Abstract: A near field RF communicator has an integrated first antenna (107). The near field RF communicator also has a second antenna (101) physically separate from the first antenna. The second antenna has at least one first antenna region (103) to couple inductively with the first antenna and at least one second antenna region (102) coupled to the first antenna region to couple inductively with another near field RF communicator to enable near field communication between the near field RF communicators via the first and second antennas. Such an antenna for use with a near field RF communicator is also described.
A near field RF communicator and an antenna for near field RF communicators

This invention relates to near field RF communicators and antennas for near field RF communicators.

Near field RF (radio frequency) communication is a form of wireless (non-contact) communication between compatible communicators that requires an antenna of one near field RF communicator to be present within the alternating magnetic field (H field) generated by the antenna of another near field RF communicator by transmission of an RF signal (for example a 13.56 Mega Hertz signal) to enable the magnetic field (H field) of the RF signal to be inductively coupled between the communicators. The magnetic field may be modulated to enable communication of control and/or other data. Ranges of up to several centimetres (generally a maximum of 1 metre) are common for near field RF communicators.

Near field RF communication may be referred to as near-field RFID (Radio Frequency Identification) or near-field communication. NFC communicators are a type of near field RF communicator that is capable of both initiating a near field RF communication (through transmission or generation of an alternating magnetic field) with another near field RF communicator and of responding to initiation of a near field RF communication by another near field RF communicator. The term "near field RF communicator" includes not only NFC communicators but also initiating near field RF communicators such as RFID transceivers or readers that are capable of initiating a near field RF communication but not responding to initiation of a near field RF communication by another near field RF communicator and responding near field RF communicators such as RFID transponders or tags that are capable of responding to initiation of a near field RF communication by another near field RF communicator but not of initiating a near field RF communication with another near field RF communicator.

An RFID tag is always a target and an RFID reader always an initiator of communication. However, as will be understood from the above, an NFC
communicator may operate in an "initiator" mode in which the NFC communicator seeks to initiate near field RF communication or in a "target" mode in which the NFC communicator is receptive to initiation of near field RF communication. NFC communicators may also operate in either a "passive communications mode" or an "active communications mode". When communication is by the "passive communications mode" an initiator NFC communicator will generate an RF field and a target NFC communicator will respond by modulation of the received RF signal, usually by load modulation. When communication is by the "active communications mode" both the initiator NFC communicator and the target NFC communicator use their own RF field to enable communication.

An RFID tag may be an active tag, that is a tag which is self-powered, or a passive tag, that is a tag which derives power by inductive coupling to the magnetic field (H-field) generated by an RFID reader or NFC communicator. The terms "passive" and "active" in the context of NFC communicators thus do not have the same meaning as "passive" and "active" when used in the context of traditional RFID tags and readers.

It will be apparent from the foregoing that an initiator NFC communicator operating in the "active communication mode" operates in a manner similar to an RFID reader while a target NFC communicator operating in the "passive communications mode" operates in a manner similar to an RFID tag, using an RF field generated by an RFID reader or initiator NFC communicator to respond to that RFID reader or initiator NFC communicator. Thus, an initiator NFC communicator can communicate with both target NFC communicators and RFID tags and a target NFC communicator can communicate with both initiator NFC communicators and RFID readers.

Examples of near field RF communicators are defined in various standards for example ISO/IEC 18092, ISO/IEC 14443, ISO/IEC 15693 ISO/IEC 21481.

Near field RF communicators may be provided as standalone or discrete devices (hand-held or free-standing) or may have a host, for example a near field RF communicator may be incorporated within, associated with or coupled to a host to enable the host to communicate by the near field with other near field RF communicators or hosts. A host may be a larger device or system. When incorporated within a host, a near field RF
A communicator may be in a discrete (stand-alone) form or integrated within the host. Examples of hosts are mobile transceivers such as mobile or cellular telephones ("cellphones"), portable computing devices (such as personal digital assistants, notebooks, lap-tops), other computing devices such as personal or desk top computers, computer peripherals such as printers, portable audio and/or video players such as MP3 players, IPODs®, CD players, DVD players and the like, other electrical devices, vending machines.

Near field RF communicators comprise antenna circuitry and additional functional components such as control and data storage functionality, and at least one of demodulation and modulation functionality, depending upon the type of near field RF communicator.

A near field RF communicator may be implemented by means of a single integrated circuit (a so-called one-chip solution or system on chip) or a number of integrated circuits or separate functional components provided on one or more printed circuit boards.

Where an RFID transponder is implemented by means of a single integrated circuit or chip, because of the required antenna size and the fact that integrated circuit costs are directly related to the area or "real estate" of semiconductor (generally silicon), the usual approach is to provide the antenna coil as a separate component. In such cases, the antenna coil may be defined on an inlet layer (generally a PVC or like foil) of the RFID transponder as an electrically conductive path by, for example, deposition of conductive ink, etching of a conductive layer or laying down of a conductive track. As another possibility, the antenna coil may be wound around the inlet layer. The chip may be bonded directly onto the inlet layer carrying the antenna. Bonding the chip onto the inlet layer requires precision in picking the chip or die up from the diced silicon wafer, precision in placing the chip in the right place on the inlet and precision in bonding the chip to the antenna. Such precision is expensive and requires expensive precision tools. As an alternative and to minimise the precision requirement, an interposer or strap may be used. In such cases the chip or die is attached to the interposer which is then itself bonded to the antenna. The interposer makes the chip easier to handle and to bond out to the antenna. However using an interposer increases cost and reduces the flexibility in
end antenna design because the interposer and antenna have to be compatible in shape and design to ensure the chip is correctly bonded.

However, flexibility in end antenna design is desirable, particularly where the RFID transponder is to have a host with electromagnetic characteristics or where the transponder is intended to operate in different environments, because the magnetic coupling characteristics of a near field RF communicator are affected by its environment. It is therefore desirable, in order to achieve optimum performance, to adapt the design of the antenna to the particular environment within which the near field RF communicator is to operate. In addition, particularly where the RFID transponder has a host, there may be physical constraints on the positioning of the RFID transponder and its antenna that again may place constrains on the design of the antenna. These considerations mean that different antenna designs may be desirable for different transponder communicator environments and applications. Without significant cost to customise each antenna, this is very difficult to achieve with pre-existing solutions.

The same requirement for design flexibility can also apply to other near field RF communicators, for example RFID readers and NFC communicators. As with transponders, such near field RF communicators may be required to operate within different localised environments or be comprised within different hosts. For example an NFC communicator may be required to operate within different mobile phones, where the local environment (for example battery presence, power supply, other transceivers) affects operation of the chosen antenna. In order not to compromise operation of the near field RF communicator, existing NFC communicator designs or reader designs may be provided with multiple antennas, which can be costly and often requires multiple antenna drivers or multiple antenna functionality within the reader. Such multiple antennas may take up significant real estate within the host.

In addition to the above, in order to improve the inductive coupling, it is desirable for an antenna to operate at or near resonance which may be difficult to achieve, given the above size constraints.

Also impedance matching between the antenna of an RFID tag and the antenna of an RFID reader or NFC communicator may be difficult to achieve because an RFID tag antenna will generally be designed to be as small as possible to keep costs down while
the size of an RFID reader or NFC communicator antenna will often not be so constrained and thus may be designed to provide as large as possible inductive coupling range.

An aspect of the present invention provides a near field RF communicator that alleviates at least some of the aforementioned problems. An aspect of the present invention provides an additional antenna that is configured to couple inductively to an integrated antenna of a near field RF communicator.

An aspect of the present invention provides an RFID tag or transponder comprising an integrated circuit having the integrated antenna.

An aspect of the present invention provides an RFID reader or NFC communicator wherein the integrated antenna is integrated within a functional body or unit of the RFID reader or NFC communicator, for example is integrated in an integrated circuit of the RFID reader or NFC communicator or is provided on a circuit board or processor board comprising the RFID reader or NFC communicator.

An aspect of the present invention provides an antenna or series of antennas for use with a near field RF communicator to enable coupling of orthogonal magnetic fields where direct coupling of the magnetic fields is difficult or not possible. An aspect of the present invention provides an antenna for use with a near field RF communicator, where the antenna has a plurality of regions, one region being designed to couple to an integrated antenna of the near field RF communicator and one region being designed to couple to an antenna or antenna region of another near field RF communicator, so that each region may be impedance matched to the antenna or antenna region with which it is to couple.

An embodiment provides a near field RF communicator having a main body with a first antenna, the near field RF communicator also having a second antenna, the second antenna having a first antenna region arranged to enable inductive coupling between the first antenna and the first antenna region, the second antenna also having a second antenna region arranged to enable inductive coupling with another near field RF communicator to enable near field communication between the near field RF communicators via the first and second antennas.
An embodiment provides a near field RF communicator having an integrated first antenna. The near field RF communicator also has a second, antenna physically separate from the first antenna. The second antenna has at least one first antenna region to couple inductively with the first antenna and at least one second antenna region electrically coupled to the first antenna region to couple inductively with another near field RF communicator to enable near field communication between the near field RF communicators via the first and second antennas.

An embodiment provides a near field RF communicator wherein the first region of the second antenna is impedance matched to the first antenna.

An embodiment provides a near field RF communicator wherein the first region of the second antenna and the first antenna are positioned so as to be responsive to the same magnetic field.

An embodiment provides a near field RF communicator wherein the first region of the second antenna and the first antenna are positioned so as to be subject to magnetic flux in a given direction.

An embodiment provides a near field RF communicator wherein the first region of the second antenna and the first antenna are positioned so as to lie in substantially parallel planes which may be offset from one another but at least partially overlap.

An embodiment provides a near field RF communicator wherein the first region of the second antenna, the second region of the second antenna and the first antenna each comprises a coil defined by a conductive track on a substrate.

An embodiment provides a near field RF communicator wherein the coils have turns of a rectangular, square, rectangular or square with rounded corners, circular, oval or other suitable shape.

An embodiment provides a near field RF communicator wherein the first antenna is defined in at least one electrically conductive layer of an integrated circuit of the near field RF communicator.

An embodiment provides a near field RF communicator wherein the second antenna
region lies in a plane that is one of transverse or perpendicular to the first antenna region.

An embodiment provides a near field RF communicator wherein the first antenna and the first antenna region form a transformer.

An embodiment provides a near field RF communicator wherein the first antenna has a core.

An embodiment provides a near field RF communicator wherein the first antenna region and the second antenna region are configured to have different inductive coupling ranges.

An embodiment provides a near field RF communicator wherein the second antenna is physically separate.

An embodiment provides a near field RF communicator wherein the near field RF communicator functionality and the second antenna are carried by respective ones of first and second components.

An embodiment provides a near field RF communicator wherein one of the first and second components is a disposable or consumable component.

An embodiment provides a near field RF communicator wherein the near field RF communicator comprises at least one of: an RFID tag; an RFID reader; and an NFC communicator.

An embodiment provides a near field RF communicator having a controller and at least one of a demodulator to demodulate a modulated RF signal inductively coupled to the first antenna and a modulator to modulate an RF signal.

An embodiment provides an electrical device comprising a near field RF communicator. The near field RF communicator may be integrated within or dispersed within the functionality of the electrical device. The near field RF communicator may comprise at least one integrated circuit within the electrical device.
The device may comprise at least one of a mobile telephone, a portable computing device such as a personal digital assistant, notebook, or lap-top, a personal or desk top computer, a computer peripheral such as a printer, or other electrical device such as a portable audio and/or video player.

An embodiment provides a portable communications device incorporating a near field RF communicator.

An embodiment provides an antenna for use with a near field RF communicator, where the antenna has a plurality of regions, one region being designed to couple to an integrated antenna of the near field RF communicator and one region being designed to couple to an antenna or antenna region of another near field RF communicator, so that each region may be impedance matched to the antenna or antenna region with which it is to couple.

As used herein, inductive coupling means inductive coupling by the magnetic field (the H field) of an RF signal, which may be a 13.56 Mega Hertz RF signal, for example.

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

Figure 1 shows a diagrammatic plan representation of a near field RF communicator embodying the invention;

Figure 2 shows a simplified block electrical diagram of the near field RF communicator shown in Figure 1;

Figure 3 shows a functional block diagram of an RFID tag embodying the invention;

Figure 4 shows a diagrammatic plan representation of an electronic ticket comprising an RFID tag embodying the invention;

Figure 5 shows a representation of a host and a host accessory or component having respective near field RF communicators to enable data to be communicated between the host and the accessory or component;

Figure 6 shows a representation of another example of an accessory or component, carrying a near field RF communicator embodying the invention;

Figure 7 shows a functional block diagram of an RFID reader embodying the invention;
Figure 8 shows a functional block diagram of an NFC communicator embodying the invention.

With reference to the drawings in general, it should be understood that any functional block diagrams are intended simply to show the functionality that exists within the device and should not be taken to imply that each block shown in the functional block diagram is necessarily a discrete or separate entity. The functionality provided by a block may be discrete or may be dispersed throughout the device or throughout a part of the device. In addition, the functionality may incorporate, where appropriate, hard-wired elements, software elements or firmware elements or any combination of these.

Referring now to the drawings in detail, Figure 1 shows a diagrammatic plan representation of a near field RF communicator 1 embodying the invention while Figure 2 shows a simplified block electrical diagram of the near field RF communicator shown in Figure 1.

The near field RF communicator 1 comprises a main body 104 having near field RF communicator functionality 105 comprising control, data processing and data storage functionality 106 and an antenna circuit comprising a built-in or integrated first antenna 107. The main body 104 may be provided as a single integrated circuit with the first antenna 107 being provided in a layer or layers of the integrated circuit, for example in a metal layer or in multiple metal layers.

In addition to the main body 104, the near field RF communicator 1 also comprises an additional or second antenna 101. The additional antenna 101 is provided separately from the main body 104. For example, as illustrated diagrammatically in Figure 1, the additional antenna 101 may be provided on any suitable substrate 100, for example a card or plastics substrate, by printing, deposition and etching and so on or could be formed by winding around a former. The additional antenna 101 may or may not be provided within the same housing 1’ (shown in phantom lines in Figure 1) or encapsulation as the main body 104. Where the near field RF communicator 1 is a standalone device, then the additional antenna 101 may be mounted to the same substrate or encapsulated within the same housing as the main body 104. Where the near field RF communicator comprises part of or is associated with a host, then the additional antenna 101 may again be mounted to the same substrate or encapsulated in
the same housing as the main body 104 or may be provided within or on a different part of the host as will be explained below with reference to some illustrative examples. In some applications, the main body 104 and additional antenna 101 may be completely separately housed or mounted so that the main body 104 can be used with or without the additional antenna 101. Housing the main body 104 and additional antenna 101 completely separately may also give additional flexibility enabling changes to the design of an electrical device such as a mobile phone to be made more easily.

The additional antenna 101 has at least two antenna regions, at least one of which is designed to be an impedance match to the first antenna 107 of the main body 104 and at least one of which is designed to be an impedance match to the antenna or an antenna region of a near field RF communicator with which the near field RF communicator 1 is intended to communicate. As shown in Figures 1 and 2, the additional antenna 101 comprises two antenna regions or coils 102 and 103 with antenna region 103 being designed to impedance match the built-in or integrated antenna 107 and antenna region 102 being designed to impedance match the antenna or an antenna region of a near field RF communicator with which the near field RF communicator 1 is intended to communicate. In order to achieve impedance matching, antenna regions or coils may have a similar physical layout, as shown in Figure 1 for coils or antenna regions 103 and 107.

In an example, antenna region 103 may form a step-up or step-down transformer in combination with the built-in antenna 107 enabling voltage variations on the near field RF communicator. To provide additional directionality, the built-in antenna 107 may have a core, generally a ferrite core.

As shown in Figure 1, the antenna 107 and the antenna regions 102 and 103 are rectangular turn coils. They may however be may be square, rectangular or square turns with rounded corners, oval, circular etc. turn coils or any other suitable shape, depending upon the required specification and environment within which the near field RF communicator is to operate.

The integrated antenna 107 will, as mentioned above, generally be formed within a metal layer or layers of the integrated circuit. The second antenna 101 may be formed by patterning an electrically conductive, for example metal, layer or layers on a
substrate or by depositing electrically conductive material such as conductive ink onto a
substrate, for example, or by winding a 3D (for example spiral) wire coil, for example
using a former, or by any other suitable process.

Different antenna regions may provide different coupling ranges. This may be achieved
by, for example, providing the different antenna regions so that they have at least one of
different numbers of turns, different overall coil sizes, different materials, different
cores, different orientations within their local environment, different layers, different
degrees of overlap and so on. In the example shown, the antenna region or coil 102 is of
larger area than the antenna region 103 and so has a longer inductive coupling range.
For example, the coupling range between the built-in tag antenna 107 and the additional
antenna region 103 may be up to 1 cm whereas the coupling range between the
additional antenna region 102 and another near field RF communicator may be up to 1
metre.

The antenna region 103 and the built-in antenna 107 should be designed so as to operate
at or near resonance. Generally, although not shown, the antenna circuitry will comprise
capacitors and resistors to improve coupling and assist with overall impedance
matching. The manner of manufacture of the second antenna may allow integration of
resistors and/or capacitors by appropriate design of the electrically conductive
(generally metal) paths or tracks. For example, a capacitor may be formed by
overlapping electrically conductive regions separated by a dielectric, electrically
conductive regions tracks on two sides of the substrate or by regions of respective metal
layer of a multi-level structure separated by an intervening dielectric layer.

In operation, the antenna region 103 of the additional antenna 101 and the built-in
antenna or coil 107 couple inductively to increase the operable range of the near field
RF communicator or to enable coupling within a different magnetic field, as will be
explained below.

In one example, the near field RF communicator illustrated by Figures 1 and 2 is an
RFID tag. Figure 3 shows a block diagram of an RFID tag 3 to illustrate a typical
example of the functionality provided by the main body 104 of an RFID tag 3
embodying the invention. As shown in Figure 3, the functionality 106 shown in Figure
1 in this example comprises a demodulator 301, a power deriver 302 operable in the
example shown to derive a power supply for the RFID tag from an incoming RF signal inductively coupled to the RFID tag, a modulator 303, a controller 304 and a memory 305 (which may at least partly be provided by the controller). The RFID tag may additionally have one or more sensors 308 as shown in phantom lines in Figure 3). For example the tag may include at least one or more of a temperature sensor, movement sensor, moisture sensor. Also, the tag controller 304 may contain or be associated with a user interface 309 or the like as shown in phantom lines in Figure 3. For simplicity, the connections between the power deriver 302 and the other components of the RFID tag 3 are not shown in Figure 3.

In Figure 3, the built-in antenna 107 is provided within the integrated circuit or forms part of a layer or layers of the integrated circuit, for example a metal layer or layers of the integrated circuit. As described above, the antenna 107 is designed to match impedance with an antenna region 103 or regions of the additional antenna 101.

The controller 304 may be a microprocessor, state machine, microcontroller or other similar processor. The type of processor will depend on the RFID tag and functionality required, in particular the complexity of the RFID tag and any applicable cost constraints. The memory 305 may be any suitable form of memory or combination of memory forms, for example EEPROM, flash, ROM, OTP.

In operation of the RFID tag 3 shown in Figure 3, when a compatible initiating near field RF communicator (a compatible initiator NFC communicator or RFID reader) in near field range provides an RF signal, the magnetic (H) field 307 of that RF signal is inductively coupled, via the inductive coupling of the additional antenna region 102 to the initiating near field RF communicator and the inductive coupling of the additional antenna region 103 and the built-in antenna 107, to the antenna 107. A voltage is thus generated across the antenna 107, from which the power deriver 302 derives a power supply for the RFID tag. The demodulator 301 extracts any modulation from the inductively coupled signal and supplies the resulting data to the tag controller 304. Depending upon the particular tag configuration, the controller 304 may respond to data from demodulator 301, to the supply of power by the power deriver 302, or to some other stimulus (for example a signal from the sensor 308 if present) and may or may not cause data to be read from or written to the memory 305. The controller 304 may also
respond to data, power or stimulus by causing the modulator 303 to modulate the RF
signal inductively coupled to the antenna 107 with data (which may be read from the
memory 305) so that the modulated signal is coupled via the magnetic field 307 to the
device originally generating the field, that is an RFID reader or NFC communicator in
initiator mode. Such modulation may be through load modulation of the antenna
circuitry or any suitable form of modulation.

In the example shown in Figure 3, the RFID tag is a passive tag and the power deriver
302 is coupled to derive a power supply from an RF signal inductively coupled to the
tag. As another possibility, the RFID tag could be an active tag, in which case the
power deriver may be a power supply such as a battery or, where the RFID tag has a
host with a power supply, may be a connection to a power supply of that host.

An RFID tag as described above may be used in many applications. Some non-
exhaustive and non-limiting examples are given below.

Thus, the RFID tag may comprise an ISO 14443 compatible tag and be designed for use
in transport ticketing. Figure 4 illustrates an example ticket 108 comprising an RFID tag
in accordance with the invention. The ticket 108 may, for example, be designed to
provide access to train travel, bus travel etc.. The ticket may have a plastics material
(for example an ID-I format), paper cardboard, or any other suitable substrate. The
ticket substrate carries both the main body 104 of the RFID tag (which, as shown in the
enlarged scale inset in Figure 4, contains the RFID functionality 106 and the built-in or
first antenna 107 (formed as described above within the integrated circuit or as part or
one of the layers of the integrated circuit)) and the additional or second separate antenna
101 which, as described above has first and second regions 103 and 101 with the first
region 103 being impedance matched to the first or built-in antenna 107. The impedance
matched first region 103 and first or built-in antenna 107 are configured so as to be
inductively coupled during operation of the RFID tag 3. This coupling is facilitated by
the impedance matching and by the positioning of the impedance matched first region
103 and first or built-in antenna 107 relative to each other so that they share at least part
of a common magnetic field or common lines of flux. Generally, for the two-
dimensional coils shown in Figure 1, this will mean that the impedance matched first
region 103 and first or built-in antenna 107 will be arranged so that the planes of the first antenna region 103 and the first or built-in antenna 107 fully or at least partially overlap to avoid null zones and are parallel to one another.

The memory 305 of the RFID tag holds the data necessary for the ticket to function, for example data relating to number of trips permitted, details of trips, unique identification number. In use of such an electronic ticket, when the ticket is brought into near field range or proximity of a compatible initiator near field RF communicator (an RFID reader or NFC communicator in initiator mode) at a transport access gate, the magnetic field of an RF signal generated by the initiator near field RF communicator is inductively coupled to the additional antenna region 101 and, via the inductive coupling of the additional antenna region 103 and the built-in antenna 107, to the built-in antenna 107, enabling the power deriver to derive a power supply for the RFID tag. Thus, the magnetic field of the RF signal generated by the initiator near field RF communicator powers up the RFID tag 104 by coupling with antenna 101 and thereby indirectly coupling with antenna 107 of the main body 104 of the RFID tag. The initiator near field RF communicator, through modulation of its RF signal, sends a request for identification, verification and data to the RFID tag. The RFID tag responds to the request in accordance with its stored communication protocol and through modulation of the magnetic field of the received RF signal. Provided the correct data is provided to the initiator near field RF communicator, then the initiator near field RF communicator will communicate with the access gate to cause the access gate to open to allow the ticket holder to travel.

Although the example described above with reference to Figure 4 is an electronic ticket, the substrate may, as other possibilities, be any form of stand-alone medium, for example a product label, a token, packaging material, advertising material, a magazine page, a book page etc.

Figure 5 illustrates an example where the RFID tag 3 as described above with reference to Figures 1 to 3 is carried by a power source in the form of a battery or fuel cell 112 intended for insertion within a power source receptacle 111 of an electrical device 110 (for example a mobile telephone, PDA, IPOD, printer, personal computer or other
device requiring a power source) so that electrical contacts of the power source 112 contact corresponding contacts (not shown) within the receptacle to connect the power source to the electrical device to provide power to the electrical device. In this example, the memory (not shown in Figure 5) of the RFID tag 3 may, for example, hold data (for example derived via a sensor 308 such as a voltage sensor of the RFID tag) on power source usage and remaining power providing capability to enable the electrical device to ascertain when the power source should be replaced. In the interests of simplicity, the normal functionality found within the electrical device is not shown in Figure 5.

The power source 112 carries the main body 104 (as it is attached to a housing or casing 112a of the power source) of the RFID tag 3. In this example, the additional or second antenna 101 is provided separately from the main body 104 and is mounted within the power source receptacle 111. The insets in Figure 5 show the second antenna 101 and the main body 104 in greater detail. Once the power source is inserted into the receptacle 111, the relative positions of the antenna region 103 of the additional or second antenna 101 and the built-in antenna will be such as to enable inductive coupling of an RF signal between them, so that an initiator near field RF communicator 109 carried by the electrical device 110 or external thereto can couple inductively to the RFID tag 3 via inductive coupling between its antenna and the antenna region 101 and inductive coupling between the antenna region 103 and the built-in antenna 107. The data carried by the RFID tag may then be communicated to the initiator near field RF communicator 109 in accordance with compatible communication protocols.

The arrangement shown in Figure 5 ensures that communication can only occur when the power source is correctly inserted in the receptacle 111. In addition, the use of the additional antenna 101 increases the operable range of the RFID tag 3 so that the initiator near field RF communicator 109 can be located further from the power source receptacle 111 than would have been the case if the additional antenna 101 had not been present. The use of the additional antenna also facilitates operation with pre-existing readers and enables local environment differences to be taken into account so that the electrical device, for example a mobile telephone, can cooperate with different components carrying RFID tags without having to have different readers for each component, while still enabling the design of the RFID tag and reader to meet shape and
other constraints dictated by the host and yet maximize optimization of inductive coupling.

An RFID tag of the form described above with respect to Figure 5 may be used in any application where there is a set or controlled relationship between a main body 104 and a second device. For example, the main body 104 may be carried by other forms of consumable or disposable component in addition to power sources, for example an ink cartridge such as an ink jet cartridge, or a laser printer cartridge or a medical consumable or disposable. As another example the main body 104 may be carried by a smart card, memory stick or other device which is arranged to be inserted into a receptacle in a host such as a mobile telephone, PDA or personal computer and the second or additional antenna may be sited within the host receptacle or adjacent part of the host. As another possibility, the main body 104 may form part of a product label or packaging and the second antenna may be sited within a vending device, shelf or display system. Any configuration is possible provided that in the set relationship that first antenna and first antenna region couple inductively.

Figure 6 illustrates a modification of the arrangement described above with reference to Figure 5. In this arrangement, the first region 103 (see the inset in Figure 6) of the second antenna (101 in Figure 5) is provided (for example printed) onto one side or surface 703a of a disposable or consumable component or product 703 such as a power source (battery or fuel cell for example), printer cartridge, memory card, medical disposable etc.. The RFID tag 3 main body 104 is then attached to that side or surface 703a of the component or product 703 such that the antenna 107 and the first region 103 of antenna are impedance matched and are arranged so that they can share the same lines of flux (generally speaking their planes are parallel and overlap) to enable inductive coupling therebetween. In this example, the second region 102 of the second antenna (101 in Figure 5) occupies a different magnetic field space, as shown it is provided (for example printed) on another side or surface 703b of the product so as to lie in a plane perpendicular to the first region 103 and to the tag antenna 107 and therefore is associated with different lines of magnetic flux.
The present invention may also be applied to initiator near field RF communicators such as RFID readers and NFC communicators.

Figure 7 shows an RFID reader 1000 which is operable to transmit a radio frequency signal and to receive and demodulate a modulated magnetic field. The RFID reader comprises a main body 113 having a controller 2, a signal generator 30, a differential driver 4a, antenna circuitry 6 having an antenna 9, and a demodulator 10 (capacitors 13 and 14 may be present to limit the amplitude of the signal input to the demodulator 10 and so avoid over-voltage damage to the demodulator). In addition to the main body 113, the RFID reader 1000 has a second or additional antenna 101.

The RFID reader 1000 also has or has access to a data store or memory 4. For example, the data store may be within the RFID reader external to the controller 2 or may be provided by the controller 2. As another possibility, the data store or memory 4 may at least partially be provided by a host (not shown) to which the RFID reader 1000 is interfaced or connected. Examples of possible hosts are as given above.

The RFID reader may have or be associated other functionality 17 such as a user interface, memory devices or functionality of a host to which the controller 2 provides an interface. Where there is a host, then at least some control functions may be provided by the host. The controller 2 may be a microprocessor, a processor (for example a reduced instruction set (RISC) processor) or a state machine, for example. The choice will depend on the design of the RFID reader and operational requirements.

As shown in Figure 7, the antenna circuitry 6 is in the form of a tuned circuit in which the ends of the antenna 9 are coupled to positive and inverting outputs of the driver 4a via capacitors 8 and 7, respectively, and are coupled to earth (ground) by respective series connections of capacitors 8 and 5 and capacitors 7 and 9, where the capacitors serve to reduce unwanted carrier harmonics. It may be possible to omit some of the capacitors where the signal generated by the differential driver 4 does not exceed emissions regulations. Also, other antenna circuit configurations are possible.

The RFID reader main body 113 may be an integrated circuit, in which case preferably the antenna circuitry 6 in its entirety is within the integrated circuit or forms a part of one of the layers of the integrated circuit. As another possibility, the RFID reader main
body 113 may be provided on a single circuit board and the first antenna defined in a metal layer on the circuit board or by electrically conductive material, for example conductive ink, laid down on the circuit board.

The second antenna 101 is separate from and thus is not part of the RFID reader main body 113.

The second antenna 101 has a first region or regions 103 impedance matched to the antenna 9 and arranged to enable an RF signal to be inductively coupled between the first region or regions 103 and the antenna 9. Figure 7 shows the antenna 9 and antenna region(s) 103 adjacent to one another. However, this is simply for ease of illustration. In practice, the first region or regions 103 and the antenna 9 are positioned so as to lie within the same magnetic field and share the same lines of magnetic flux, which generally means that the planes of the antenna region(s) 103 and the antenna 9 should be parallel and at least partially or overlapping to avoid null zones. The impedance matched region(s) 103 of second antenna 101 may be located directly above or below antenna 9. The second antenna 101 also has a second region or regions 102 configured to enable inductive coupling of an RF signal between a target (an RFID tag or NFC communicator operating in target mode) and the RFID reader.

In operation of the RFID reader, the controller 2 controls the generation and timing of an RF signal by the signal generator 30 in accordance with the protocols under which the RFID reader operates. The RF signal may, for example, be at 13.56 MHz and the RFID reader 1 may be compatible with one or more standards or communications protocols, for example ISO/EEC 14443 or ISO/IEC 15693. The signal generator 2 may generate the RF signal in a variety of ways. For example the RF signal may be generated by sine synthesis resulting in a pulse-width modulated (PWM) or pulse-density modulated (PDM) digital signal. As another possibility, a digital signal may be generated by use of a pre-configured algorithm or direct digital synthesis. Where sine synthesis is not used additional filtering circuitry (not shown) may be required in the antenna circuitry.

The digital signal generated by the signal generator 30 is fed into the differential driver 4a which outputs complementary pulses to the antenna circuitry 6. Depending upon the RFID reader and the circumstances, for example the communications protocol, the
controller 2 may cause the RF signal to be modulated by providing modulation control signals to the differential driver 4a to control at least one of the signal level and the modulation depth in accordance with the data to be transmitted and the communication protocols under which the RFID reader 1000 is operating. The modulation pattern will represent a series of binary ones and zeros reflecting the data to be transmitted.

The magnetic field resulting from an RF signal generated by the RFID reader will automatically be coupled to the second antenna 101 via the inductive coupling between the impedance matched antenna 9 and region(s) 103 of the second antenna, thereby enhancing the magnetic field being generated and so increasing the potential range within which the RFID reader can couple inductively to a target. Any incoming modulated RF signal or modulation (where a target modulates the received RF signal) from an in-range target will be inductively coupled to the antenna region(s) 102 and thence to the antenna circuitry 6 via the inductive coupling between the region(s) 103 and the antenna 9.

Where a received signal is modulated, the modulation will be demodulated by demodulator 10 and the resulting signal supplied to the controller 2 which will then determine whether and/or how to respond to the received data, in accordance with the protocols under which the RFID reader operates.

Received or transmitted data may be in the form of control instructions and/or other data. The data may, for example, provide identification of the target and/or may provide instructions to write certain data to the data store 15. The nature of the data provided will be determined by the target.

As in the case of the RF tag described above, by providing a relatively small on-chip or integrated antenna 9 and an additional antenna 101, the cost of the main body (generally an integrated circuit) of the RFID reader can be kept to a minimum because area sufficient for the entire antenna structure is not required, rather only the relatively small first antenna 9 need be accommodated by the main body 113. Also, there is no need to attach or bond the external antenna to the main body 113, thereby reducing manufacturing complexity and easing manufacturing tolerances. In addition, flexibility can be obtained where the RFID reader is, for example, inserted into a host. For example, where the RFID reader forms part of a mobile telephone, the RFID
functionality (the main body 113 in Figure 7) may be provided by a separate integrated
circuit placed onto the main processor or circuit board of the host or may form part of
the main processor or circuit board of the host while the second or additional antenna
101 can be manufactured separately and located separately (provided it is within
coupling distance) of the first antenna 9, thereby facilitating low cost design, flexibility
and ease of manufacture and facilitating adaptation to deal with local environment
effects, such as battery position.

An RFID reader embodying the invention may be used in applications of the type
described above with reference to Figures 4 and 5. For example, where the RFID reader
is designed to be inserted into a host electrical device, for example a mobile phone or
PDA, the RFID functionality or main body 113 may be provided by a separate device
for insertion into a receptacle within the mobile phone or PDA and the second antenna
101 may be provided within the receptacle in a manner similar to that described above
with reference to Figure 5 such that coupling only occurs once the RFID reader
functionality is inserted. The main body 113 may for example be in the form of a smart
card, PMCIA card, memory stick or other similar device. As another possibility, the
RFID reader main body 113 and second antenna may be comprised within the same
device, for example a smart card, memory stick, packaging, label etc.

Figure 8 shows an NFC communicator in accordance with the invention.

The NFC communicator 60 is capable of communicating with RFID tags, RFID readers
and/or other NFC communicators. The NFC communicator 60 may operate as an
initiator or target. In initiator mode, the NFC communicator 60 acts in a similar fashion
to the reader described with respect to Figure 7 and will transmit an RF signal. In target
mode, the NFC communicator 60 will wait for receipt of an RF signal i.e. it acts more
akin to a tag (as described with reference to Figure 3 above). Two NFC communicators
may communicate with each other in an active or a passive communication mode. In the
active communication mode an initiator NFC communicator transmits an RF signal and
then ceases RF signal transmission and a target NFC communicator responds by
transmitting its own RF signal and then ceasing RF signal transmission. In the passive
communication mode, the initiator NFC communicator transmits its RF signal and
maintains that RF signal throughout the duration of the communication cycle and the
responding or target NFC communicator modulates that the transmitted RF signal. Therefore passive and active in the context of NFC communicators are not used to refer to the derivation of power.

The NFC communicator 60 comprises an NFC main body or NFC functionality 66 having a controller 61, a modulator 63, a differential driver 65 which provides the RF signal, a demodulator 58, a data store 62, a built-in or integrated first antenna 57, other functionality 59 (which may be as described above with reference to Figure 7), an external or additional second antenna 101 and a power provider 91 (connections not shown) which may be a battery or other power source specific to the NFC communicator 60 or a coupling to a host power source. The NFC communicator 60 may also derive either all or part of its operational power from a supplied RF field when in active mode, or when operating as a target. The controller 61 may comprise a microcontroller, RISC computer or state machine, for example.

The controller 61 controls overall operation of the NFC functionality 66. Thus the controller 61 controls RF signal generation by the driver, modulation characteristics of any transmitted RF signal, any response to any received RF signal, interpretation of any received demodulated signal, mode of operation (for example initiator or target, active or passive mode) and the communication protocol under which the NFC communicator operates. Thus, when the NFC communicator 60 is transmitting an RF signal (whether modulated or not) such signal transmission will be controlled by the controller 61. The NFC communicator 60 may or may not have a modulation controller 64 separate from but controlled by the controller 61. The controller will control modulation of the signal (via the modulation controller if present) and in accordance with control data and other or content data held within the controller and data store 62 (or in the alternative in accordance with data from any host apparatus). Modulation may be effected by controlling the amplitude of the signal supplied by the modulator 63 to the differential driver 65.

As described above for the cases of the RFID tag and reader, an NFC communicator 60 in accordance with the invention has a built-in antenna 57 and an external or additional antenna 101 (both shown simply as blocks in Figure 8) having at least one first region 103 and at least one second region 102, with the first region(s) 103 being impedance
matched to the built-in antenna 57 so as to optimise inductive coupling of an RF signal therebetween and the second region(s) 102 being optimised to, for example, increase the range over which inductive coupling can be achieved with another near field RF communicator, or to provide a differing magnetic field to antenna 57.

Where the NFC functionality or main body 66 is provided by an integrated circuit, then the first antenna 57 is preferably provided by that integrated circuit, for example by part of one of the layers of the integrated circuit. The second antenna 101 is separate from the NFC communicator 60 integrated circuit 66. As shown in Figure 8, the second antenna 101 is shown above and overlapping the first antenna 57. It should be apparent to the skilled man that position of second antenna 101 may vary provided that the region(s) 103 is (are) within the same magnetic field and lines of flux as the first antenna 57. Generally the first antenna 57 and the first region(s) 103 will be arranged to avoid null zones and will lie in fully or partially overlapping planes that may be parallel or substantially parallel to one another.

When the NFC communicator 60 is operating in target mode, it will await receipt of an RF signal at the antenna 57 or 101. Signals inductively coupled to the region(s) 102 of the antenna 101 will be inductively coupled to antenna 57 via the region(s) 103 and therefore to the NFC functionality 66. Any received signal will be demodulated by the demodulator 58 and the demodulated signal supplied to the controller 61 which will cause any response to be provided in accordance with the communications protocols under which it is operating and whether it is operating in the passive or active communications mode. Where the NFC communicator 60 is operating in active mode, it will respond through the generation of a modulated signal at antenna 57 which will be inductively coupled to the antenna region(s) 102 and thence via the antenna region(s) 103 to the communicating initiator NFC communicator or RFID reader. Where the NFC communicator 60 is operating in passive mode, the NFC communicator 60 may either modulate the received RF signal directly by load modulation or through interference with the carrier signal (simulates load modulation).

When the NFC communicator 60 is operating in initiator mode, it generates an RF signal, which may or may not be modulated and which will be inductively coupled to the antenna region(s) 102 and thence via the antenna region(s) 103 to the
communicating target NFC communicator or RFID tag. Where the initiator NFC communicator 60 is operating in the active communications mode, the NFC communicator will then cease RF signal transmission and await a response RF signal. Where the initiator NFC communicator 60 is operating in the passive communication mode, the initiator NFC will maintain its RF signal throughout the duration of the communication cycle and the responding or target NFC communicator or RFID tag will modulate that the transmitted RF signal.

Any received signal will be demodulated by the demodulator 58 and the thus extracted data signal supplied to the controller 61 which will cause any response to be provided in accordance with the communications protocols under which it is operating and whether it is operating in the passive or active communications mode.

As described above, the presence of the additional antenna enables near field communication over a larger range than would have been possible with just the antenna 57.

The NFC communicator 60 may be a stand-alone device or have a host as described above, possible examples of a host being a mobile telephone, printer, personal digital assistant or computer or other electrical or electronic device or system. Where the NFC communicator 60 is within a host, the controller 61 may provide an interface to a host controller (represented by other functionality 59) which may then be responsible for control of at least some of the NFC communicator operations. For example, the host controller may control most of the operations of the NFC communicator 60 or the controller 61 may provide some control functions and an interface to the host controller for other control functions and/or data.

NFC communicators in accordance with the invention may be used in any appropriate ones of the ways described above for RFID readers and tags.

NFC communicators may enable communication between hosts, for example communication between a portable computer (laptop, PDA etc.) and a mobile telephone or between two mobile telephones or between a portable computer (laptop, PDA etc.) and a printer, or communication between three or more such devices.
As described above, the built-in or integrated antenna and corresponding antenna region of the external antenna are impedance matched. Such impedance matching need not necessarily be perfect impedance matching, although of course the better the impedance matching the better the inductive coupling of the RF signal. As described above, the built-in or integrated antenna and corresponding antenna region of the external antenna are described as lying in generally parallel planes. Although this is optimum, it is not necessarily essential, what is required is that there is sufficient overlapping of magnetic fields of the antenna region(s) 103 and the first antenna and that null zones are avoided, which generally requires at least some overlap of the antenna region(s) 103 and the first antenna 107. Thus, although the planes of the built-in or integrated antenna and corresponding antenna region and the magnetic field direction should not of course be perpendicular to one another, they need not necessarily be parallel, although the closer they are to parallel the better the inductive coupling.

Features from different embodiments described above may be combined. For example the RFID reader in Figure 7 or the NFC communicator in Figure 8 may have a sensor 308 and/or a user interface 309. It will be apparent from the foregoing that many different embodiments of near field RF communicators embodying the invention are possible and that the examples of near field RF communicators described are given by way of illustration only. Modifications, substitutions and additions may be made to the described embodiments without departing from the spirit and scope of the invention.

Embodiments enable the design of the antenna of an RFID transponder implemented by means of a single integrated circuit or chip to be adapted to the particular environment within which the RFID transponder is to operate and enable different antenna designs for different RFID transponder environments and applications so as to enable adaptation to different physical constraints on the positioning of the RFID transponder and its antenna, without significant cost increase.

Embodiments also enable design flexibility to be achieved for other near field RF communicators, for example RFID readers and NFC communicators, that may be required to operate within different localised environments or be comprised within different hosts.
Whilst certain combinations of features have been identified in the accompanying claims, the scope of the present invention is not limited to those combinations and instead extends to encompass any combination of features herein described irrespective of whether or not that particular combination has been explicitly enumerated.
Claims

1. A near field RF communicator having an integrated first antenna, the near field RF communicator also having a second antenna, the second antenna having a first antenna region arranged to enable inductive coupling between the integrated first antenna and the first antenna region, the second antenna also having a second antenna region arranged to enable inductive coupling with another near field RF communicator to enable near field communication between the near field RF communicators via the first and second antennas.

2. A near field RF communicator according to claim 1, wherein the near field RF communicator comprises an integrated circuit and the first antenna forms part of the integrated circuit.

3. A near field RF communicator in the form of an RFID transponder, the RFID transponder comprising an integrated circuit including an integrated first antenna, the RFID transponder also having a second antenna, the second antenna having a first antenna region arranged to enable inductive coupling between the integrated first antenna and the first antenna region, the second antenna also having a second antenna region arranged to enable inductive coupling with another near field RF communicator to enable near field communication between the RFID transponder and the near field RF communicators via the first and second antennas.

4. A near field RF communicator according to claim 2 or 3, wherein the first antenna comprises a coil defined by at least one electrically conductive layer of the integrated circuit.

5. A near field RF communicator according to claim 1, wherein the first antenna comprises a coil integrated in a body of the near field RF communicator.

6. A near field RF communicator according to claim 1, wherein the first antenna comprises a coil integrated on a circuit board of the near field RF communicator.

7. A near field RF communicator according claim 6, wherein the first antenna coil is defined by an electrically conductive path on the circuit board.

8. A near field RF communicator according to any of claims 1 to 7, wherein the
first and second regions of the second antenna each comprises a coil defined by an electrically conductive path on a substrate.

9. A near field RF communicator according to any of claims 4 to 8, wherein the coils have turns of a shape selected from: rectangular, square, rectangular or square with rounded corners, oval, and circular.

10. A near field RF communicator according to any of the preceding claims, wherein the first region of the second antenna is impedance matched to the first antenna.

11. A near field RF communicator according to any of the preceding claims, wherein the first region of the second antenna and the first antenna are positioned so as to both be associated with the same magnetic field.

12. A near field RF communicator according to any of claims 1 to 10, wherein the first region of the second antenna and the first antenna are positioned so as to both be associated with the same magnetic flux lines.

13. A near field RF communicator according to any of claims 1 to 12, wherein the first region of the second antenna and the first antenna are positioned so as to lie in substantially parallel overlapping planes.

14. A near field RF communicator according to any of claims 1 to 13, wherein the second antenna region lies in a plane that is one of transverse or perpendicular to the first antenna region.

15. A near field RF communicator according to any of claims 1 to 14, wherein the first antenna and the first antenna region form a transformer.

16. A near field RF communicator according to any of claims 1 to 15, wherein at least one of the first and second antennas has a core.

17. A near field RF communicator according to any claims 1 to 16, wherein the first antenna region and the second antenna region are configured to have different inductive coupling ranges.

18. A near field RF communicator according to any of the preceding claims,
wherein the second antenna is physically separate.

19. A near field RF communicator according to any of claims 1 to 17, wherein the first antenna and the second antenna are carried by respective ones of first and second components.

20. A near field RF communicator according to claim 19, wherein one of the first and second components is a disposable or consumable component.

21. A near field RF communicator according to any of the preceding claims, wherein the near field RF communicator comprises at least one of: an RFID tag; an RFID reader; and an NFC communicator.

22. A near field RF communicator according to any of the preceding claims, having a controller and at least one of a demodulator to demodulate a modulated RF signal inductively coupled to the first antenna and a modulator to modulate an RF signal.

23. An electrical device comprising a near field RF communicator according to any of the preceding claims.

24. An electrical device according to claim 23, wherein the near field RF communicator is integrated within or dispersed within the functionality of the electrical device.

25. An electrical device according to claim 23, wherein the near field RF communicator comprises at least one integrated circuit within the electrical device.

26. An electrical device according to any of claims 23 to 25, wherein the device comprises at least one of a mobile telephone, a portable computing device such as a personal digital assistant, notebook, or lap-top, a personal or desk top computer, a computer peripheral such as a printer, or other electrical device such as a portable audio and/or video player.

27. A portable communications device incorporating a near field RF communicator according to any of claims 1 to 22.
28. An antenna for use with a near field RF communicator, where the antenna has a plurality of regions, one region being designed to couple inductively with an integrated antenna of the near field RF communicator and one region being designed to couple inductively with to an antenna or antenna region of another near field RF communicator.

29. An antenna according to claim 28, wherein each region is impedance matched to the antenna or antenna region with which it is to couple.

30. An antenna according to claim 28 or 29 having the antenna features set out in any of claims 1 to 22.
FIG. 6
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04B5/00 H04B5/02 G06K19/077

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)
H04B G06K

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 practical, search terms Used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with Indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
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<td>US 2005/130389 Al (YAMAZAKI SHUNPEI [JP]) ET AL) 16 June 2005 (2005-06-16) paragraphs [0040], [0043], [0045], [0049], [0052], [0060], [0063] figure 3D</td>
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D. Further documents are listed in the continuation of Box C.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier document but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"X" document of particular relevance; the claimed Invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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.
"A" document member of the same patent family

Date of the actual completion of the international search
29 May 2007

Date of mailing of the international search report
06/06/2007

Name and mailing address of the ISA/
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Authorized officer
Lustrini, Donato
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