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(71) **Applicant** *(for all designated States except US):* **UNIVERSITY OF FLORIDA RESEARCH FOUNDATION, INC.** [US/US]; 223 Grinter Hall, Gainesville, FL 32611 (US).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only):* **LOW, Zhen, Ning** [SG/US]; 712 S.W. 16th Avenue, #311, Gainesville, FL 32601 (US). **LIN, Jenshan** [US/US]; 910 S.W. 105th Terrace, Gainesville, FL 32607 (US). **CHEN, Mingqi** [CN/US]; 111 S.W. 16th Ave., Apt. 128, Gainesville, FL 32601 (US).

(74) **Agents: PARKER, James, S.** et al; Saliwanchik, Lloyd, Saliwanchik, P.O. Box 142950, Gainesville, FL 32614-2950 (US).

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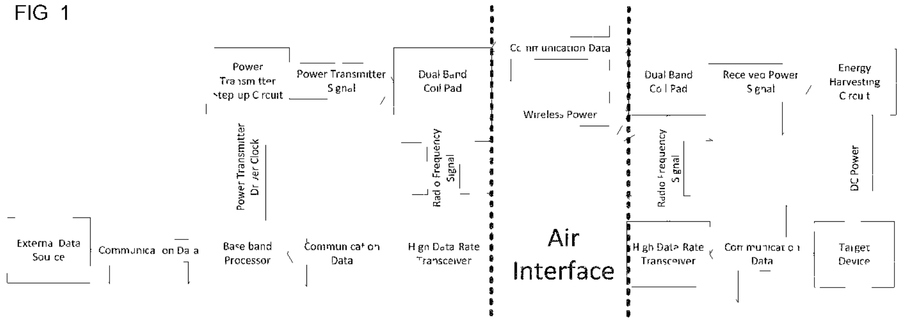
(54) **Title:** PLANAR NEAR-FIELD WIRELESS POWER CHARGER AND HIGH-SPEED DATA COMMUNICATION PLATFORM

FIG 1



(57) **Abstract:** In one aspect, the present disclosure describes a planar near-field wireless power charging system that is capable of charging small portable devices. Embodiments can incorporate coils for generating time-varying magnetic fields into a pad. In an exemplary embodiment, the charging system incorporates a charging pad that can act as an electrically small coil antenna for the low frequencies and long wavelengths, used for charging, and long wavelengths, and which can also be used for communication purposes by treating it as an electrically large antenna at higher frequencies, and shorter wavelengths, used for communications. In an exemplary embodiment, the system uses multiple lower powered transmitters, where each transmitter feeds a separate coil. The separate coils can be stacked so that the magnetic fields are substantially coextensive. The simultaneous driving of the multiple coils by the multiple transmitters can achieve similar power delivery as a single high powered transmitter. Multiple stacked sets of coils can be integrated into a pad such that each stacked set of coils provides vertical magnetic fields over a section of the pad. Embodiments of the subject invention can be designed to couple energy to the receiver coil of the device via magnetic fields that have a substantial vertical component. An embodiment of the present disclosure describes a receiver coil attached to a portable electronic device with a mechanical connection that allows the receiver coil to be positioned such that the vertical fields do not need to pass through a substantial portion of the device to pass through the receiver coil during charging and can allow the receiver coil to be conveniently positioned adjacent the device when not changing.

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DESCRIPTION

PLANAR NEAR-FIELD WIRELESS POWER CHARGER AND HIGH-SPEED DATA COMMUNICATION PLATFORM

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims the benefit of U.S. Provisional Application Serial No. 60/970,201, filed September 5, 2007, which is hereby incorporated by reference herein in its entirety, including any figures, tables, or drawings.

BACKGROUND OF INVENTION

Portable electronic equipment, such as mobile phones, handheld computers, and personal data assistants, are normally powered by batteries. In many cases, rechargeable batteries are preferred because of environmental and economical concerns. The most common way to charge rechargeable batteries is to use a conventional charger, which normally includes an AC-DC power supply when the AC mains are used, or a DC-DC power supply when a car battery is used. Conventional chargers normally use an electric cable to connect the charger circuit to the battery located in the portable electronic equipment.

In large part due to the inconvenience of conventional chargers, wireless power solutions have been presented. Examples of wireless power solutions include electric toothbrushes and electric razors. Current wireless power solutions have limitations such as requiring a particular alignment of the device being charged to the charging unit, or other inconveniences such as the need for the device being charged to be within a certain distance of a certain section of the charging unit.

Thus, there remains a need for a system for wireless charging of portable electronic devices in an efficient manner.

BRIEF SUMMARY

In one aspect, the present disclosure describes a planar near-field wireless power charging system that is capable of charging small portable devices. Embodiments can incorporate coils for generating time-varying magnetic fields into a pad. In an exemplary embodiment, the charging system incorporates a charging pad that can act as an electrically small coil antenna for the low frequencies and long wavelengths, used for charging, and long wavelengths, and which can also be used for communication purposes by treating it as an electrically large antenna at higher frequencies, and shorter wavelengths, used for communications.

In an exemplary embodiment, the system uses multiple lower powered transmitters, where each transmitter feeds a separate coil. The separate coils can be stacked so that the magnetic fields are substantially coextensive. The simultaneous driving of the multiple coils by the multiple transmitters can achieve similar power delivery as a single high powered transmitter. Multiple stacked sets of coils can be integrated into a pad such that each stacked set of coils provides vertical magnetic fields over a section of the pad. Embodiments of the subject invention can be designed to couple energy to the receiver coil of the device via magnetic fields that have a substantial vertical component.

An embodiment of the present disclosure describes a receiver coil attached to a portable electronic device with a mechanical connection that allows the receiver coil to be positioned such that the vertical fields do not need to pass through a substantial portion of the device to pass through the receiver coil during charging and can allow the receiver coil to be conveniently positioned adjacent the device when not charging. In exemplary embodiments, the mechanical connection can be a flip or slide mechanism that allows the receiver coil to be positioned such that a vertical magnetic field does not need to pass through the portable device in order to pass through the receiver coil during charging, but allows the receiver coil to reside adjacent to the device when not charging in order to make the device with receiver coil easier to carry and store.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 shows one embodiment of a system architecture of a planar near-field wireless power charger and high-speed data communication platform.

Figure 2 shows an embodiment of a planar wireless power charger platform in accordance with the present disclosure.

Figure 3 shows a diagram of one embodiment of a multiple-transmitter power delivery system.

Figure 4 shows a system block diagram of a multiple-transmitter power delivery system.

Figures 5A-5B show embodiments of a single transmitter coil for a wireless power system.

Figure 6 shows an existing technology using a horizontal field to charge the portable device.

Figure 7 shows a cell phone incorporating an embodiment of a power charging receiver in accordance with the present disclosure.

Figures 8A-8B show a power charging receiver attached to a cell phone using a flip mechanism.

Figure 9 shows a power charging receiver attached to a cell phone using the a slide mechanism.

DETAILED DISCLOSURE

In one aspect, the present disclosure describes a planar near-field wireless power charging system that is capable of charging small portable devices. Embodiments can incorporate coils for generating time-varying magnetic fields into a pad. Embodiments of the wireless power charging system can allow powering devices at close proximity. In an embodiment, a charging efficiency of greater than 75% can be achieved. In a further embodiment, a charging efficiency of greater than 85% can be achieved. Specific embodiments can allow charging to occur at a distance of, for example, up to about 5 inches above the pad. The ability to charge the device with up to a 5 inch separation between the device and the charging unit, or portion thereof, allows versatility as to where devices can be positioned during the charging process. In a specific embodiment, a receiver coil as small as 10% of the transmitting coil can be utilized. In an exemplary embodiment, the system is capable of charging multiple devices at the same time.

In an exemplary embodiment, the charging system incorporates a charging pad that can act as an electrically small coil antenna for the low frequencies and long wavelengths, used for charging, and long wavelengths, and which can also be used for communication purposes by treating it as an electrically large antenna at higher frequencies, and shorter wavelengths, used for communications. In a specific embodiment, a power signal for charging can have a frequency less than or equal to IMHz. in a further embodiment, the data signal for communications can have a frequency in the ultra wide band (UWB) of 3.IGHz-10.6GHz and use a carrier-less signal with pulses, or a carrier based signal with a carrier frequency in the WiFi band, e.g., at 2.4GHz.

Figure 1 shows one embodiment of a system architecture of a planar near-field wireless power charger and high-speed data communication platform. The system architecture can include a power transmitter, power receiver and energy harvesting circuit, and transmitting coil pad. In an exemplary embodiment, the subject platform is designed for short range applications using near field coupling. This embodiment can achieve high data rates using a simple transceiver architecture. In various embodiments, the base station can: transmit a power signal; transmit a power signal and transmit a data signal; transmit a power signal, transmit a data signal, and receive a data signal; or transmit a power signal and receive a data signal. The base station can break the various transmit and/or receive functions into separate transmitters and receivers, or combine such functions into one or more transceivers. By using a single coil to transmit and receive costs and space can be saved. Likewise, the receiver can: receive a power signal; receive a power signal and transmit a data signal; receive a power signal, transmit a data signal, and receive a data signal; or receive a power signal and transmit a data signal. The transmit power, transmit data, receive power, and receive data functions can be performed sequentially or simultaneously.

The wireless transfer of power and data can allow a variety of configurations. An embodiment can use a first pad and a second pad, each having a base station, and a television having a receiver, with the TV on the first pad and a DVD player having a receiver on a second pad. Power is provided to the DVD player and data can be received by the second pad from the DVD player. The received data can then be transferred from the second pad to the first pad and then from the data transmitter in the first pad to the receiver in the TV. Other embodiments can use a pad and an audio device, such as and MP3 player, where power is supplied to the audio device and music data is received by the pad from the audio device. The received audio data can then be delivered to, for example, speakers or some sort of device to further utilize the audio data. The pad can be networked to a home or office network, such that received data can be distributed as needed. The data can also include information about the charging state of the receiver device. In a specific embodiment, the data can be transmitted at a rate of 50Mb-500Mb. In another specific embodiment, the data can be transmitted at a rate up to lGbps.

Figure 2 shows an embodiment of a platform in accordance with the present disclosure. Exemplary applications of this system include its use as a platform for wireless power charging and high data rate communication for portable devices, such as mobile phones and mp3 players. The system can be implemented in various locations, such as homes, airports, and hotel rooms. This adds convenience as it provides a universal charging interface and can reduce, or eliminate, the need to bring multiple chargers. In addition, it can serve as a high speed data link between devices so that data can be exchanged on the same platform, instead of separate ones. This can be integrated with a smart home or smart office space. The system can have simple hardware architecture so as to achieve low cost for mass production. In one embodiment, a wireless near-field high-speed data communication capability is implemented as part of the system.

Preferably, the magnetic flux generated by the transmitting coil pad is substantially uniform over at least a major part of the planar charging surface. In this way, the impact that the precise position and orientation of the electronic device on the charging surface has on the charging efficiency is reduced. The system illustrated in Figure 2 includes a power transmitter 4 that powers a power-transmitting coil pad 6. The power transmitter 4 is powered by power source 2. The transmitting coil pad 6 wirelessly sends power to a power receiver and energy harvesting circuit 8. The power receiver is connected to the target electronic device 10. In alternative embodiments, the power receiver and energy harvesting circuit can be attached or integrated with the target device, such that the target device can be placed on or near the coil pad for charging. In an exemplary embodiment, discussed later, the power receiver is formed as a back cover of the electronic device. In an exemplary embodiment, the equipment is charged simply by placing the power receiver on, or near, the transmitting coil pad surface.

In an exemplary embodiment, the system uses multiple lower powered transmitters, where each transmitter feeds a separate coil. The separate coils can be stacked so that the magnetic fields are substantially coextensive. The simultaneous driving of the multiple coils by the multiple transmitters can achieve similar power delivery as a single high powered transmitter. In a specific embodiment, the size of each lower powered transmitter can be reduced up to 80-90% compared with a single high-powered transmitted, such that the large transformer typically used to step up the voltage to a high voltage can be eliminated from the system. Removing the large transformer can enhance safety. Figure 3 shows a diagram of one embodiment incorporating a multiple-transmitter power delivery system for a multiple coil design having seven coils. Multiple stacked sets of coils can be integrated into a pad such that each stacked set of coils provides vertical magnetic fields over a section of the pad. Figure 4 shows a system block diagram of a multiple-transmitter power delivery system that can be used with a coil design having eight coils.

Figures 5A -5B show embodiments of a single transmitter coil for a wireless power system. The coils can have a variety of shapes. This coil can be integrated with a pad, or other object, for placing devices to be charged on or near the pad. In an embodiment, the coils are positioned such that the resulting magnetic field is normal to a surface of the pad, such that receiver coils can be located on the pad's surface to receive the magnetic fields. In a specific embodiment, the transmitter coil, such as the coil shown in Figure 5, can be driven by multiple transmitters, which can each be selectively turned on or off, and tuned. In a specific embodiment incorporating a stacked set of coils, each transmitter can be tuned independently, thereby achieving a wide tuning range. Individual tuning of the coils can be performed in near real time and increase energy transfer efficiency for different charging circumstances. Power control can be achieved by individually turning on and off the individual transmitters depending on the charging load, making it more energy efficient. The multiple-transmitter design enables the transmitter system to be more flexible and adaptive to a wider range of environmental situations while consuming less power. Thus, a significant improvement in efficiency can be attained. In a specific embodiment, each transmitter for the stacked set of coils is identical, or each transmitter for the multiple transmitters driving a single coil, allowing low cost for mass production. Since the transmitters are the same, additional transmitters can be easily added to the system to boost the maximum output, thereby offering a great advantage for scalability. Having multiple transmitters also gives the system many extra degrees of freedom for achieving a higher dynamic range. In a specific embodiment, the coils in the stacked configurations are driven in place by the plurality of transmitters.

Referring to Figure 6, a device incorporating a coil design to receive power from surface magnetic fields that are substantially horizontal is shown. In accordance with current wireless power charging technology that uses horizontal magnetic fields for coupling of energy to charge portable electronic devices. The receiver coil used with the device to be charged receives magnetic field flux that is substantially parallel with the surface of the pad the device is placed on and does not extend very far above the surface of the pad. Such use of horizontal magnetic fields is inefficient because the cross sectional area of the receiver coil is limited; thus, the coupling factor is low. Embodiments of the subject invention can be designed to couple energy to the receiver coil of the device via magnetic fields that have a substantial vertical component. Examples of transmitter coil design that can be used to produce magnetic fields that have a substantial vertical component are shown in Figure 3 and Figure 5. Other designs can also be used in accordance with the invention.

Using a vertical field for coupling of energy can be more efficient. However, by mounting the receiver on the back of a portable device, the efficiency of such coupling can be reduced as the magnetic field must pass through the portable device in order to pass through the receiver coil. An embodiment of the present disclosure describes a receiver coil attached to a portable electronic device with a mechanical connection that allows the receiver coil to be positioned such that the vertical fields do not need to pass through a substantial portion of the device to pass through the receiver coil during charging and can allow the receiver coil to be conveniently positioned adjacent the device when not charging. In specific embodiments, the receiver coil can be positioned so that the magnetic fields pass through less than one half of the body of the device. In exemplary embodiments, the mechanical connection can be a flip or slide mechanism that allows the receiver coil to be positioned such that a vertical magnetic field does not need to pass through the portable device in order to pass through the receiver coil during charging, but allows the receiver coil to reside adjacent to the device when not charging in order to make the device with receiver coil easier to carry and store. The use of such a mechanical connection can enable efficient charging of the device without significant modification to the device's form factor, as shown in Figure 7.

The receiver can be designed as an add-on device or as part of a portable electronic device such as a mobile phone. In an exemplary application, a user need not replace an entire phone to take advantage of the new technology. For example, the user can replace the back panel or the battery cover of a phone or device to make the device compliant to this technology.

Figures 8A and 8B show a power charging receiver coil attached to a cell phone using a flip mechanism. In one embodiment, the flip mechanism includes a catch at one end of the device and a hinge on the other end of the device for allowing the receiver coil to flip open. The receiver coil can flip out, as shown by arrows in Figure 8B, such that the receiver coil is rotated 180 degrees and is parallel with the surface of the device from where it rotated from. In an alternative embodiment, the receiver coil can rotate 90 degrees and be used to receive horizontal magnetic fields for charging the device. Figure 9 shows a power charging receiver attached to a cell phone using a slide mechanism. In this embodiment, the receiver coil is slid out away from the phone body and placed on the charging pad so that the receiver coil is substantially parallel with the surface of the charging pad so as to allow the vertical portion of the magnetic field to pass through the receiver coil. Other mechanisms can be incorporated with embodiments of the invention to coordinate the relative position of the device body and the receiver coil.

The large cross-sectional area of the receiver coil provides for increased coupling for use with a near-field planar wireless power charger system. Positioning the receiver coil, for example, via the flip mechanism or the slide mechanism, such that the magnetic field flux does not pass through the body of the device enhances the charging efficiency. The device can be charged in the pre-flip or pre-slide position, but at a slower rate. To fully realize the benefits of the subject receiver coil design, the wireless power charger system can incorporate a vertical magnetic field for coupling of energy to the receiver coil. Such a vertical magnetic field achieves a higher efficiency coupling and, therefore, higher efficiency charging. Further, embodiments using vertical fields can allow the receiver coil to be positioned higher off of the pad having the transmitted coils than with systems using horizontal fields, while achieving the same coupling efficiency. In a specific embodiment, the receiver coil can be up to 5 inches above the pad.

All patents, patent applications, provisional applications, and publications referred to or cited herein are incorporated by reference in their entirety, including all figures and tables, to the extent they are not inconsistent with the explicit teachings of this specification.

It should be understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application.

CLAIMS

1. A wireless power transfer system, comprising:

a base station, wherein the base station comprises:

a transmitter coil;

a power transmitter, wherein the power transmitter is capable of driving the transmitter coil such that a first magnetic field is produced; and

a data receiver,

a receiver station, wherein the receiver station comprises:

a receiver coil, wherein the receiver coil inductively couples the first magnetic field to produce a received power signal; and

a data transmitter, wherein the data transmitter drives the receiver coil to produce a transmitted data signal,

wherein the transmitter coil inductively couples the transmitted data signal to produce a received RF data signal, wherein the data receiver receives the received RF data signal and outputs a received data signal.

2. The wireless power transfer system according to claim 1, where in the receiver station further comprises an energy harvesting circuit, wherein the energy harvesting circuit receives the received power signal and outputs DC power.

3. The wireless power transfer system according to claim 1, wherein the receiver station further comprises a target device, wherein the target device provides a data input signal to the data transmitter, wherein the data input signal is used by the data transmitter to produce the data signal.

4. The wireless power transfer system according to claim 1, wherein the base station further comprises:

a second data transmitter, wherein the second data transmitter drives the transmitter coil to produce a second transmitted data signal, wherein the receiver station further comprises a second data receiver, wherein the receiver coil inductively couples the second transmitted data signal to produce a second received RF data signal.

5. The wireless power transfer system according to claim 1, wherein the power transmitter and the data receiver are integrated as a first transceiver.

6. The wireless power transfer system according to claim 4, wherein the data transmitter and the second data receiver are integrated as a second transceiver.

7. The wireless power transfer system according to claim 4, wherein the second data transmitter is integrated with the power transmitter and the data receiver as the first transceiver.

8. The wireless power transfer system according to claim 4, wherein the second data receiver is integrated with the data transmitter and the second data receiver as the second transceiver.

9. The wireless power transfer system according to claim 4, wherein the power transmitter and the second data transmitter are capable of simultaneously driving the transmitter coil, wherein the power transmitter drives the transmitter coil at a first wavelength and the second data transmitter drives the transmitter coil at a second wavelength.

10. A wireless power transfer system, comprising:

a base station, wherein the base station comprises:

a transmitter coil;

a power transmitter, wherein the power transmitter is capable of driving the transmitter coil such that a first magnetic field is produced; and

a data transmitter,

a receiver station, wherein the receiver station comprises:

a receiver coil, wherein the receiver coil inductively couples the first magnetic field to produce a received power signal; and

a data receiver, wherein the data transmitter drives the transmitter coil to produce a transmitted data signal,

wherein the reciever coil inductively couples the transmitted data signal to produce a received RF data signal, wherein the data receiver receives the received RF data signal and outputs a received data signal.

11. A method of wireless power transfer, comprising:

providing a base station, wherein the base station comprises:

a transmitter coil;

a power transmitter; and

a data receiver,

providing a receiver station, wherein the receiver station comprises:

a receiver coil; and

a data transmitter,

driving the transmitter coil with the power transmitter such that a first magnetic field is produced;

inductively coupling the first magnetic field to the receiver coil to produce a received power signal;

driving the receiver coil with the data transmitter to produce the transmitted data signal;

inductively coupling the transmitted data signal to the transmitter coil to produce a received RF data signal;

receiving the received RF data signal by the data receiver; and

outputting a received data signal by the data receiver.

12. The method according to claim 11, where in the receiver station further comprises an energy harvesting circuit, further comprising receiving the received power signal by the energy harvesting circuit and outputting DC power by the energy harvesting circuit.

13. The method according to claim 11, wherein the receiver station further comprises a target device, further comprising providing a data input signal from the target device to the data transmitter, wherein the data input signal is used by the data transmitter to produce the data signal.

14. The method according to claim 11, wherein the base station further comprises:

a second data transmitter and the receiver station further comprises

a second data receiver, the method further comprising:

driving the transmitter coil with the second data transmitter to produce a second transmitted data signal; and

inductively coupling the second transmitted data signal to the receiver coil to produce a second received RF data signal.

15. The method according to claim 11, wherein the power transmitter and the data receiver are integrated as a first transceiver.

16. The method according to claim 14, wherein the data transmitter and the second data receiver are integrated as a second transceiver.

17. The method according to claim 14, wherein the second data transmitter is integrated with the power transmitter and the data receiver as the first transceiver.

18. The method according to claim 14, wherein the second data receiver is integrated with the data transmitter and the second data receiver as the second transceiver.

19. The method according to claim 14, wherein the power transmitter and the second data transmitter are capable of simultaneously driving the transmitter coil, wherein the power transmitter drives the transmitter coil at a first wavelength and the second data transmitter drives the transmitter coil at a second wavelength.

20. A method of wireless power transfer, comprising:

providing a base station, wherein the base station comprises:

a transmitter coil;

a power transmitter; and

a data transmitter,

providing a receiver station, wherein the receiver station comprises:

a receiver coil; and

a data receiver,

driving the transmitter coil with the power transmitter such that a first magnetic field is produced;

inductively coupling the first magnetic field to the receiver coil to produce a received power signal;

driving the transmitter coil with the data transmitter to produce the transmitted data signal;

inductively coupling the transmitted data signal to the receiver coil to produce a received RF data signal;

receiving the received RF data signal by the data receiver; and

outputting a received data signal by the data receiver.

21. A wireless power transfer system, comprising:

a plurality of transmitters;

a corresponding plurality of transmitter coils, wherein each transmitter delivers power to a corresponding transmitter coil, so as to produce a corresponding plurality of magnetic fields, wherein the plurality of transmitter coils are positioned such that corresponding plurality of magnetic fields are substantially coextensive.

22. The system according to claim 21, wherein the plurality of transmitter coils are positioned such that the plurality of magnetic fields are normal to a surface.

23. The system according to claim 22, further comprising at least one receiver coil, wherein the at least one receiver coil is positionable with respect to the surface such that the at least one receiver coil is substantially parallel with the surface.

24. The system according to claim 22, wherein the plurality of transmitter coils are integrated in a pad, wherein the surface is on the pad.

25. The system according to claim 21, wherein each of the plurality of transmitters can be tuned independently.

26. The system according to claim 21, wherein the plurality of transmitters can be individually turned on and off depending on a needed charging load.

27. The system according to claim 21, wherein the plurality of transmitters drive the plurality of transmitter coils in phase.

28. An electronic device, comprising:

a body;

a receiver coil; and

a connector, wherein the connector moveably connects the receiver coil to the body such that the receiver coil can transition between at least two positions relative to the body, wherein at least one of the at least two positions the receiver coil can receive magnetic fields normal to the receiver coil without the received magnetic fields passing through a substantial portion of the body.

29. The device according to claim 28, wherein the connector allows the receiver coil to slide relative to the body to transition between the at least two positions.

30. The device according to claim 28, wherein the connector allows the receiver coil to rotate relative to the body to transition between the at least two positions.

31. The device according to claim 28, wherein in at least one other of the at least two positions the receiver coil is adjacent the body such that magnetic fields normal to the receiver coil pass through a substantial portion of the body.

32. The device according to claim 31, wherein the connector comprises a hinge locateded at an end of the body, wherein the hinge allows the receiver coil to rotate from a first position adjacent the body to a second position that is an approximately 180° rotation of the receive coil with to the hinge.

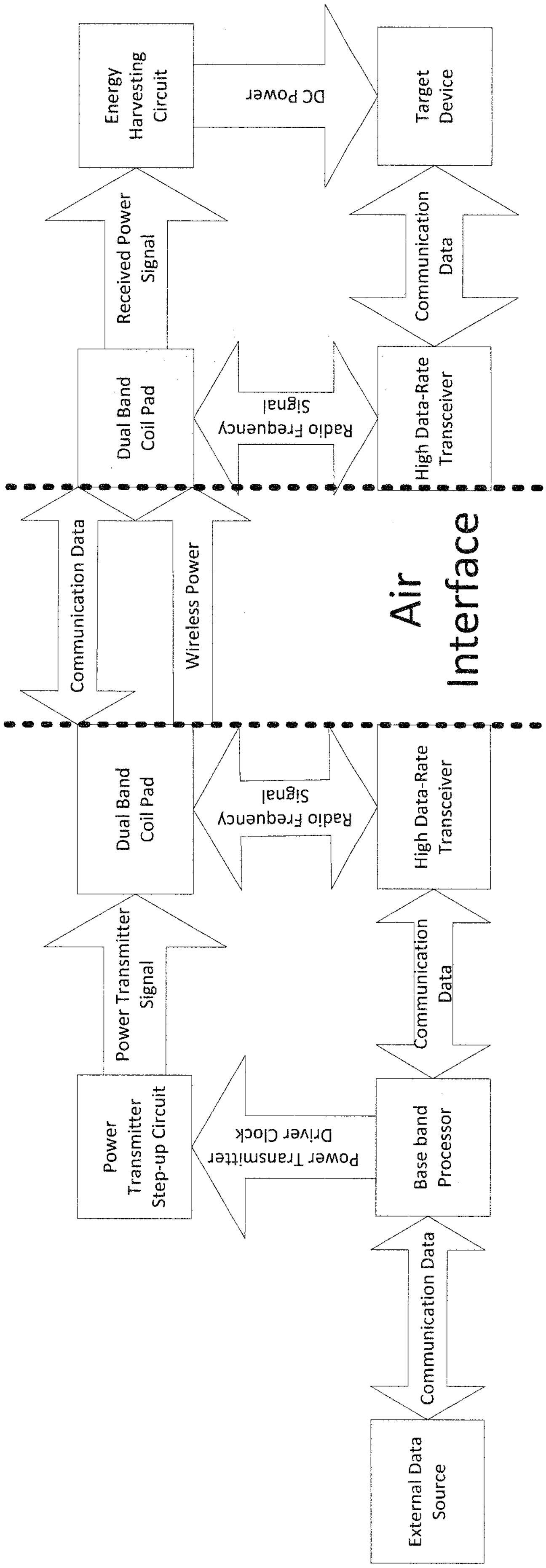

External Data Source
Communication Data
Base band Processor
Power Transmitter Driver Clock
Power Transmitter Step-up Circuit
Communication Data
Power Transmitter Signal
High Data-Rate Transceiver
Radio Frequency Signal
Dual Band Coil Pad
Communication Data
Wireless Power
Air Interface
Dual Band Coil Pad
Radio Frequency Signal
High Data-Rate Transceiver
Received Power Signal
Communication Data
Energy Harvesting Circuit
DC Power
Target Device

FIG. 1

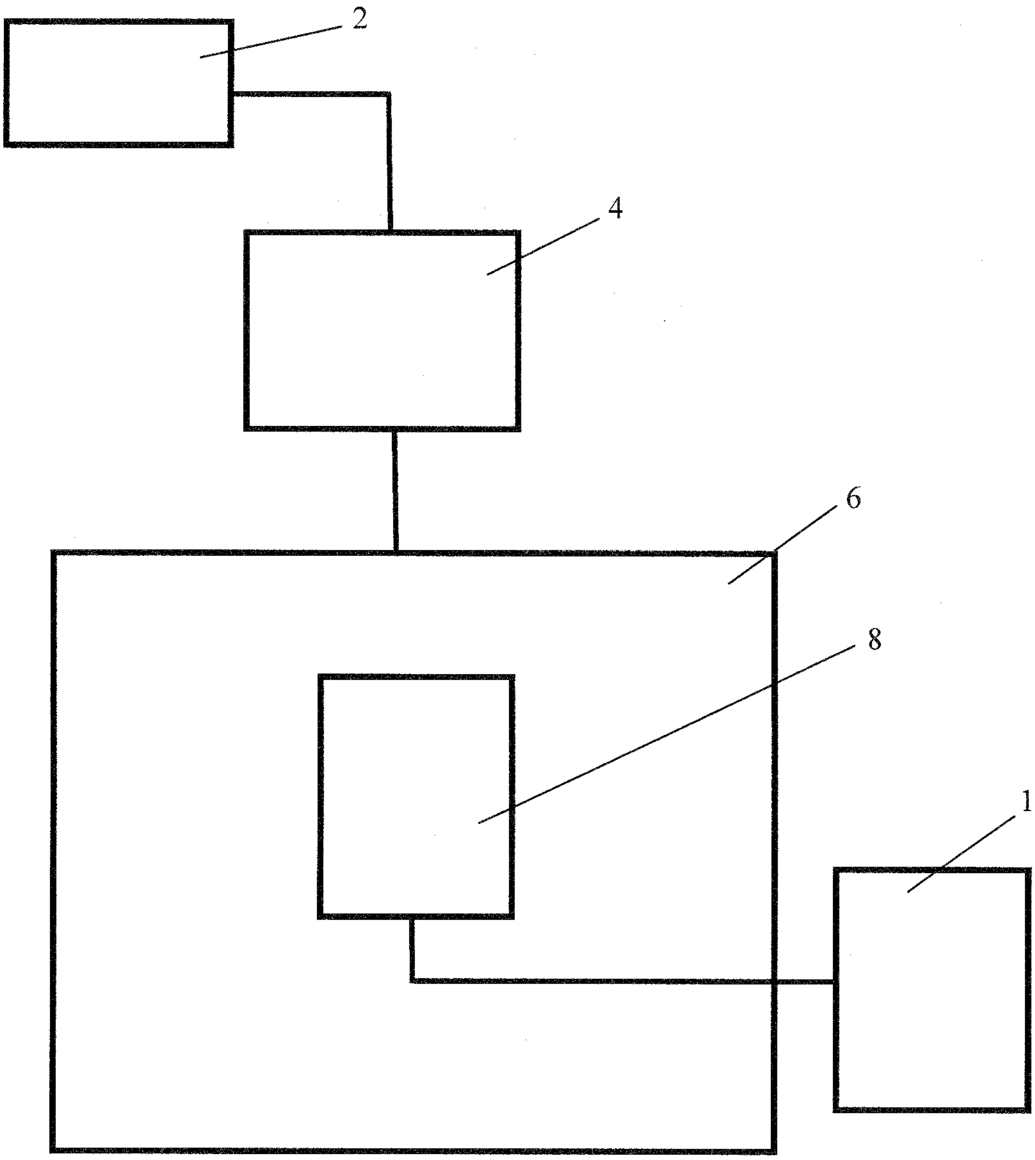


FIG. 2

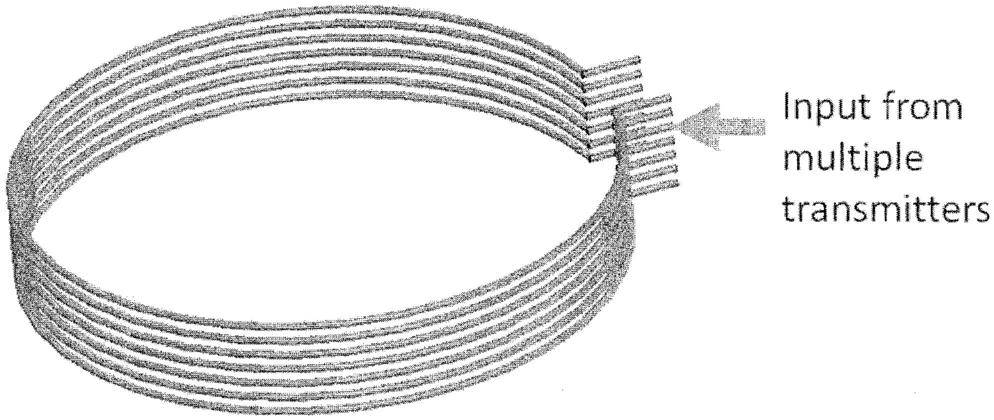
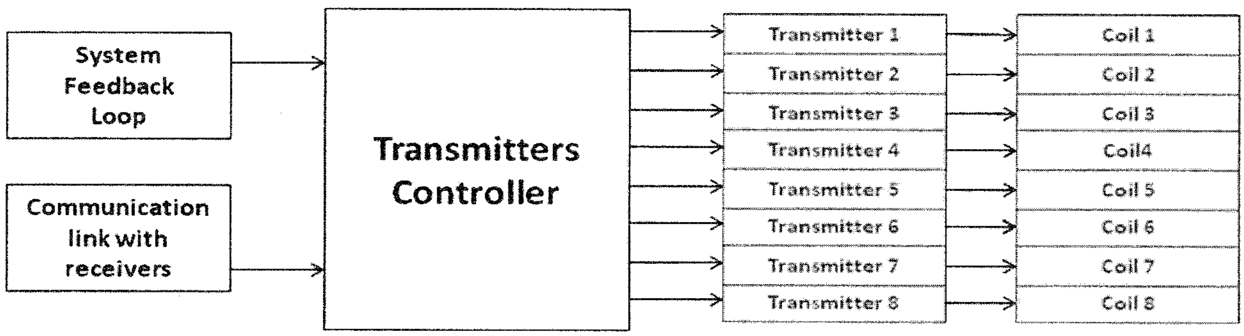

Input from
multiple
transmitters

FIG. 3


System
Feedback
Loop
Communication
link with
receivers
Transmitters
Controller
Transmitter 1
Transmitter 2
Transmitter 3
Transmitter 4
Transmitter 5
Transmitter 6
Transmitter 7
Transmitter 8
Coil 1
Coil 2
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Coil4
Coil 5
Coil 6
Coil 7
Coil 8

FIG. 4

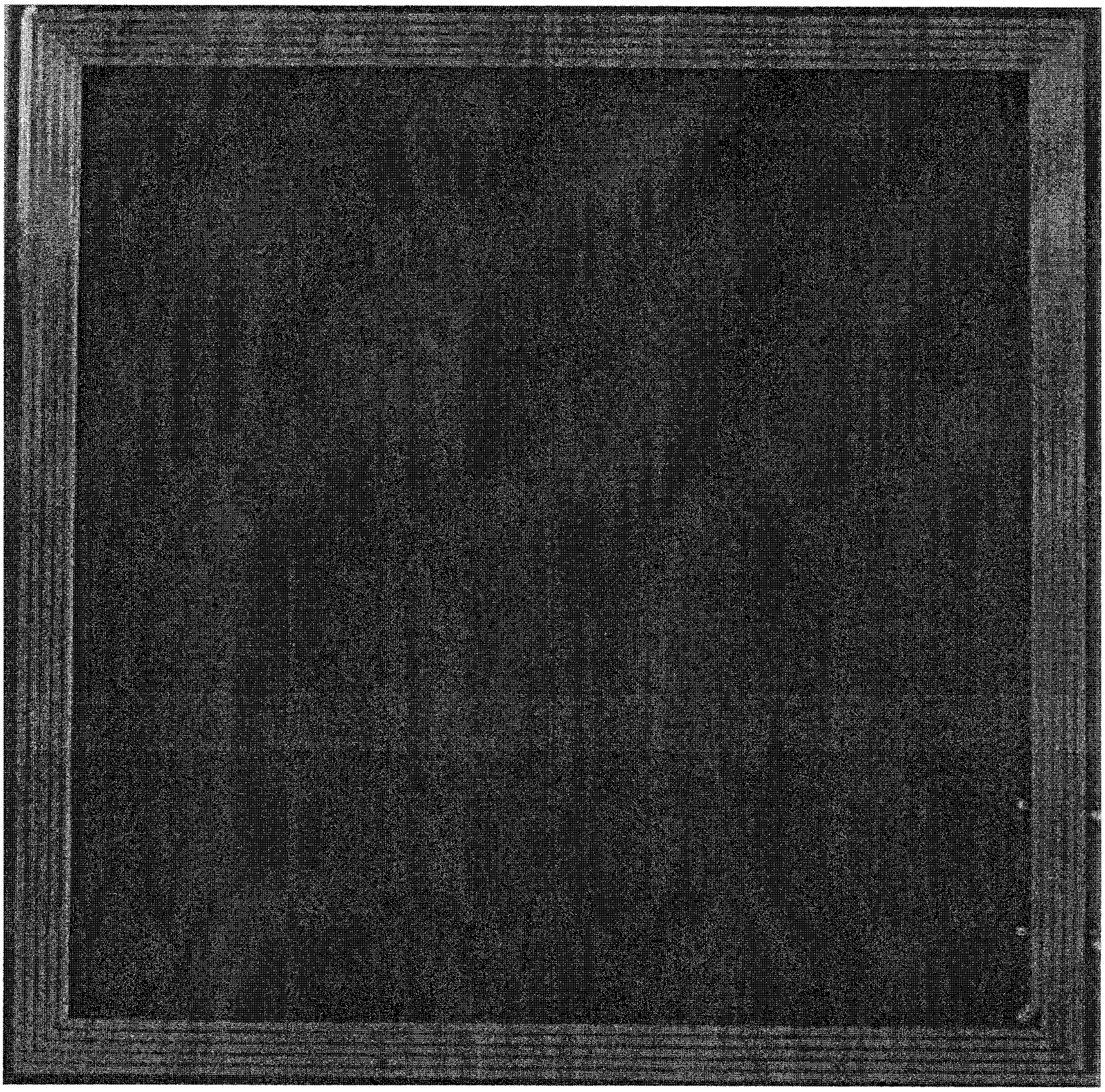

FIG. 5A

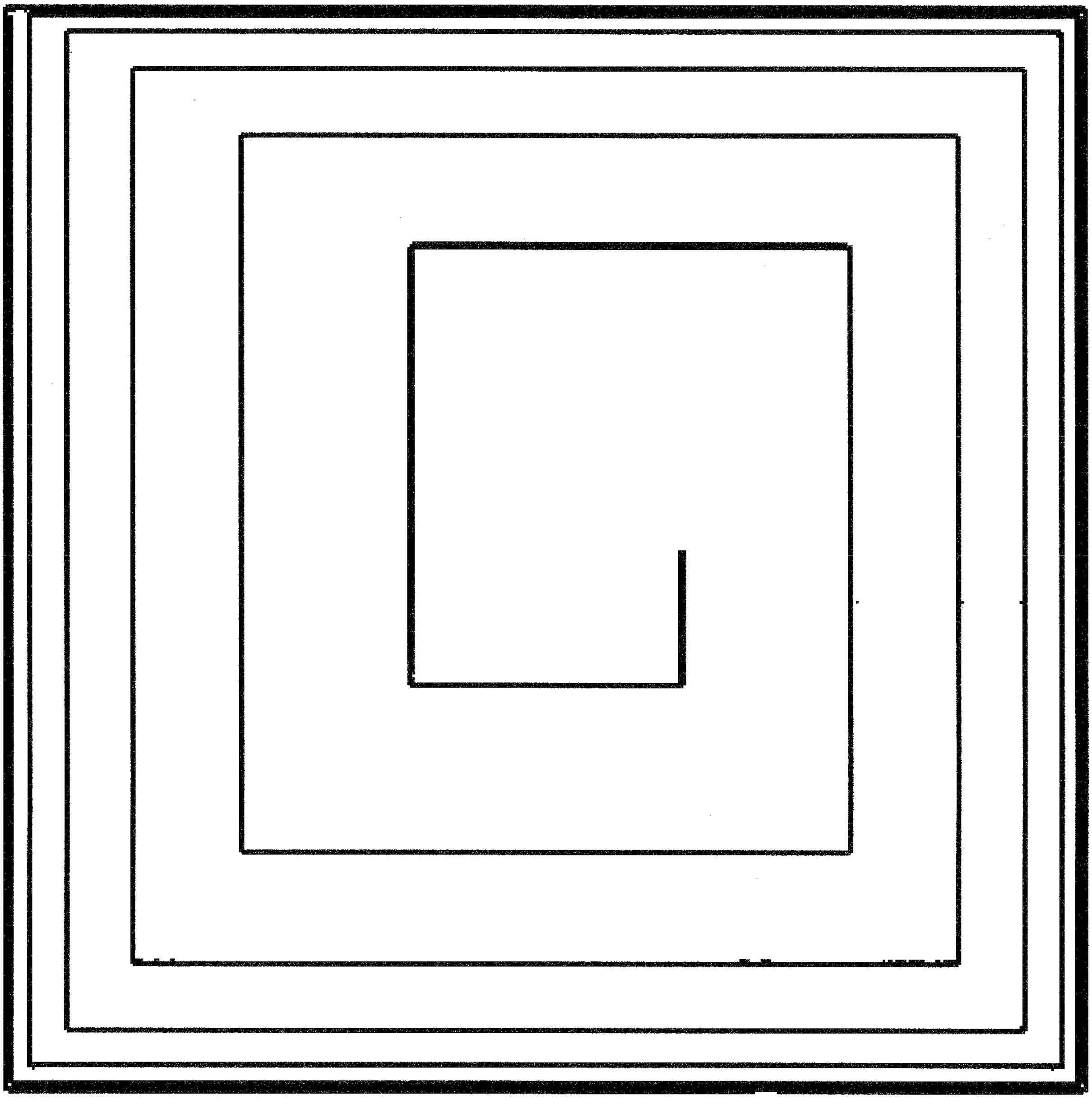

FIG. 5B

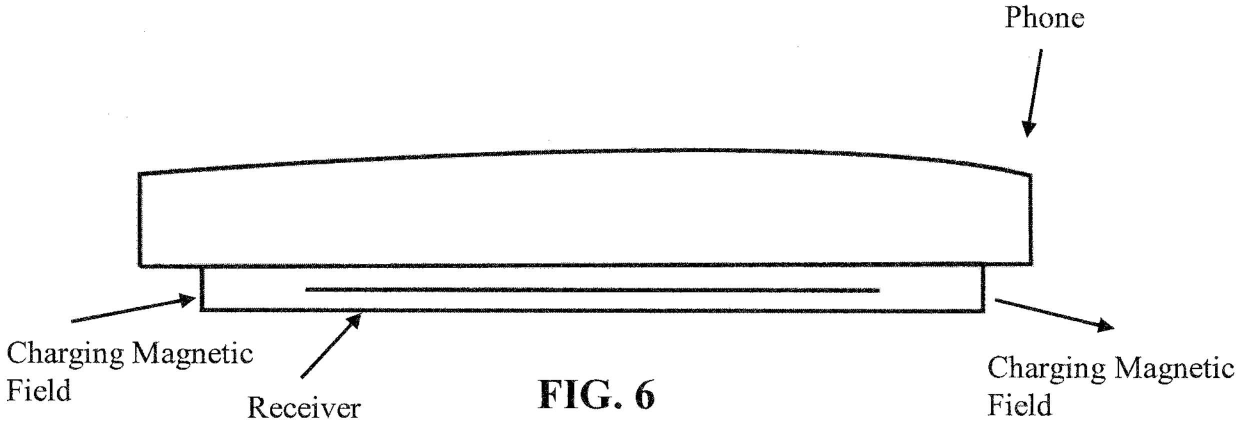

FIG. 6

(Prior Art)

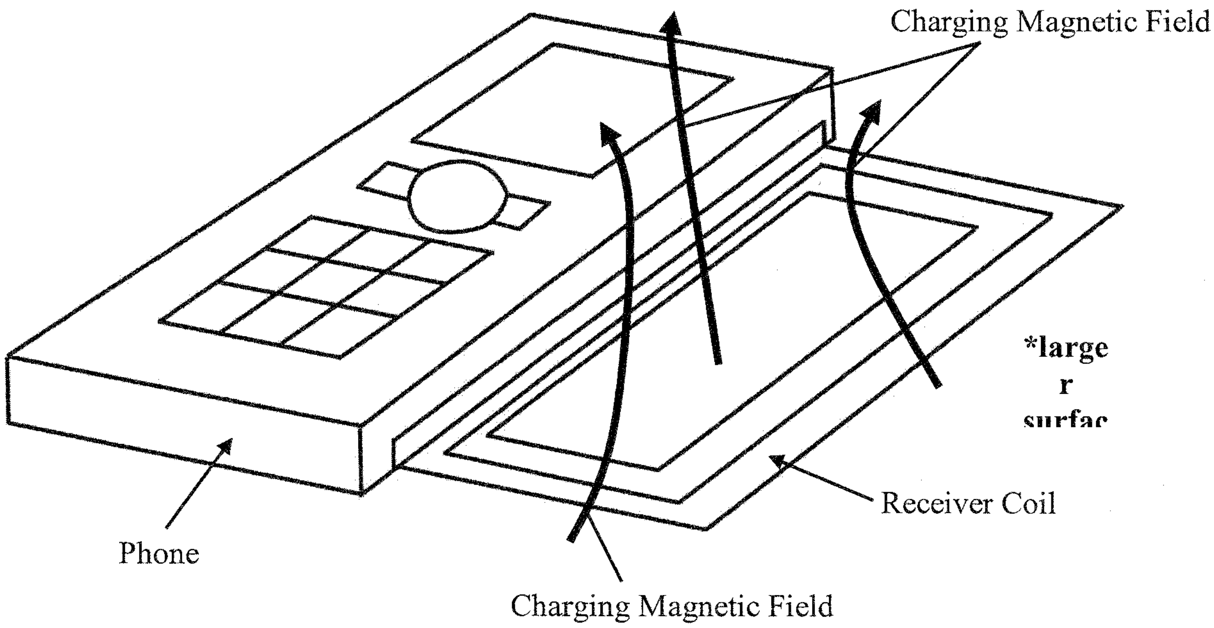

FIG. 7

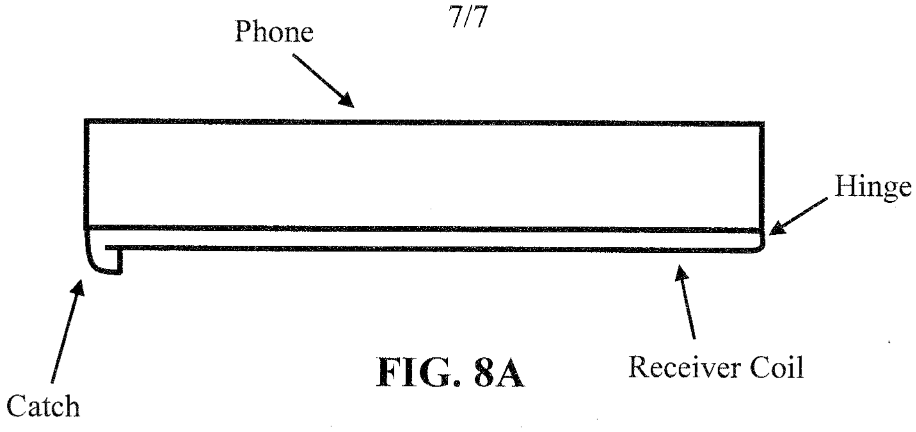

FIG. 8A

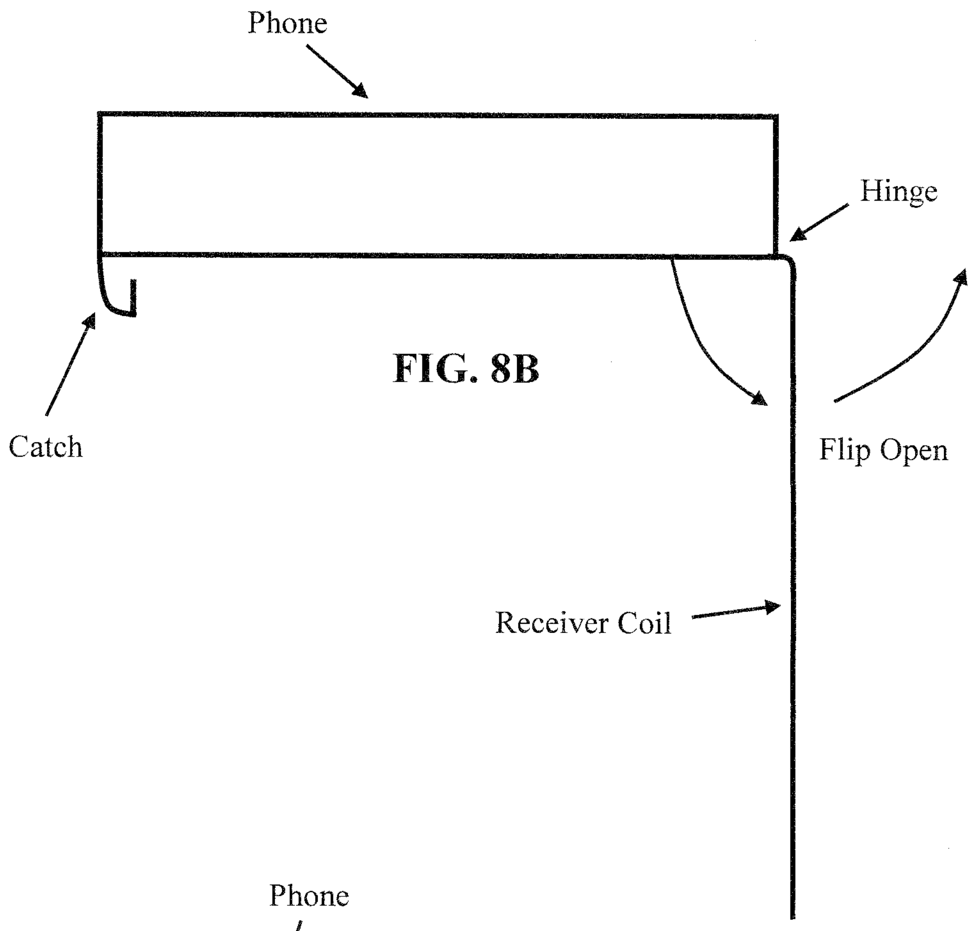

FIG. 8B

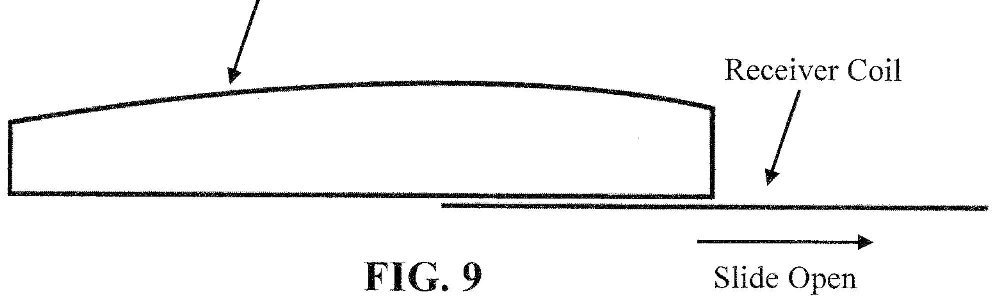

FIG. 9