and a low resistance, as in the first embodiment. In addition, it is possible to compose the compact coil antenna that operates even if the coil antenna is arranged closely to its conductor plate.

[0038]

<<Third Embodiment>>

Fig. 6(A) is a top view of a coil antenna 203 according to a third embodiment. Fig. 6(B) is a bottom view of the coil antenna 203. Fig. 6(C) is a front view of the entire antenna apparatus including the coil antenna 203.
A flexible substrate 103 includes the base 10 and the coil conductor 11. The coil conductor 11 is formed on one surface of the base 10.

The coil conductor 11 includes the lower coil conductor part and the upper coil conductor part each having a substantially rectangular and spiral shape, as in the first and second embodiments. The coil antenna 203 differs from the coil antenna in the second embodiment in that the flexible substrate 103 is folded to be arranged so as to wrap the magnetic-material core 1.

The coil conductor 11 includes the parallel-to-axis parts PA that are parallel to the axis of the magnetic-material core 1 and the orthogonal-to-axis parts CA that are orthogonal to the axis of the magnetic-material core 1.

The flexible substrate 103 is folded along a line through the coil conductor opening CW of the coil conductor 11 to be arranged so as to wrap the magnetic-material core 1.

Also with the above structure, it is possible to compose the coil antenna having a high coupling coefficient with a target antenna and a low resistance, as in the first and second embodiments. In addition, it is possible to
compose the compact coil antenna that operates even if the coil antenna is arranged closely to its conductor plate.

[Reference Numerals]

[0043]

CA  orthogonal-to-axis part  CW  coil conductor opening  PA  parallel-to-axis part  S  aperture  1  magnetic-material core  2  planar conductor  10  base  11  coil conductor  11S  upper coil conductor part  11U  lower coil conductor part  12, 13  terminal electrode  101 to 103  flexible substrate  201 to 203  coil antenna
CLAIMS

1. A coil antenna comprising a flexible substrate having a coil conductor formed thereon and a planar magnetic-material core,
   wherein, of the coil conductor, the arrangement interval in a part that is parallel to the axis of the magnetic-material core is shorter than the arrangement interval in a part that is orthogonal to the axis of the magnetic-material core.

2. The coil antenna according to Claim 1,
   wherein the coil conductor is composed of multiple layers, and the parts of the respective layers of the coil conductor, which are parallel to the axis of the magnetic-material core, are arranged so as to be superposed on one another.

3. The coil antenna according to Claim 1 or 2,
   wherein the coil conductor is formed in a spiral form around a coil conductor opening, the flexible substrate has an aperture at a position corresponding to the coil conductor opening of the coil conductor, and the magnetic-material core passes through the aperture.
4. The coil antenna according to Claim 1 or 2, wherein the coil conductor is formed in a rectangular spiral form including two parts that are parallel to the axis of the magnetic-material core and two parts that are orthogonal to the axis of the magnetic-material core, and part of either of the two parts of the coil conductor, which are orthogonal to the axis of the magnetic-material core, is covered with the magnetic-material core.

5. The coil antenna according to Claim 1 or 2, wherein the coil conductor is formed in a spiral form around a coil conductor opening, and the flexible substrate is folded in the coil conductor opening of the coil conductor to be arranged so as to wrap the magnetic-material core.

6. A coil antenna substantially as herein described with reference to Figures 2, 3, 5 or 6 of the accompanying drawings.
**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

<table>
<thead>
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<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
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<tr>
<td>X,P</td>
<td>1 - 5</td>
<td>WO 2009/078214 A1 (MURATA) see figs.1 - 18 and paragraph [0035].</td>
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<td>X</td>
<td>1 &amp; 3</td>
<td>EP 1477927 A1 (SONY) see figs.8 - 13 &amp; 32.</td>
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<td>EP 1689028 A1 (FUJITSU) see figs.13(A) - 13(D) and paragraphs [0001], [0048] and [0052].</td>
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<td>-</td>
<td>EP 1484816 A1 (MITSUBISHI) see figs.1 - 16.</td>
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<tr>
<td>A</td>
<td>-</td>
<td>EP 2202843 A1 (MURATA) see figs.1 - 6 and paragraph [0001].</td>
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**Categories:**
- **X:** Document indicating lack of novelty or inventive step
- **Y:** Document indicating lack of inventive step if combined with one or more other documents of same category.
- **&:** Member of the same patent family
- **A:** Document indicating technological background and/or state of the art.
- **P:** Document published on or after the declared priority date but before the filing date of this invention.
- **E:** Patent document published on or after, but with priority date earlier than, the filing date of this application.

**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
- G06K; H01Q

The following online and other databases have been used in the preparation of this search report
- EPODOC, WPI

**International Classification:**

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