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(54) **Title**: METHOD AND APPARATUS FOR WIRELESS CHARGING

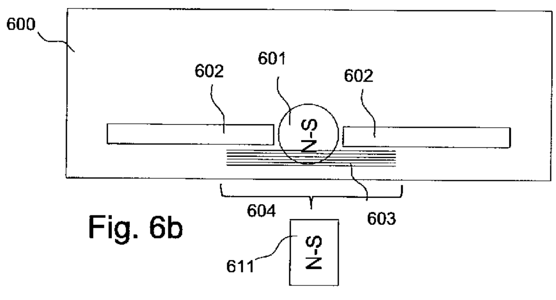

Fig. 6b

(57) **Abstract**: In accordance with an example embodiment of the present invention the application discloses an apparatus (600) comprising: at least one inductive means (603) arranged to inductively transform a magnetic flux into an electric current; and at least one magnet (601) capable of rotating between an inactive and an active position, wherein in the active position the magnetic flux through the surface (604) of the apparatus is maximized, and wherein in the inactive position the magnetic flux through the surface of the apparatus is minimized.

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METHOD AND APPARATUS FOR WIRELESS CHARGING

TECHNICAL FIELD

[0001] The present application relates generally to wireless charging systems wherein electromagnetic field is used to transfer energy over the air. A wireless charging system may for example comprise a pair of coils coupled to each other for transferring energy by means of electromagnetic induction. In particular, the invention relates to positioning of the devices and alignment of the coils to maximize efficiency.

BACKGROUND

[0002] Electromagnetic induction has been known for a long time and it has been used in many applications such as generators, electronic motors, and transformers. In electromagnetic induction a time-varying magnetic flux induces an electromotive force to a closed conductor loop. Vice versa, a time-varying current creates a varying magnetic flux. In transformers, this phenomenon is utilized to transfer energy wirelessly from circuit to another via inductively coupled coils. A primary coil transforms an alternating current into a varying magnetic flux, which is arranged to flow through the secondary coil. The varying magnetic flux then induces an alternating voltage over the secondary coil. The proportion of the input and output voltage can be adjusted by the number of turns in the primary and secondary coils.

[0003] Wireless charging is another application where electromagnetic induction is used to transfer energy over the air. A wireless charging system comprises a charger device with a primary coil, and a device to be charged with a secondary coil. The current in the charger device is transferred to the charged device through these electromagnetically coupled coils, and the induced current may further processed and used to charge the battery of the charged device. Since the induced electromotive force depends on the magnetic flux through the secondary coil it is d that the coils are well aligned to maximize the efficiency of the energy transfer. Displacement of the primary and secondary coils may result in poor charging performance and long charging times.

SUMMARY

[0004] Various aspects of examples of the invention are set out in the claims. According to a first aspect of the present invention, an apparatus is disclosed. The apparatus comprises at least one inductive means arranged to inductively transform a magnetic flux into an electric current; and at least one magnet capable of switching between an inactive and an active position, wherein in the active position the magnetic flux through the surface of the apparatus is maximized, and wherein in the inactive position the magnetic flux through the surface of the apparatus is minimized.

[0005] According to a second aspect of the present invention, a method is disclosed. The method comprises arranging a magnet to switch from an inactive position to an active position, wherein in the active position the magnetic flux through the surface of the apparatus is maximized, and wherein in the inactive position the magnetic flux through the surface of the apparatus is minimized; and inductively transforming a magnetic flux into an electric current by an inductive means.

[0006] According to a third aspect of the present invention, an apparatus is disclosed. The apparatus comprises at least one inductive means arranged to transform an electrical current into a magnetic flux; and least one magnet capable of switching between an inactive and an active position, wherein in the active position the magnetic flux through the surface of the apparatus is maximized, and wherein in the inactive position the magnetic flux through the surface of the apparatus is minimized.

[0001] According to a fourth aspect of the present invention, a method is disclosed. The method comprises arranging a magnet to switch from an inactive position into an active position, wherein in the active position the magnetic flux through the surface of the apparatus is maximized, and wherein in the inactive position the magnetic flux through the surface of the apparatus is minimized; and transforming an electric current into a magnetic flux by an inductive means.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For a more complete understanding of example embodiments of the present invention, reference is now made to the following descriptions taken in connection with the accompanying drawings in which:

[0008] FIGURE 1 illustrates the inductive charging principle;

[0009] FIGURE 2ab illustrates the alignment of the coils;

[0010] FIGURE 3 presents exemplary efficiency loss due to coil misalignment;

[0011] FIGURE 4ab presents wireless charging systems according to embodiments of the invention;

[0012] FIGURE 5 illustrates the magnetic flux around a magnet.

[0013] FIGURE 6abc illustrates functionality of the rotating magnet; and

[0014] FIGURE 7 illustrates the magnetic flux in the ferromagnetic material, when the magnet is in the inactive position.

[0015] FIGURE 8 illustrates an exemplary device using one or more embodiments of the invention.

DETAILED DESCRIPTON OF THE DRAWINGS

[0016] Wirless charging may be applied for a range of devices such as mobile phones, cameras, laptops, personal data assistants (PDA), music/video players and the like. Alternatively, the device may instantly consume the delivered energy without storing it for future use.

[0017] It is accepted that products from different manufacturers are interoperable and, for example, the same charging platform can be used for charging different devices. Wireless Power Consortium is an open international consortium developing interoperable solutions for wireless charging technology. Coil alignment is considered to be an area of interest, and therefore different solutions are presented. These solutions include for example the three following methods

[0018] First, coil alignment can be realized by a coil array in the charger platform, which allows free positioning of the charged device. The charging platform comprises a plurality of primary coils, which can be selectively activated based on the position of the charged device. Second, free positioning can be achieved by a moving coil in the charging platform. Third, the charging platform may use guided positioning where magnetic attraction is used to guide the charged device into the best position. Coil alignment by magnetic attraction provides an inexpensive method for accurate coil positioning since only single coil is needed in the charging platform and using magnetic attraction guarantees that the coils are well-positioned.

[0019] An example embodiment of the present invention and its potential advantages are understood by referring to FIGURES 1 through 8 of the drawings.

[0020] FIGURE 1 illustrates an exemplary wireless charging system, where energy can be transferred through electromagnetic induction. Charging platform 121, which is also referred to as transmitter, comprises at least a primary coil 122 and an electric power supply 120. The charging platform 121 may also comprise any internal circuitry, one or more processors 124 and one or more memories 125, which are necessary to control the operation of the charging platform 121.

[0021] The electric current available from the power supply is arranged to flow through the primary coil 122, which causes the magnetic flux 110 to appear. The power supply may provide an alternating current (AC), which causes the magnet flux to be time-variant and thus capable of inducing an electromotive force in a conductor.

[0022] The charged device 100, which is also known as the receiver, comprises a secondary coil 102 arranged to transform the magnetic flux 110 into an electric current. The charged device may include also an AC-to-DC converter 103 for converting an alternating current to a direct current. The charged device may also include a battery 106 for storing the electric energy captured by the secondary coil 102. The coils can be generalized to include any inductive means, i.e. any kind of elements that make the inductive coupling possible and are capable of creating interdependence between a current and a magnetic flux.

[0023] Alternatively, the device may not include a battery and the transferred energy may be instantly consumed in the receiver device. The charged device may also include any circuitry, processors 104, and memory 105 necessary for delivering the electric currents in the device or controlling the operation of the charged device 100.

[0024] The receiver device may be any type of device including, e.g., battery operated devices like mobile phones, cameras, tablet computers, personal data/digital assistants (PDA), music/video players and the like. The devices may include also other consumer appliances such as electric toothbrushes, torches, console controllers etc. Despite throughout the specification wireless charging is presented as the main application it is not the intention to limit the scope of the invention only to battery operated devices.

[0025] FIGURE 2ab presents an example of alignment between a primary coil 201 and a secondary coil 202. Since the induced current depends on the magnetic flux through the secondary coil it is important that the coils are well aligned to maximize the efficiency of the energy transfer. In FIGURE 2ab, primary coil 201 is intended to create a magnetic flux through the secondary coil 202. In Figure 2a, the coils are well aligned and most of the magnetic flux produced by the primary coil 201 flows through the secondary coil 202. Therefore, the efficiency of the energy transfer is maximized. In Figure 2b, the coils are not well aligned and only part of the magnetic flux produced by the primary coil 201 goes through the secondary coil 202. Therefore, the efficiency is worse than in Figure

2a. In a wireless charging system the displacement may result in poor charging performance and long charging times. It is also desirable that the coils are close to each other and that the angle between the coils is such that it allows maximal flux through the secondary coil.

[0026] As discussed above, inductive charging needs good positioning. This is illustrated in FIGURE 3 by presenting the power efficiency as a function of the coil displacement. In order to achieve good efficiency the coils need to be exactly on top of each other. Poor alignment causes the efficiency to drop dramatically and ultimately will cause the charging to stop. As an example, a 30% efficiency drop may be measured with 100 kHz inductive charger prototypes with approximately 18 mm coil displacement.

[0027] One way to improve coil alignment is to use magnets. For example, the charging platform may include a magnet in the proximity of the primary coil to guide the charged device, equipped with another magnet, into the best position. Compared to other solutions, e.g., coil arrays and moving charger coils, coil alignment by magnetic attraction provides an inexpensive way for accurate coil positioning, since only single coil is needed in the charging platform and using magnetic attraction guarantees that the coils are well-positioned. Magnetic attraction is also a user-friendly method, since pulling force automatically provides feedback for the user when the positioning is successful.

[0028] However, placing a magnet in the device, either in the transmitter or the receiver, causes a magnetic flux appear in the neighborhood of the device. This magnetic field is present also during normal operation when there is no need for any magnetic alignment. It would be desirable to minimize the magnetic flux through the surface of the device, when the magnet is not in use.

[0029] FIGURE 4ab presents two exemplary embodiments according to the invention. FIGURE 4ab includes a receiver device 400 and a transmitter device 410. The terms transmitter/transmitting and receiver/receiving are in this context to be understood as terms referring to the delivery of electrical energy. In a broader context, both of the devices may include other transmitting and receiving means, e.g., for cellular, short-range, or satellite communication.

[0030] In other embodiments, the receiver device 400 may be an accessory or a wireless charging adapter connected to the charged device. Such accessory, e.g. a sleeve attached to a mobile phone, may include wireless charging functionality and means for supplying the charging current to the charging input jack of the charged device. For example, such accessory may comprise a rectifier, i.e. an AC-DC converter, for converting the generated anternating current into direct current, a wireless power management unit for controlling the charging, and/or a DC-DC converter for adapting the output voltage according to the mobile phone input.

[0031] In FIGURE 4a, the transmitter 410 includes a primary coil 412 capable of transforming an electric current to a magnetic flux. The transmitter 410 also includes a primary magnet 411, which can be rotated or switched to change its polarity around an axle 413 with respect to the receiver 400. The receiver 400 includes a secondary coil 402, which is capable of transforming the magnetic flux produced by the transmitter 410 to an electric current. The receiver may also include a magnet 401, which may be fixed to a certain position. The receiver may further comprise circuitry, not shown in the figure, for delivering the generated current to a battery or an output in a suitable form, or, circuitry to deliver the generated current to a load in a suitable form. The receiver may for example comprise a rectifier for converting an alternating current into a direct current. The magnets can be generalized to include any magnetic means capable of creating a magnetic field.

[0032] FIGURE 4b presents another embodiment according to the invention. In this embodiment, the rotatable primary magnet 411 is located in the receiver device 400. The transmitting device 410 includes its own magnet 401 which may be fixed to certain position. In other embodiments, both the transmitting device and the receiving device may comprise a magnet capable of being rotated or switched between an inactive and an active position, such as primary magnet 411.

[0033] Although in FIGURE 4ab the rotatable primary magnet 411 is presented to be rotatable around axle 413, but it is not the intended to limit the scope of the invention to such arrangement. Other embodiments such as magnets rotating inside a cavity may be implemented as well. These embodiments may also let the primary magnet 411 rotate freely in any direction. Also, the invention does not limit the geometry of the primary magnet 411 in any way. Primary magnet 411 may have a shape of a cylinder as in FIGURE 4ab, but other shapes such as ball or cubicle are not excluded.

[0034] FIGURE 5 illustrates the magnetic flux 502 around magnet 501. Outside the magnet, the direction of the magnetic flux 502 is from the north pole (N) to the south pole (S) and the intensity of the magnetic flux is illustrated by the density of the lines. The strongest magnetic flux appears inside the magnet and in the proximity of the poles.

[0035] FIGURE 6abc illustrates the principle of rotatable magnet in accordance of an embodiment of the invention. Device 600 may be either a transmitter device capable of generating a magnetic flux, or a receiver device capable of transforming the magnetic flux generated by the transmitter into an electric current, as described earlier in this document. Device 600 may also be a wireless charging accessory, e.g. a sleeve, which receives the wireless energy and delivers the charging current to the charged device.

[0036] FIGURE 6a illustrates a device including a rotatable primary magnet 601 and a primary or secondary coil 603. In a transmitter device coil 603 is a primary coil and in a receiver device coil 603 is a secondary coil. Device 600 may further comprise ferromagnetic material 602 around or in the proximity of the magnet 601. In some embodiments of the invention the ferromagnetic material 602 may be in one piece, but in other embodiments it may comprise several pieces.

[0037] Ferromagnetic materials can be either permanent magnets or they will be temporarily magnetized when placed next to a magnet so that the magnetic moments of the ferromagnetic material will align to one direction. Ferromagnetic material 602 collects the magnetic flux of the primary magnet 601 and also prevents the coil 603 from interfering the electronics of the charged device. For example Fe, Co, Ni and alloys containing these materials are ferromagnetic.

[0038] FIGURE 6a shows the rotatable primary magnet 601 in its inactive position. In the inactive position the poles of the magnet are placed along the surface of the device, and therefore the strongest magnetic flux is in the same direction as the surface. In this context, the surface of the device is considered to be the surface closest to the primary magnet 601. Figure 6a also shows an exemplary attraction area 604 of the primary magnet 601. In the inactive position the magnetic flux through the attraction area 604 of the device 601 is minimized.

[0039] FIGURE 6b shows the rotatable magnet 601 in its active position. When an external magnet 611 is brought into the attraction area 604 of the rotatable primary magnet 601, the magnetic attraction between the magnets causes the rotatable primary magnet 601 to turn towards the external magnet 611. When the rotatable primary magnet 611 has turned towards the external magnet 611, the magnetic flux through the attraction are 604 is maximized, and therefore also the magnetic force between the magnets 611 and 601 is maximized. The magnetic force draws the magnets 611 and 601 closer to each other, which guarantees good alignment between the coils.

[0040] When other magnets are not in the proximity of the device 600, it is desired to minimize the magnetic flux through the attraction area 604 and therefore it is desired to keep the rotatable primary magnet 601 in its inactive position. For this purpose, along with others, the ferromagnetic material 602 may draw the rotatable primary magnet

601 into the inactive position. The magnetic force between the ferromagnetic material 602 and the rotatable primary magnet 601 may be advantageously smaller than the magnetic force between the rotatable primary magnet 601 and the external magnet 611. This ensures that the rotatable primary magnet 601 turns into the active position only if attracted by external magnets.

[0041] FIGURE 6c presents an embodiment of the invention where the device 600 comprises an auxiliary magnet 605, which may be used instead of, or in addition to, the ferromagnetic material 602. Auxiliary magnet 605 may be used for attracting the rotatable primary magnet 601 in order to keep it in the inactive position when not attracted by any external magnets.

[0042] It is to be understood that using ferromagnetic material 602 or auxiliary magnet 605 to keep the rotatable primary magnet 601 in the inactive position are merely examples and no other means resulting in the same technical effect should be excluded. Therefore, any mechanical or electrical means to keep the rotatable primary magnet 601 in the inactive position are within the scope of the invention.

[0043] FIGURE 6abc also illustrates an embodiment of the invention where the rotatable primary magnet 601 is located in the middle, or in the vicinity of, of the primary or secondary coil 603. This arrangement may, for example, help to align the coils of the transmitter and receiver devices 400 and 410.

[0044] FIGURE 7 illustrates the magnetic field 705 generated by the rotatable primary magnet 702 in an inactive position, according to an embodiment of the invention. Ferromagnetic material 701 may be placed around the rotatable primary magnet 702. The rotatable primary magnet 702 may be located inside the primary or secondary coil 704. The rotatable primary magnet 702 may be also arranged to rotate around an axle 703. When the rotatable magnet 702 is in inactive position, the ferromagnetic material 701, or ferrite, advantageously collects most of the magnetic flux, thereby minimizing the magnetic flux through the surface of the device. Ferromagnetic material 701 has high permeability, for example higher than air permeability or the permeability of the ambient parts excluding the primary magnet. The magnetic flux density can be calculated from equation $B = \mu \times H$, where B is the magnetic flux density, H is the magnet field strength, and μ is the permeability of the material. Therefore, the high permeability causes a strong magnetic flux inside the ferromagnetic material 701 and most of the magnetic flux 705 remains inside the ferromagnetic material 701.

[0045] FIGURE 8 presents an exemplary apparatus where one or more embodiments presented herein may be implemented. Apparatus 800 may include at least one processor 802 in connection with at least one memory 803 or other computer readable media. Memory 803 may be any type if information storing media including random access memory (RAM), read-only memory (ROM), programmable readable memory (PROM), erasable programmable memory (EPROM) and the like, and it may contain software in form of computer executable instructions.

[0046] Apparatus 800 may also comprise one or more radios, for example telecom radio 805, broadcast radio 806, or short-range radio 807 such as Bluetooth radio or a wireless local area network (WLAN) radio. Apparatus 800 may further comprise a user interface 808, display 801, and audio input/output 808 for communicating with the user. The apparatus may also comprise a battery for delivering power for various operations performed in the device.

[0047] Without in any way limiting the scope, interpretation, or application of the claims appearing below, a technical effect of one or more of the example embodiments disclosed herein is changing the density of the magnetic field around a wireless charging capable device. Advantageously, the magnetic pulling force is maximized during the charging while minimizing the magnetic field around the device when not charging. Another technical effect of one or more of the example embodiments disclosed herein is possibility to provide a stronger magnet in a wireless charging platform without causing excessive magnetic fields when not charging any devices.

[0048] Embodiments of the present invention may be implemented in software, hardware, application logic or a combination of software, hardware and application logic. The software, application logic and/or hardware may reside on an energy transmitting device such as a wireless charging platform or an energy receiving device such as a mobile device to be charged. In an example embodiment, the application logic, software or an instruction set is maintained on any one of various conventional computer-readable media. In the context of this document, a “computer-readable medium” may be any non-transitory media or means that can contain, store, communicate, propagate or transport the instructions for use by or in connection with an instruction execution system, apparatus, or device, such as a computer, with one example of a computer described and depicted in FIGURE 8. A computer-readable medium may comprise a computer-readable storage medium that may be any non-transitory media or means that can contain or store the instructions for use by or in connection with an instruction execution system, apparatus, or device, such as a computer.

[0049] If desired, the different functions discussed herein may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the above-described functions may be optional or may be combined.

[0050] Although various aspects of the invention are set out in the independent claims, other aspects of the invention comprise other combinations of features from the described embodiments and/or the dependent claims with the features of the independent claims, and not solely the combinations explicitly set out in the claims.

[0051] It is also noted herein that while the above describes example embodiments of the invention, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications which may be made without departing from the scope of the present invention as defined in the appended claims.

WHAT IS CLAIMED IS

1. An apparatus, comprising:

at least one inductive means arranged to inductively transform a magnetic flux into an electric current; and

at least one primary magnet capable of switching between an inactive and an active position, wherein the magnetic flux through a surface of the apparatus is minimized in the inactive position, and wherein the magnetic flux through the surface of the apparatus is maximized in the active position.

2. The apparatus according to claim 1, wherein an external magnet placed close to the surface causes the primary magnet to rotate into the active position.

3. The apparatus according to claim 1, wherein the primary magnet is surrounded by ferromagnetic material.

4. The apparatus according to claim 1, wherein the primary magnet is placed in the vicinity of the at least one inductive means.

5. The apparatus according to claim 1, further comprising an auxiliary magnet arranged to draw the primary magnet into the inactive position.

6. The apparatus according to claim 3, wherein the ferromagnetic material draws the primary magnet into the inactive position.

7. The apparatus according to claim 1, further comprising at least one battery capable of being charged and circuitry for delivering the electric current to the battery.

8. The apparatus according to claim 1, wherein the inductive means and the primary magnet are located in a wireless charging sleeve capable of charging a device through a wired interface.

9. A method, comprising:

arranging a primary magnet to switch between an inactive position and an an active position, wherein in the inactive position the magnetic flux through the surface of the apparatus is minimized, and wherein in the active position the magnetic flux through the surface of the apparatus is maximized; and

inductively transforming a magnetic flux into an electric current using an inductive means.

10. The method according to claim 9, further comprising placing an external magnet close to the surface to cause the primary magnet to rotate into the active position.

11. The method according to claim 9, wherein the primary magnet is surrounded by ferromagnetic material.

12. The method according to claim 9, wherein the primary magnet is placed in the vicinity of the inductive means.

13. The method according to claim 9, further comprising arranging an auxiliary magnet to draw the primary magnet into the inactive position.

14. The method according to claim 11, wherein the ferromagnetic material draws the primary magnet into the inactive position

15. The method according to claim 9, further comprising:

delivering the electric current to at least one battery; and

charging the at least one battery.

16. The method according to claim 9, wherein the inductive means and primary magnet are located in a wireless charging sleeve capable of charding a device through a wired interface.

17. An apparatus, comprising:

at least one inductive means arranged to transform an electric current into a magnetic flux; and

at least one primary magnet capable of switching between an inactive position and an active position, wherein in the inactive position the magnetic flux through the surface of the apparatus is minimized, and wherein in the active position the magnetic flux through the surface of the apparatus is minimized.

18. The apparatus according to claim 17, wherein an external magnet is placed close to the surface to cause the primary magnet to rotate into the active position.

19. The apparatus according to claim 17, wherein the primary magnet is surrounded by ferromagnetic material.

20. The apparatus according to claim 17, wherein the primary magnet is placed in the vicinity of the at least one inductive means.

21. The apparatus according to claim 17, further comprising an auxiliary magnet arranged to draw the primary magnet into the inactive position.

22. The apparatus of claim 19, wherein the ferromagnetic material draws the primary magnet into the inactive position.

23. A method, comprising:

arranging a primary magnet to switch between an inactive position and an active position, wherein in the inactive position the magnetic flux through the surface of the apparatus is minimized, and wherein in the active position the magnetic flux through the surface of the apparatus is maximized; and

transforming an electric current into a magnetic flux using an inductive means.

24. The method according to claim 23, wherein placing an external magnet close to the surface causes the primary magnet to rotate into the active position.

25. The method according to claim 23, wherein the primary magnet is surrounded by ferromagnetic material.

26. The method according to claim 23, wherein the primary magnet is placed in the vicinity of the inductive means.

27. The method according to claim 23, further comprising arranging an auxiliary magnet to draw the primary magnet into the inactive position.

28. The method according to claim 25, wherein the ferromagnetic material draws the primary magnet into the inactive position.

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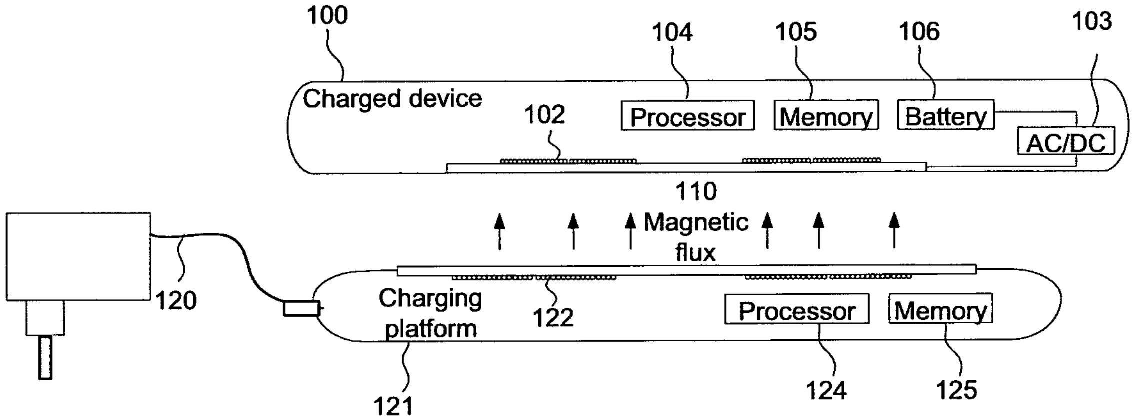
100
104
105
106
103
Charged device
102
Processor
Memory
Battery
AC/DC
110
Magnetic
flux
120
Charging
platform
122
Processor
Memory
121
124
125

Fig. 1

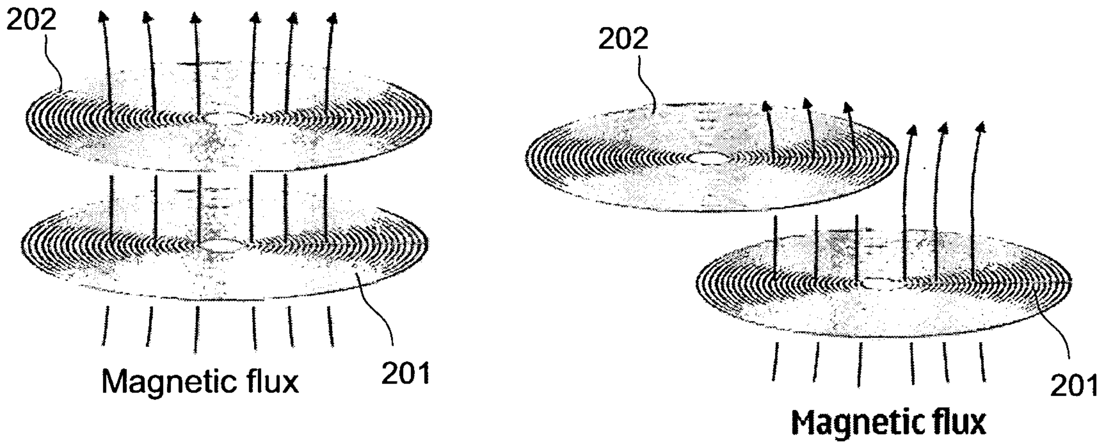

Fig. 2a Fig. 2b

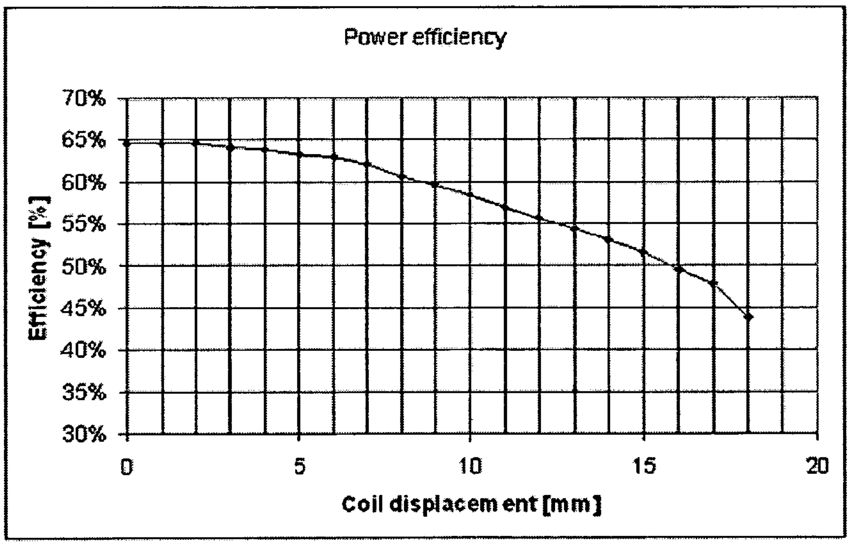

Fig. 3

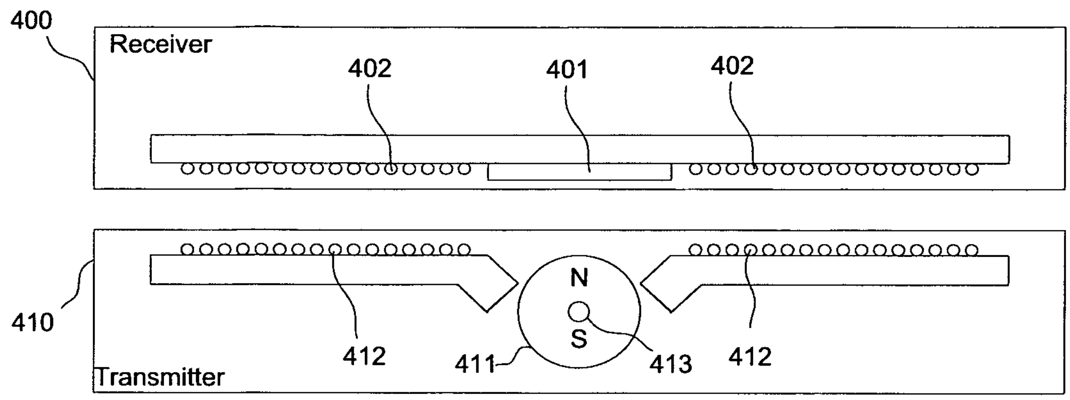

Fig. 4a

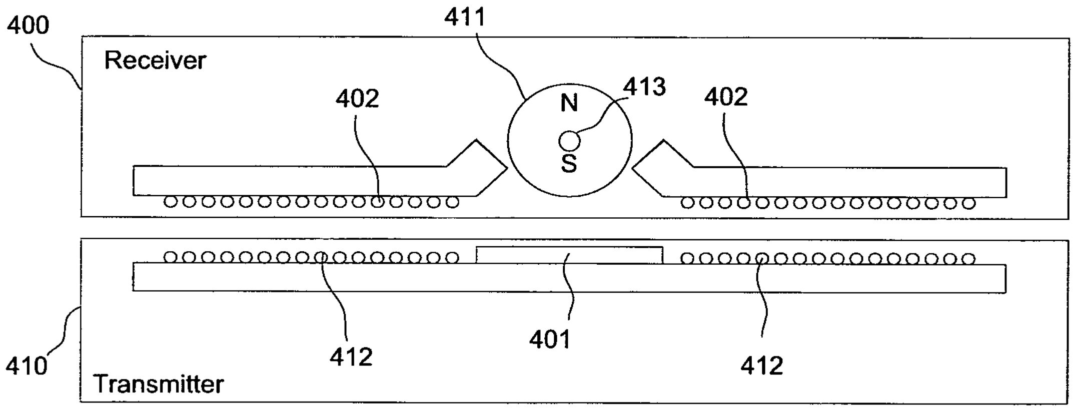

Fig. 4b

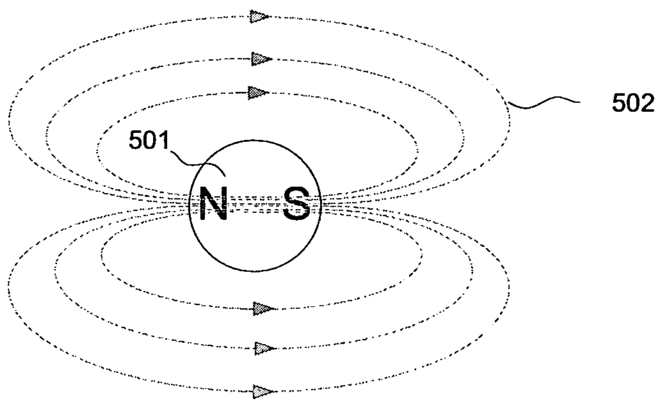

Fig. 5

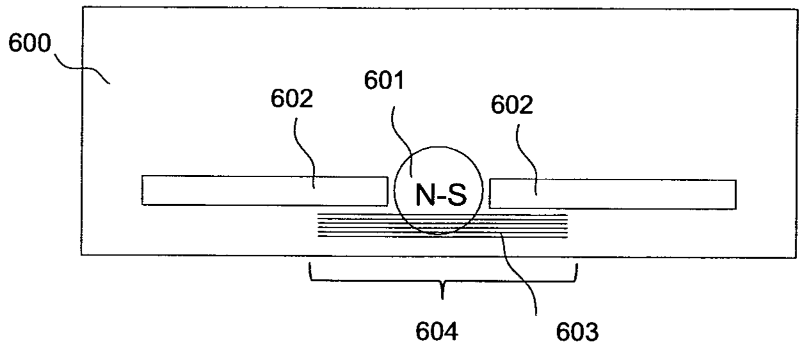

Fig. 6a

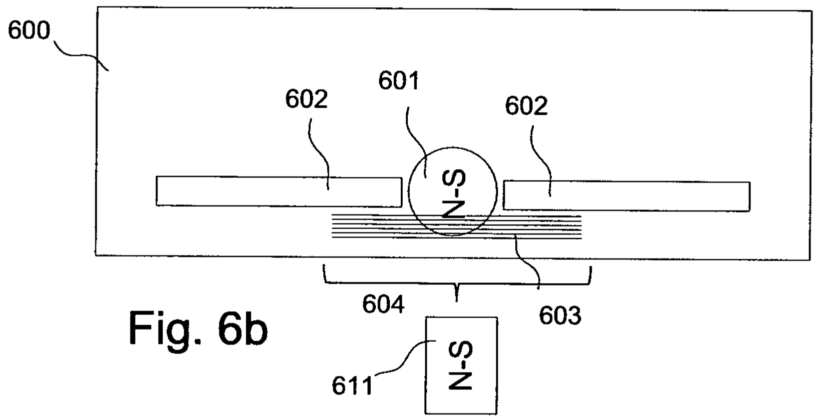

Fig. 6b

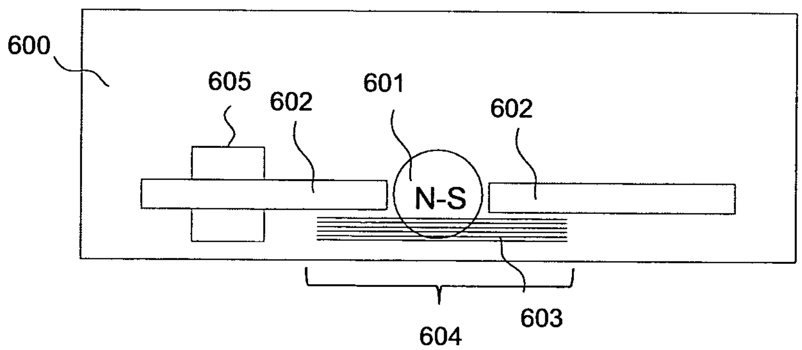

Fig. 6c

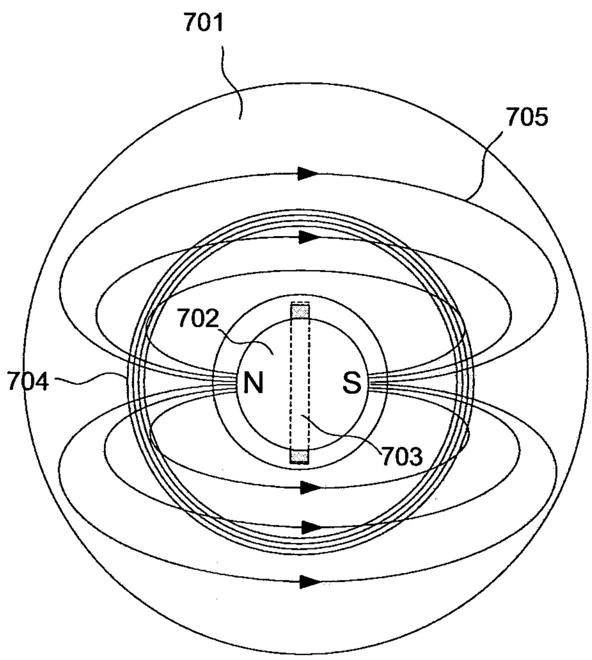
701
705
702
704
N
S
703

Fig. 7

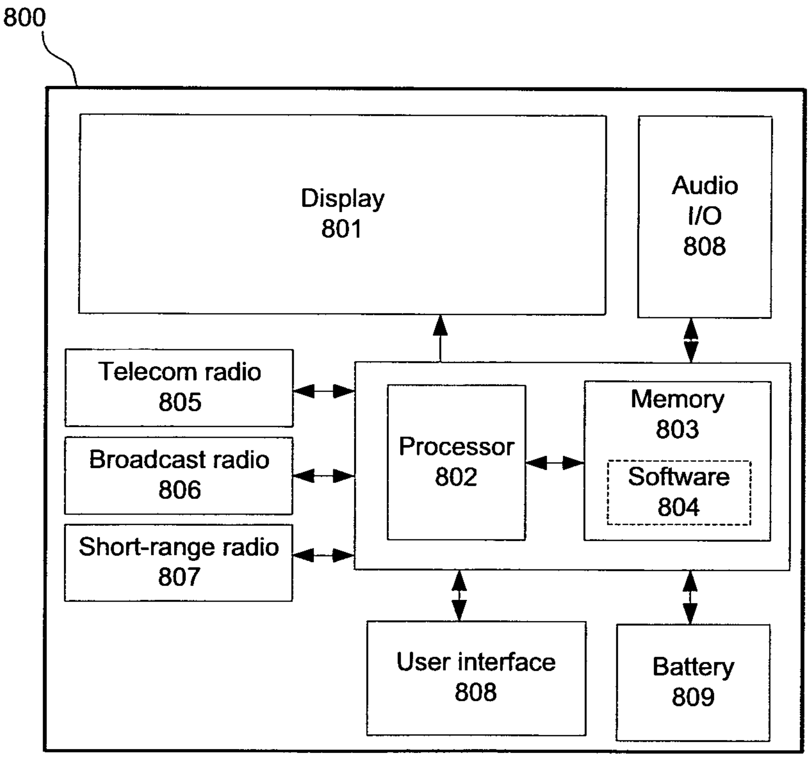
800
Display
801
Audio
I/O
808
Telecom radio
805
Broadcast radio
806
Short-range radio
807
Processor
802
Memory
803
Software
804
User interface
808
Battery
809

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2011/050419

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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: H01F, H02J

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

FI, SE, NO, DK

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

EPO-Internal, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2010225174 A1 (JIANG HAO) 09 September 2010 (09.09.2010) abstract; paragraphs [0023]-[0043]; Figs 1-3 and 5	1-4, 6-12, 14-20, 22-26, 28 5, 13, 21, 27
X A	WO 2010096917 A1 (UNIV BRITISH COLUMBIA et al.) 02 September 2010 (02.09.2010) abstract; paragraphs [0026]-[0035], Fig 4.	1-4, 6-12, 14-20, 22-26, 28 5, 13, 21, 27
X A	US 2009167449 A1 (COOK NIGEL P et al.) 02 July 2009 (02.07.2009) abstract; paragraphs [0023]-[0036]; Figs. 2 and 3	1-4, 6-12, 14-20, 22-26, 28 5, 13, 21, 27

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 August 2011 (09.08.2011)	12 August 2011 (12.08.2011)

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2011/050419

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
US 2010225174 A1	09/09/2010	None	
WO 2010096917 A1	02/09/2010	None	
US 2009167449 A1	02/07/2009	JP 2011501636 A	06/01/2011
		WO 2009049281 A2	16/04/2009
		KR 20100063823 A	11/06/2010
		EP 2208279 A2	21/07/2010
		CN 101842963 A	22/09/2010

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PCT/FI2011/050419

CLASSIFICATION OF SUBJECT MATTER

Int.Cl.
H01F 38/14 (2006.01)
H02J 17/00 (2006.01)