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(54) Title: CONTACTLESS DEVICE WITH MINIATURIZED ANTENNA

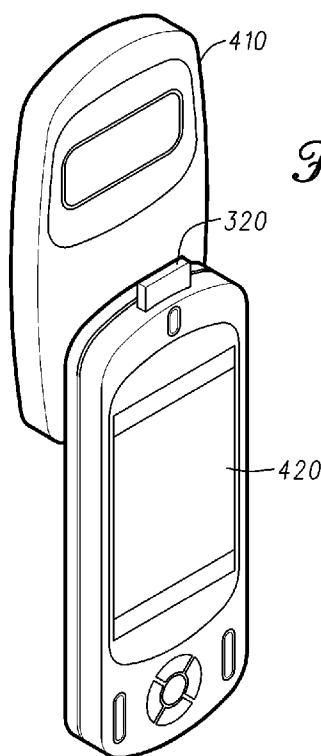


Fig. 4

(57) Abstract: A contactless device includes a miniaturized antenna. The antenna includes an inductive coupling element that presents a field coupling surface area to couple to a magnetic field. The inductive element may be made of layers where conductive loops are formed parallel to the layers or perpendicular to the layers. When conductive loops are formed perpendicular to the layers, the effective field coupling surface area is increased. The inductive element is positioned on an outside edge of a memory card compatible device with the field coupling surface area perpendicular to the card.



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CONTACTLESS DEVICE WITH MINIATURIZED ANTENNA

Related Applications

5 Benefit is claimed under 35 U.S.C. 119(e) to U.S. Provisional Application Ser. No. 61/155,144, entitled "Contactless Device with Miniaturized Antenna" by Narendra et al., filed February 24, 2009, which is herein incorporated in its entirety by reference for all purposes.

Field

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The present invention relates generally to contactless devices, and more specifically to small contactless devices.

Background

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Figures 1A, 1B, 2A and 2B show prior art. Figures 1A and 1B show antennas parallel to substrate. This is typical of credit cards that include contactless technology. Figures 2A and 2B show the prior art cards being held substantially parallel to the card reader in order to couple magnetic energy from the reader to the coil.

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Brief Description of the Drawings

Figures 1A, 1B, 2A, and 2B shows prior art contactless cards and their usage;

Figure 3 shows how the prior art antenna will affect usage of a memory card;

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Figure 4 shows how the prior art antenna will affect usage of a memory card when inserted in a mobile device;

Figure 5 shows placement of a miniaturized antenna on a memory card;

Figure 6 shows orientation of a miniaturized antenna on a memory card;

Figure 7 shows orientation of a memory card with respect to a reader;

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Figure 8 shows orientation of a mobile device with respect to a reader;

Figure 9 shows orientation of a miniaturized antenna with respect to a magnetic field emitted from a reader;

Figure 10 shows transformer design;

Figure 11 shows a flowchart of methods in accordance with various
5 embodiments of the present invention;

Figures 12-14 show miniaturized antennas;

Figure 15 shows dimensions of inductive coils;

Figure 16 shows a flowchart of methods in accordance with various
embodiments of the present invention;

10 Figures 17 and 18 show inductive element layers in accordance with various
embodiments of the present invention;

Figure 19 shows layers in an inductive element; and

Figures 20-23 show cross sections of inductive elements in accordance with
various embodiments of the present invention.

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Description of Embodiments

In the following detailed description, reference is made to the accompanying drawings that show, by way of illustration, various embodiments of an invention.

These embodiments are described in sufficient detail to enable those skilled in the
20 art to practice the invention. It is to be understood that the various embodiments of
the invention, although different, are not necessarily mutually exclusive. For
example, a particular feature, structure, or characteristic described in connection
with one embodiment may be implemented within other embodiments without
departing from the scope of the invention. In addition, it is to be understood that the
25 location or arrangement of individual elements within each disclosed embodiment
may be modified without departing from the scope of the invention. The following
detailed description is, therefore, not to be taken in a limiting sense, and the scope of
the present invention is defined only by the appended claims, appropriately
interpreted, along with the full range of equivalents to which the claims are entitled.

In the drawings, like numerals refer to the same or similar functionality throughout the several views.

Figure 3 shows how the prior art antenna will affect usage of a memory card.

If a memory card 320 has a loop antenna wound parallel to the substrate, then the
5 card will be held parallel to the reader 310 as shown.

Figure 4 shows how the prior art antenna will affect usage of a memory card when inserted in a mobile device. The field is flowing perpendicular to the reader 410. If the memory card 320 has a loop antenna wound parallel to the substrate, the mobile device 420 will be held parallel to the reader 410 as shown in Figure 4. For
10 consumer convenience, the memory card is usually not taken out of the mobile device 420. If the mobile device 420 is held as in Figure 4, the system may not work because there are other metal regions between the memory card antenna and the reader 410. These other metal regions could be because of the memory card's holder inside the mobile device as well as the mobile device's printed circuit board
15 (PCB) metal routing and components/solder. Accordingly, the field from the reader 410 may not reach the antenna's conducting metal since it may be absorbed by other metal regions.

Figure 5 shows placement of a miniaturized antenna on a memory card. Memory card 500 is shown with RFID tag 520, RFID antenna 540, memory 530,
20 and various other components. The miniaturized antenna 540 is formed from an inductive device with at least one coil. The inductive device is positioned at the outer edge of the memory card 500 as shown. The memory card 500 may be any form factor including secure digital (SD), mini-SD, micro-SD, or the like.

To allow for capturing the field from the reader that is flowing perpendicular
25 to the reader, the miniaturized antenna 540 is placed at the very edge of the memory card 500 so it is near the outer edge of the memory card slot when inserted in a mobile device.

Various embodiments of the present invention provide for manufacturing an inductive coil that is small enough to be placed at the outer edge, and placement and

orientation of the coil that allows for the field from the reader to flow into the antenna.

Figure 6 shows orientation of a miniaturized antenna on a memory card. Miniaturized antenna 540 is a three dimensional (3D) inductive coil encased in a filler material 614. The inductive device is positioned at the outer edge of the memory card as shown. The orientation of antenna 540 is such that the field from 610 couples to the 3D inductive coil of the antenna. The memory card may be any form factor including secure digital (SD), mini-SD, micro-SD, or the like.

Figure 7 shows orientation of a memory card with respect to a reader. Memory card 500 includes a miniaturized antenna at the edge of the card. See Figures 5, 6. When the antenna is positioned on memory card 500 as shown in Figure 6, the memory card 500 can be positioned perpendicular to the reader 410 as shown in Figure 7.

Figure 8 shows orientation of a mobile device with respect to a reader. When the memory card 500 of Figure 7 is inserted in the mobile device 420 of Figure 8, then the mobile device 420 may be oriented as shown. This allows the magnetic field to enter the antenna at the edge of the memory card 500 without first having to penetrate the back of the mobile device.

Figure 9 shows orientation of a miniaturized antenna with respect to a magnetic field emitted from a reader. Reader 410 emits electromagnetic energy at a particular frequency such as 13.56 MHz. As described above, the miniaturized antenna includes an inductive coil 612. The coil 612 is designed to couple as much magnetic field from reader 410 as possible.

The reader coil and the inductive coil 612 can be viewed as two coils in a transformer. The reader coil is fixed, and so coil 612 is designed as a secondary coil of the transformer coupling to the field from the reader coil (primary coil). Maximizing coupling area of the inductive coil 612 will increase the coupling between the reader coil and the antenna coil.

Figure 10 shows transformer design. The reader (primary coil of the transformer) is shown modeled with inductor L1, series resistance RL1, series

capacitance C1S, and parallel capacitance C1P. The miniaturized antenna (secondary coil of the transformer) is shown modeled with inductor L2, series resistance RL2, and parallel capacitance C2.

Transformer coupling does not lend itself well to an exact design procedure
5 because there are so many factors which influence the degree of coupling. The geometry of the coils, the spacing between them, the core materials used, and the shielding, all have a pronounced effect on the degree of coupling attained in any design. Decreasing the spacing between the primary and secondary coils increases the coupling. Increasing the permeability of the magnetic path increases the
10 coupling. And shielding a transformer decreases its loaded Q and has the effect of increasing the coupling.

Figure 11 shows a flowchart of methods in accordance with various embodiments of the present invention. Flowchart 1100 discusses factors to consider when designing a secondary transformer coil for use as a miniaturized antenna. At
15 110, it is recognized that for effective coupling, the secondary transformer coil should be strongly coupled to the reader coil, resonant at substantially 13.56 MHz, and have a high Q, but not too high since it will limit bandwidth (BW).

At 1120, it is recognized that coupling depends strongly on surface area, while inductance depends strongly on number of turns. At 1130, it is recognized
20 that for any given value of inductance, resonance can be achieved by adjusting the value of an external capacitor.

At 1140, the surface area is chosen to maximize coupling, the number of turns in the coil is chosen to define the inductance, and width/length of wire is chosen to increase Q.

25 Figures 12-14 show miniaturized antennas. Figures 12 and 13 show an inductive element suitable for use as a miniaturized antenna at an outer edge of a memory card. The side view is the direction that is exposed to the magnetic field when in use. Figure 12 defines "A" as the overall length, "B" as the overall height, and "C" as the overall depth. Figure 12 also defines "D" as the length of the
30 conductive end regions that couple the coil to the memory card. Example

dimensions when used in an SD format are A=10.4mm, B=0.7mm, C=2mm, and D=0.5mm. These dimensions are provided as examples only, and the various embodiments of the invention are not so limited. For example, an inductive element for use in a micro-SD card will generally have smaller dimensions.

5 Figure 14 shows the magnetic field entering the side view of the inductive element. Figure 14 also defines the field coupling surface area 1410. When installed on a board, the field coupling surface area is substantially perpendicular to the board.

 The mechanical structure of the antenna occupies the three dimensions of length A, height B, and depth C. The structure includes metal 1420 for forming the
10 coil and a filling material 1430 to occupy the remaining volume. The filling material 1430 may be a composite of magnetic material or ceramic material. The metal winding for the 3D coil is made to occupy the perimeter tracing the length and height of the antenna to form its one turn. Additional turns are accomplished by
15 repeating the perimeter tracing along the depth with ohmic connections between immediate turns to create a continuous rectangular coil like a rectangular spring.

 The field coupling surface area 1410 is the surface area along the two dimensions that form the perimeter tracing. This area couples the field from an external source (such as reader 410) to the 3D antenna coil inducing voltage and
20 current in the 3D antenna coil.

 In some embodiments, antenna 540 is placed in the memory card 500 so that the length of the coil aligns with what will be the outer edge of the memory card when it is inserted into a host device. The inner edge of the memory card is where there will be the electrical connectors for the memory card bus to connect to the
25 memory card slot.

 In some embodiments, antenna 540 is oriented so that when the memory card is inserted in a host device the field coupling surface area 1410 is in parallel to the outer surface of the host device. This orientation will make the incident field from the external source predominately 90 degrees to the field coupling surface
30 area. In combination with the placement this orientation will enable the field

coupling surface area to be closest to the outer surface of the host, thereby maximizing the induced voltage and current in the 3D coil due to an external field source.

Figure 15 shows dimensions of inductive coils. As shown in the top view a single antenna may include multiple coils in parallel. In the example of Figure 15, 5 $M=6$ coils are included with each coil having $N=5.5$ turns, although M and N may take on any value. The conductor length is given by $2(A_i+B_i+2w)(N-0.5)+A_i$, where A_i and B_i are the inner dimensions of the coil and w is the width of the conductor. As shown in the side view, the effective coupling surface area is 10 increased when f and w are kept small to maximize B_i .

Figure 16 shows a flowchart of design process methods in accordance with various embodiments of the present invention. At 1610, the manual winding and read distance measurements are provided. At 1620, the coupling surface area, the number of turns, and the width/length of wire are chosen. See Figure 11.

15 At 1630, the dimensions A , B , C , and D are given. These values are constrained by the form factor of the memory card. At 1632, A_i and B_i are maximized to maximize coupling. Referring now back to Figure 15, it is shown that the field coupling surface area is increased as A_i and B_i are increased.

At 1634, M is used to increase Q (decreasing the DC resistance) if possible. 20 This corresponds to increasing the number M of parallel coils. See Figure 15. At 1636, N is chosen to arrive at the desired inductance, taking into account increased number of turns N will increase DC resistance and lower Q .

At 1638, the read distance is measured. The various parameters can be modified and the read distance measured in an iterative process. At 1650, the 25 various parameters are finalized to arrive at a final design. The DC resistance, the inductance, the material, and the dimensions A , B , C , and D can be finalized. The external capacitor (see C2, Figure 10) on the printed circuit board can also be finalized given the inductance and the desired 13.56 MHz resonance.

Figures 17 and 18 show inductive element layers in accordance with various 30 embodiments of the present invention. Layers include conductive materials and

insulating materials. Figure 17 shows a traditional method of forming a surface mount inductive element. Each layer includes a conductive loop, and the layers, when stacked, form multiple conductive loops. The minimum dimension w (Figure 15) is limited by process requirements. The inductor is mounted on the board on its “side” to expose the field coupling surface area at the outer edge of the card. In these embodiments, the layers are perpendicular to the board. Figure 18 shows an improved manufacturing method. Each layer forms only a portion of a conductive loop. For example, referring now to Figure 19, the bottom layer 1970 include traces with trace ends. Intermediate layers 1920, 1930, 1940, 1950, and 1960 include through-traces at locations to electrically contact the trace ends on the lower layer, and upper layer 1910 has at least one conductive surface trace aligned to electrically contact the conductive through-traces to form a conductive coil having at least one turn. The traces on layers 1910 and 1970 can be on either side of the substrate.

In some embodiments, the inductive elements include magnetic material such that a magnetic core is formed inside the conductive coil. Further, in some embodiments, the inductive elements include magnetic material outside the conductive coils.

Figures 20-23 show cross sections of inductive elements in accordance with various embodiments of the present invention. Figures 21 and 23 show inductive elements that are made using layers in the same plane as the field coupling surface area. Figures 21 and 22 show inductive elements that are made using layers perpendicular to the field coupling surface area. Note that the width w of the traces is smaller in the Figures 21 and 22, thereby increasing the effective field coupling surface area. The effective field coupling surface area is further increased in Figures 22 and 23 by extending the conductive traces to the end of the device.

Although the present invention has been described in conjunction with certain embodiments, it is to be understood that modifications and variations may be resorted to without departing from the scope of the invention as those skilled in the art readily understand. Such modifications and variations are considered to be within the scope of the invention and the appended claims.

What is claimed is:

1. An inductive element comprising:
a bottom surface; and
5 a plurality of layers substantially parallel to the bottom surface, the plurality of layers including a combination of electrically conductive material and electrically insulating material such that when bonded together the plurality of layers form at least one conductive coil having a field coupling surface area substantially perpendicular to the bottom surface.
- 10 2. The inductive element of claim 1 further comprising bonding areas on the bottom surface.
3. The inductive element of claim 1 wherein the plurality of layers include
15 magnetic material forming a magnetic core within the at least one conductive coil.
4. A multilayer inductive coupling element comprising:
a lower layer having at least one conductive surface trace with trace ends;
at least one intermediate layer having conductive through-traces at locations
20 to electrically contact the trace ends on the lower layer; and
an upper layer having at least one conductive surface trace aligned to electrically contact the conductive through-traces to form a conductive coil having at least one turn.
- 25 5. The multilayer inductive coupling element of claim 4 wherein the at least one intermediate layer comprises magnetic material positioned between the through-traces.
6. The multilayer inductive coupling element of claim 4 wherein the lower
30 layer includes magnetic material positioned beyond the trace ends.

7. The multilayer inductive coupling element of claim 4 further comprising a bottom layer beneath the lower layer, the bottom layer including magnetic material to be positioned beneath the at least one conductive trace in the lower layer.

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8. An electronic device comprising:

a circuit board with a memory card slot interface;

a contactless communications device affixed to the circuit board, the contactless communications device having an antenna port; and

10 an inductive element affixed to the circuit board and electrically coupled to the antenna port, the inductive element having a conductive coil with a field coupling surface area substantially perpendicular to the circuit board.

9. The electronic device of claim 8 wherein the inductive element comprises a multilayer surface-mount inductor.

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10. The electronic device of claim 9 wherein the multilayer surface-mount inductor is formed with layers substantially parallel to the circuit board.

20 11. The electronic device of claim 9 wherein the multilayer surface-mount inductor is formed with layers substantially perpendicular to the circuit board.

12. The electronic device of claim 8 wherein the memory card slot interface comprises a Secure Digital (SD) compatible interface.

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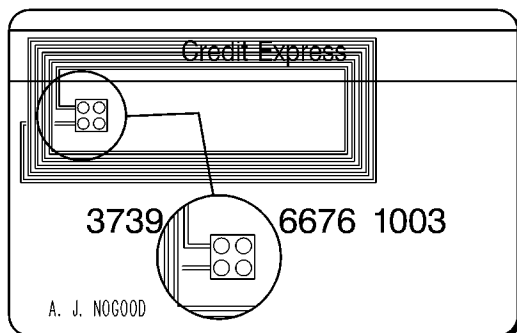
13. The electronic device of claim 8 wherein the memory card slot interface comprises a micro Secure Digital (SD) compatible interface.

14. The electronic device of claim 8 wherein the memory card slot interface comprises a mini Secure Digital (SD) compatible interface.

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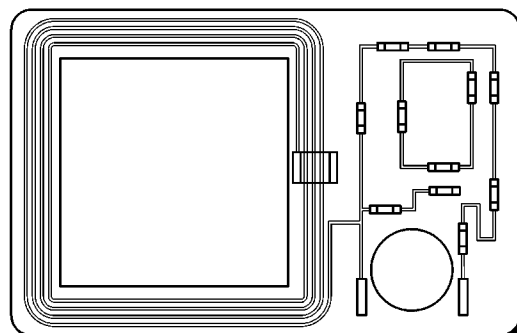
15. An apparatus comprising:
a memory card compatible substrate having at least one surface, an inner edge, and an outer edge opposite the inner edge;
5 electrical contacts on the at least one surface and situated along the inner edge; and
a conductive coil situated along the outer edge, the conductive coil having a field coupling surface area substantially perpendicular to the at least one surface.
- 10 16. The apparatus of claim 15 wherein:
the at least one surface includes a top surface and a bottom surface substantially parallel to each other; and
the electrical contacts are on the top surface, and the conductive coil is on the top surface.
- 15 17. The apparatus of claim 15 wherein:
the at least one surface includes a top surface and a bottom surface substantially parallel to each other; and
the electrical contacts are on the top surface, and the conductive coil is on
20 the bottom surface.
18. The apparatus of claim 15 wherein the conductive coil comprises a multilayer surface-mount inductor.
- 25 19. The apparatus of claim 18 wherein the multilayer surface-mount inductor is formed with layers substantially parallel to the at least one surface.
20. The apparatus of claim 18 wherein the multilayer surface-mount inductor is formed with layers substantially perpendicular to the at least one surface.
- 30

21. An apparatus comprising:
a memory card compatible substrate having at least one surface, an inner edge, and an outer edge opposite the inner edge;
electrical contacts on the at least one surface and situated along the inner
5 edge; and
a three dimensional conductive coil situated along the outer edge.
22. The apparatus of claim 21, wherein the apparatus has a micro secure digital (microSD) form factor.
- 10 23. The apparatus of claim 22 wherein the three dimensional conductive coil has a field coupling surface area substantially perpendicular to the at least one surface of the memory card.



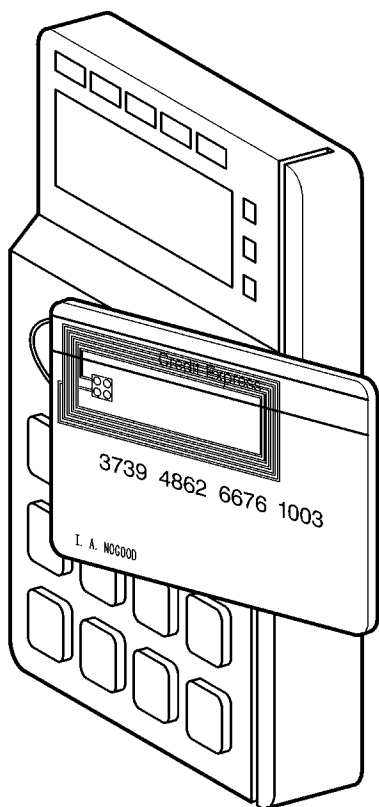
-PRIOR ART-

Fig. 1A



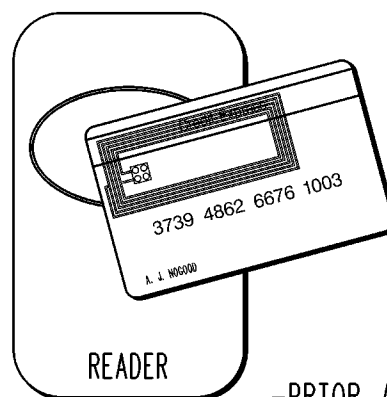
-PRIOR ART-

Fig. 1B



-PRIOR ART-

Fig. 2A



-PRIOR ART-

Fig. 2B

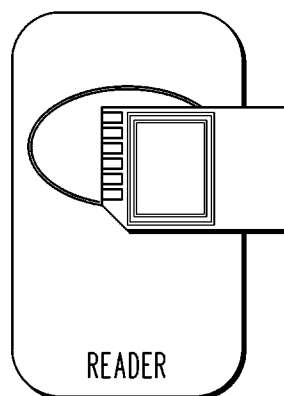


Fig. 3

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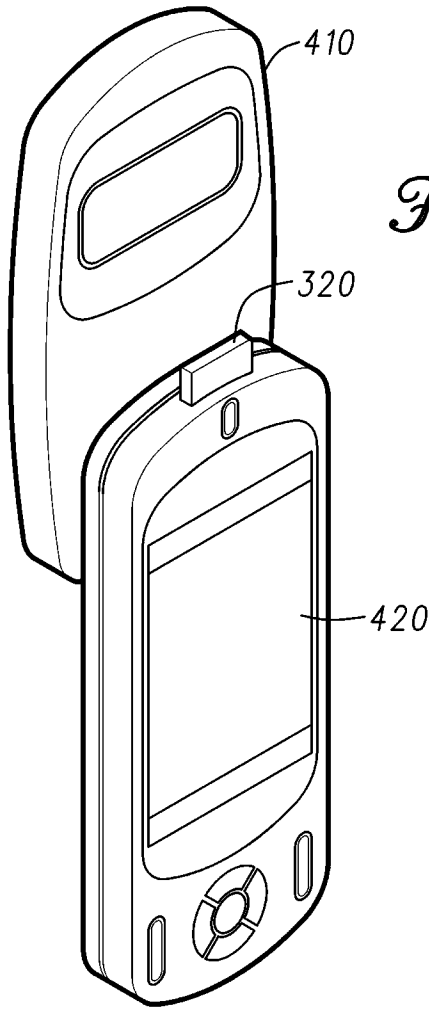


Fig. 4

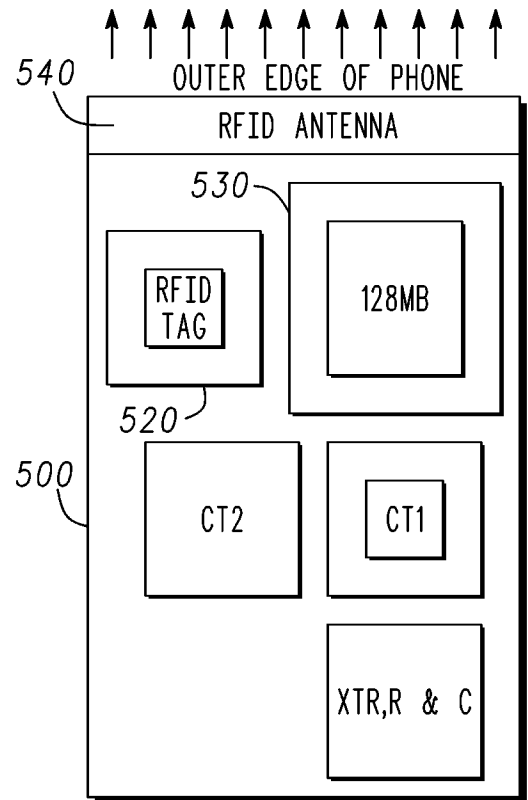


Fig. 5

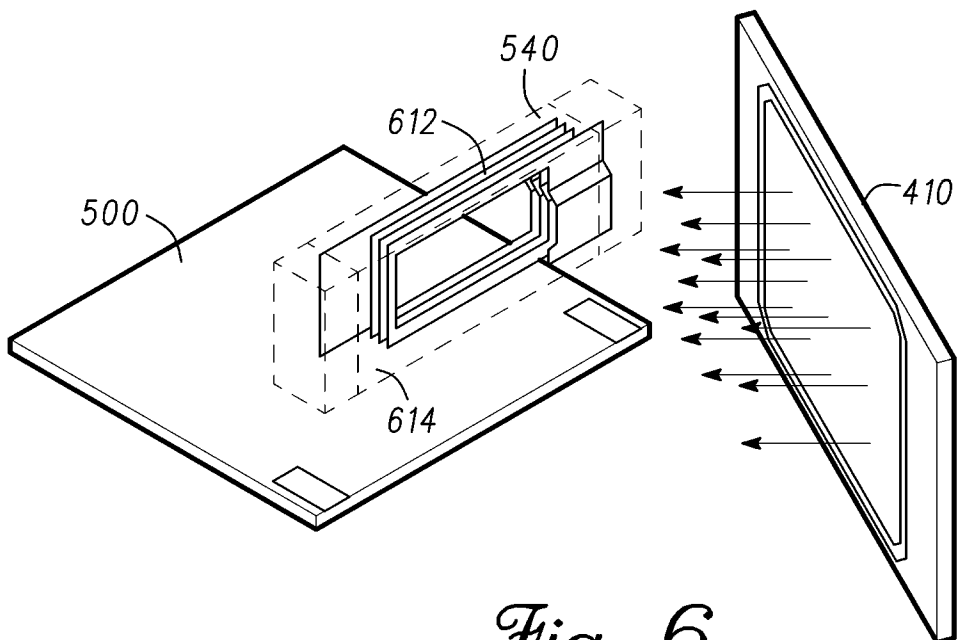


Fig. 6

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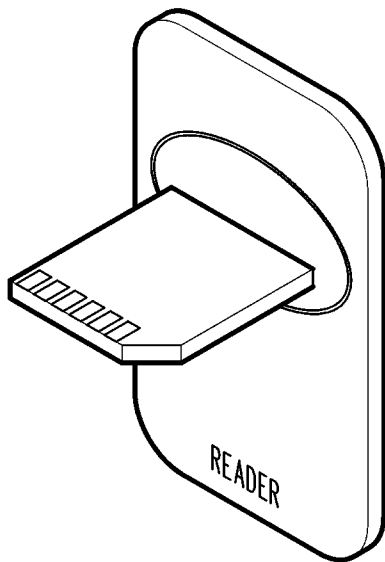


Fig. 7

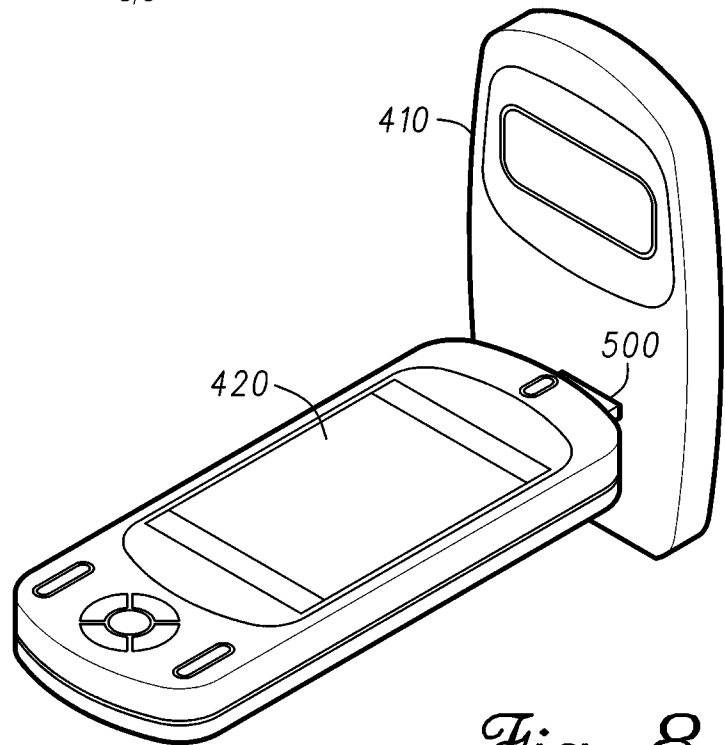


Fig. 8

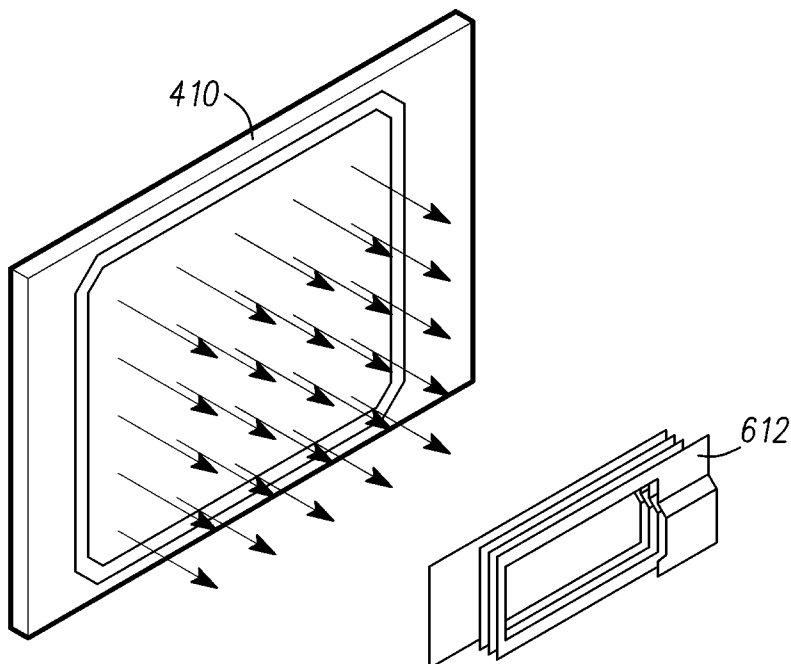
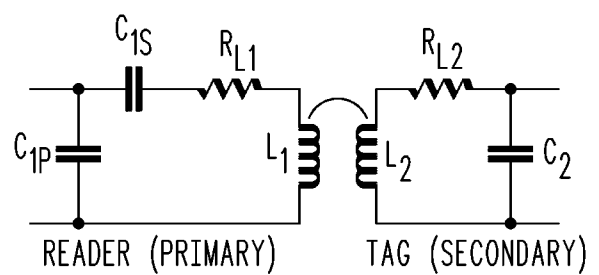
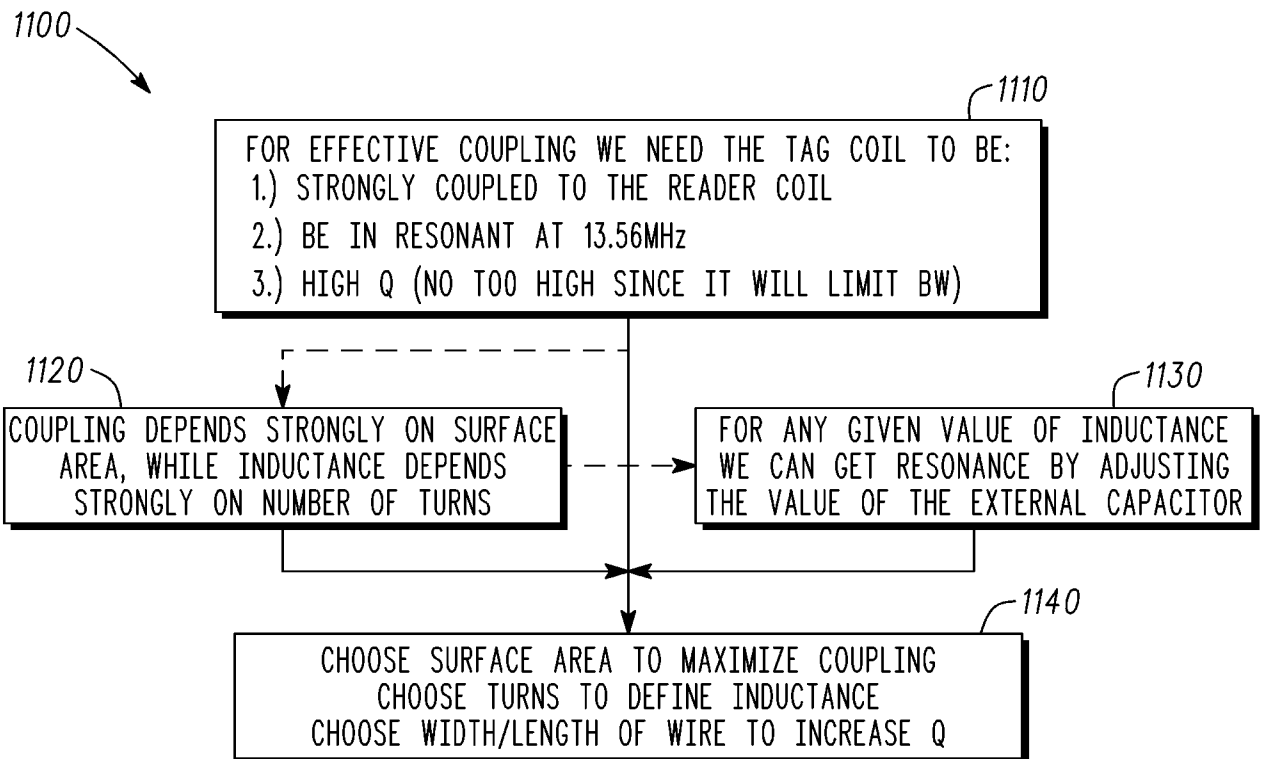
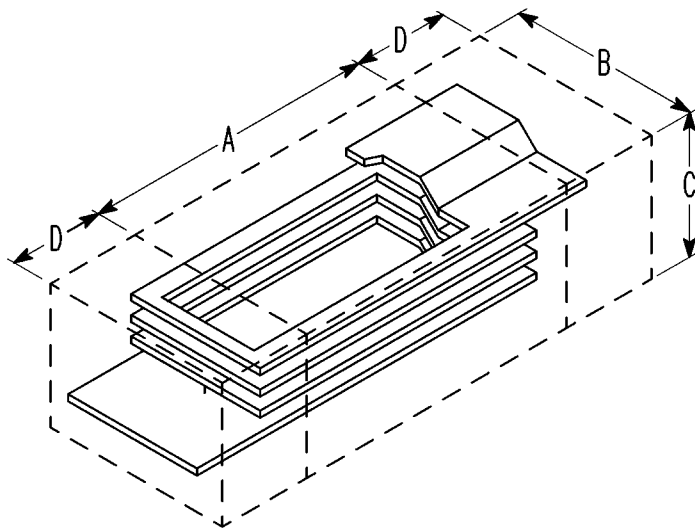
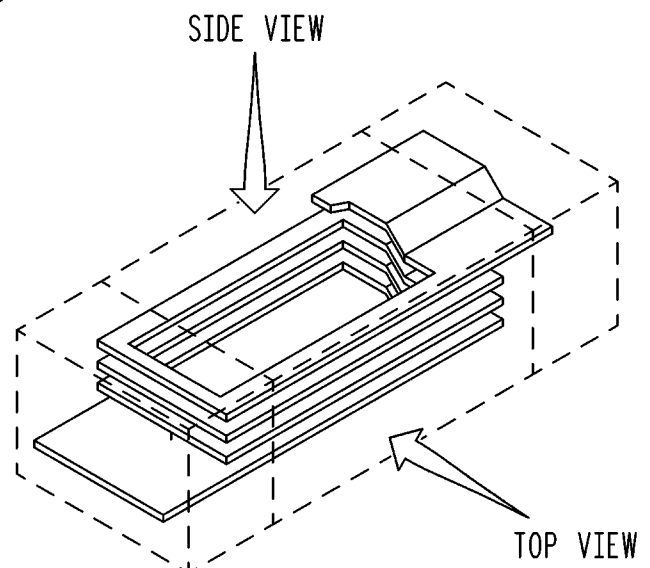


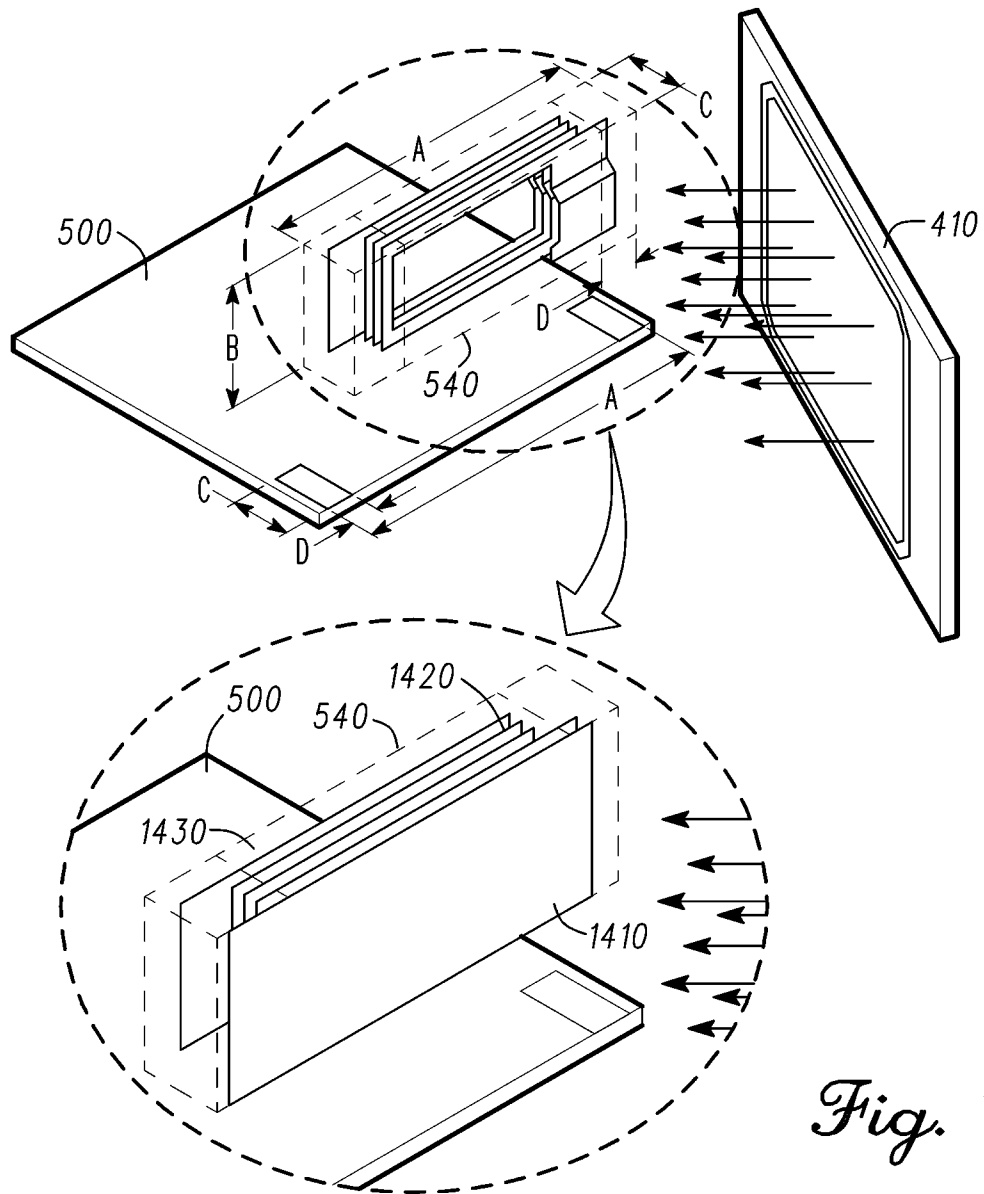
Fig. 9

Fig. 10



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*Fig. 11**Fig. 12**Fig. 13*

*Fig. 14*

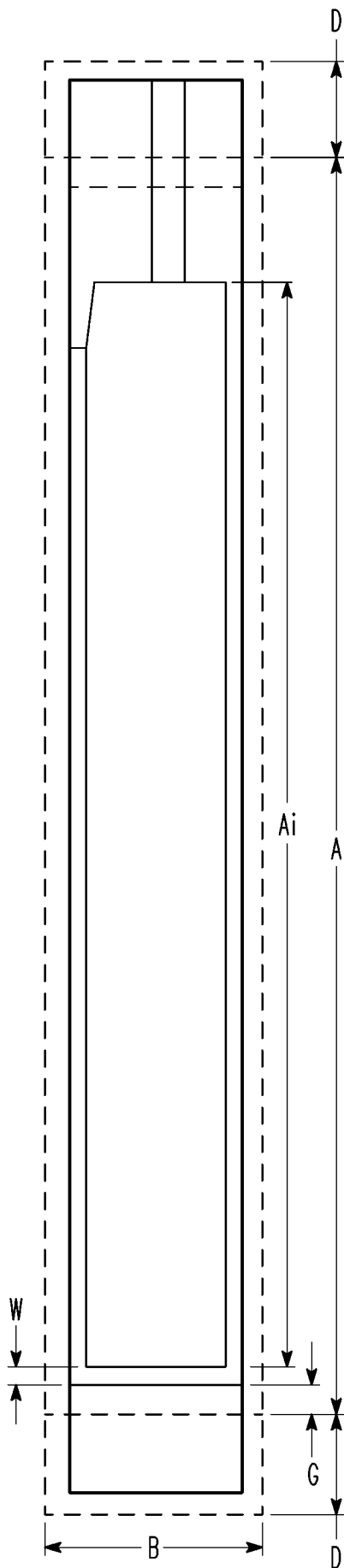


Fig. 15A

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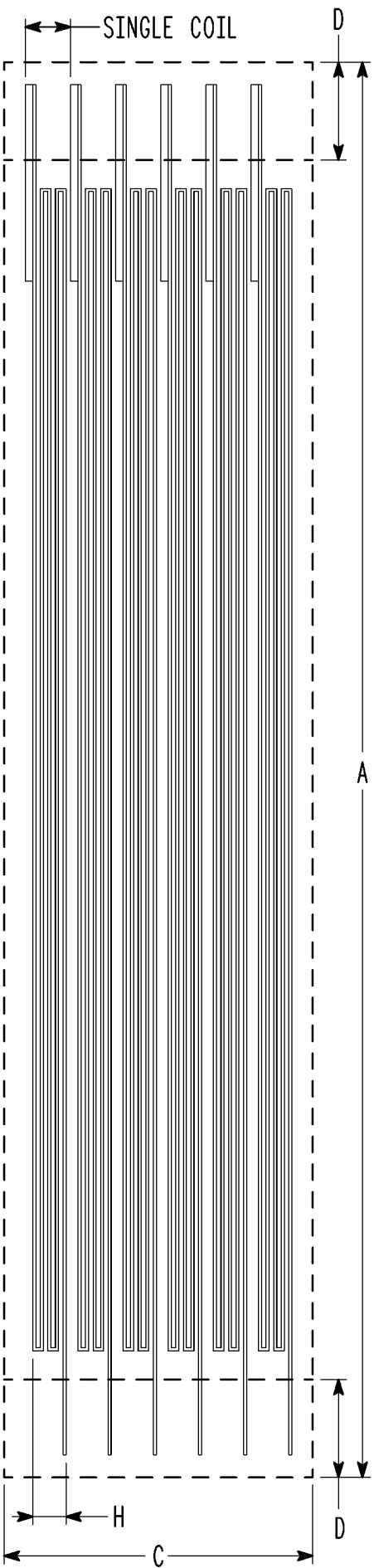
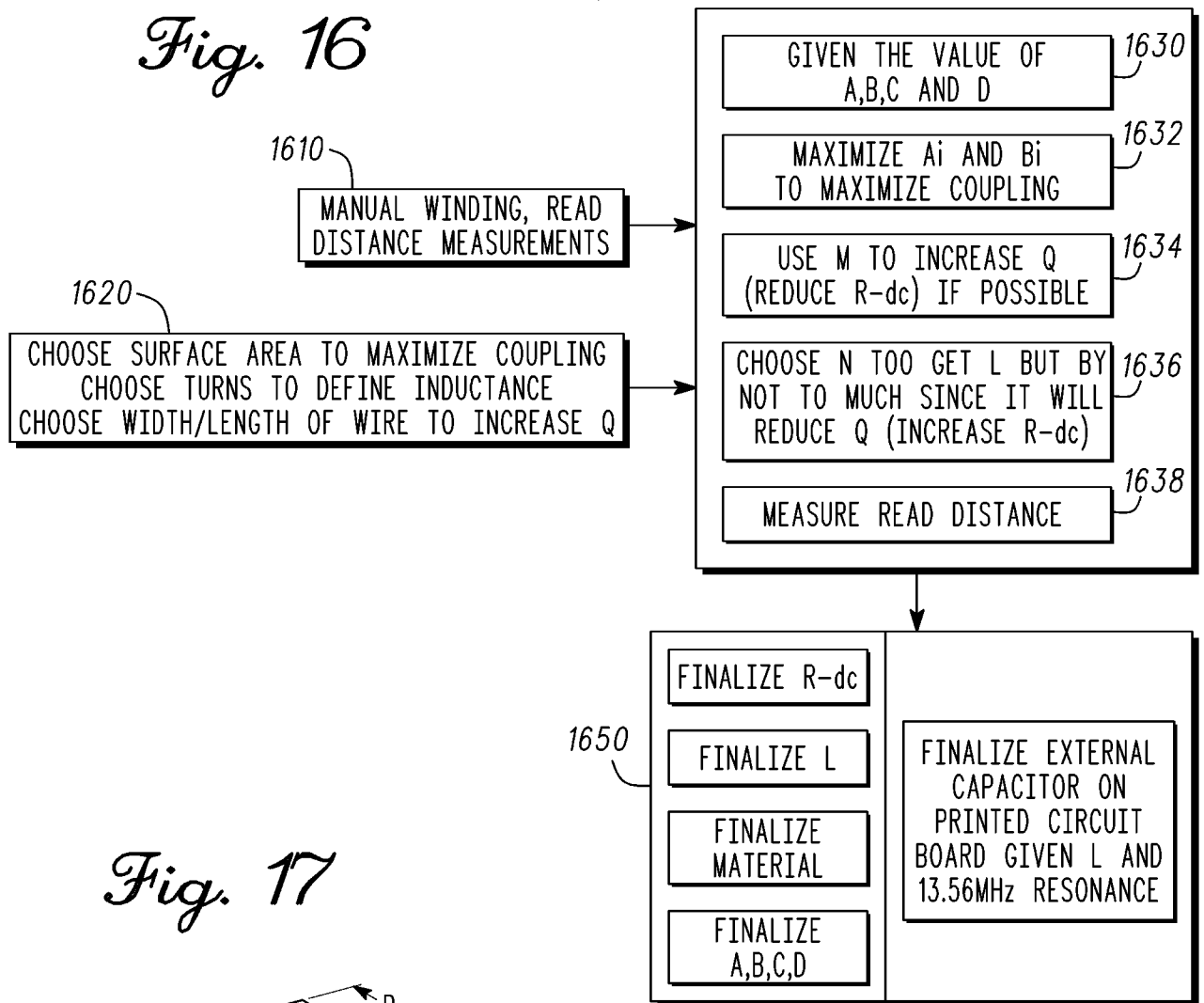
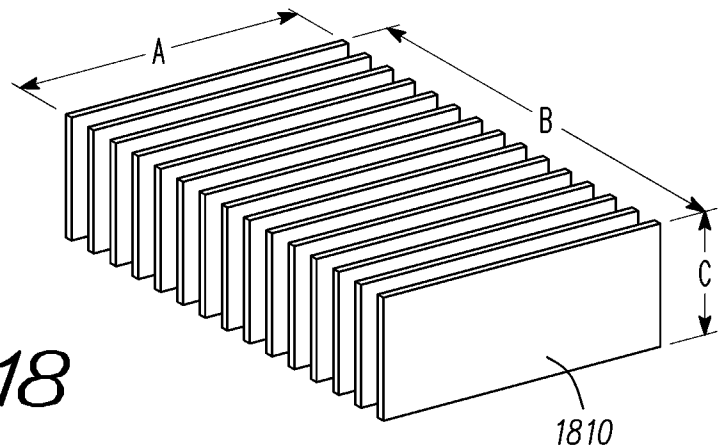
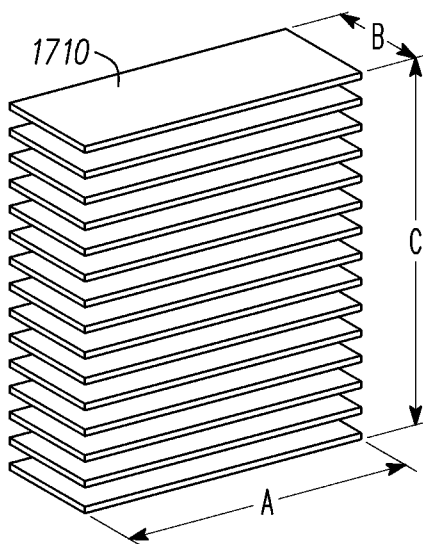
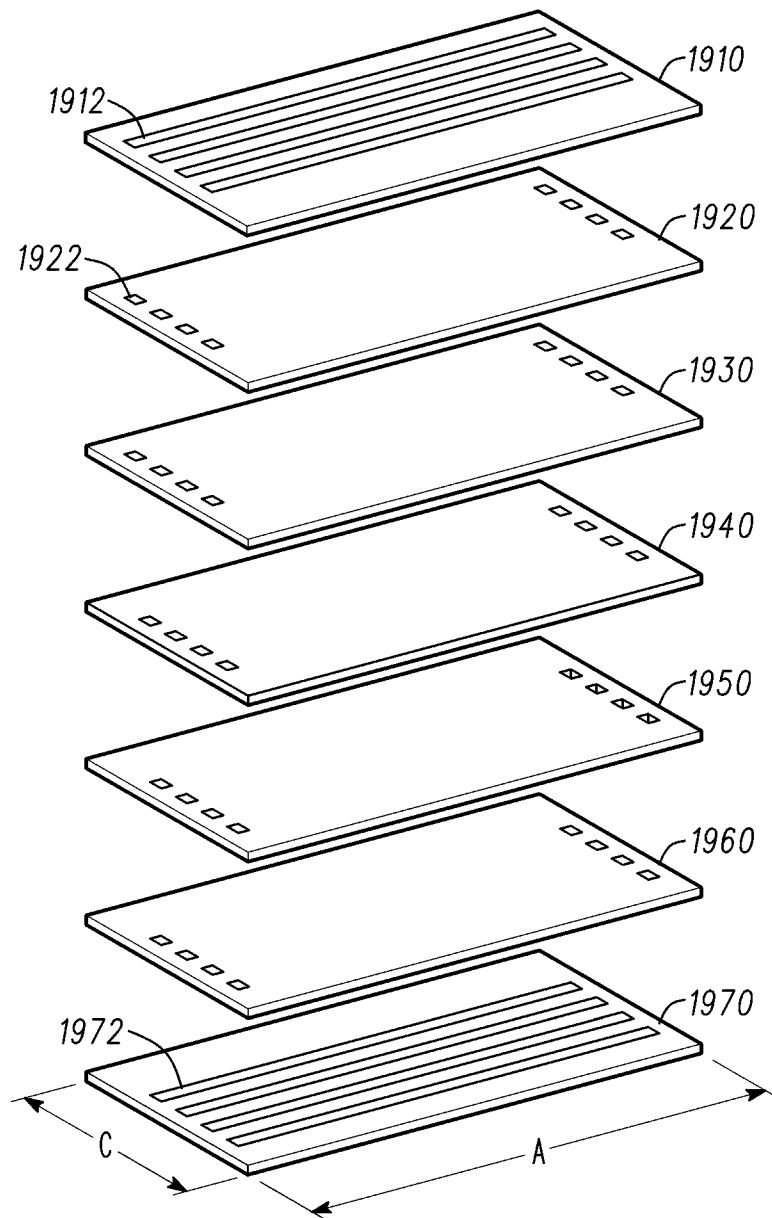


Fig. 15B

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Fig. 16*Fig. 17**Fig. 18*

*Fig. 19*

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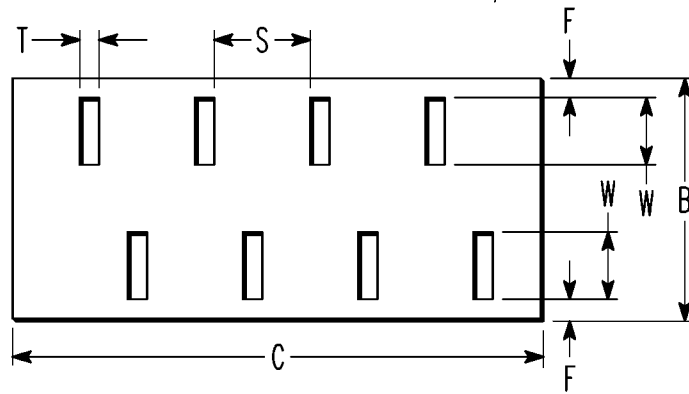


Fig. 20

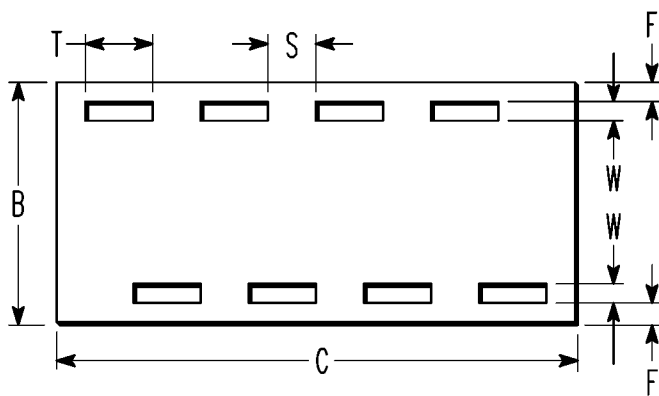


Fig. 21

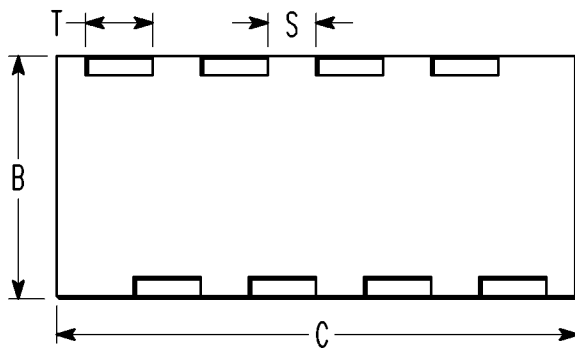


Fig. 22

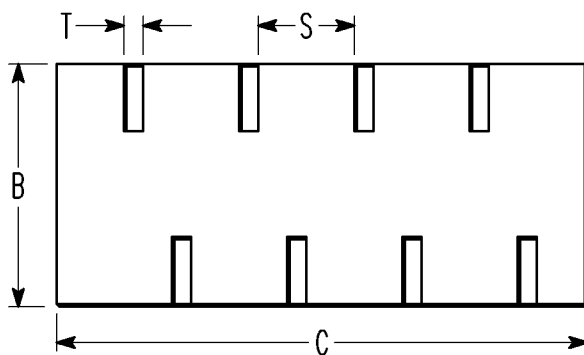


Fig. 23

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2010/025014

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G06K 19/077 (2010.01)

USPC - 257/679

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - B42D 15/00; G06K 19/07, 19/077 (2010.01)

USPC - 235/380, 488, 492; 257/531, 679; 361/737

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

PatBase; Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/0168339 A1 (ARAI et al) 04 August 2005 (04.08.2005) entire document	1-23
A	US 2001/0002035 A1 (KAYANAKIS) 31 May 2001 (31.05.2001) entire document	1-23
A	US 6,588,660 B1 (BUESCHER et al) 08 July 2003 (08.07.2003) entire document	1-23
A	US 2007/0257797 A1 (RANCIEN et al) 08 November 2007 (08.11.2007) entire document	1-23

☐ Further documents are listed in the continuation of Box C.


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Date of the actual completion of the international search

04 April 2010

Date of mailing of the international search report

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