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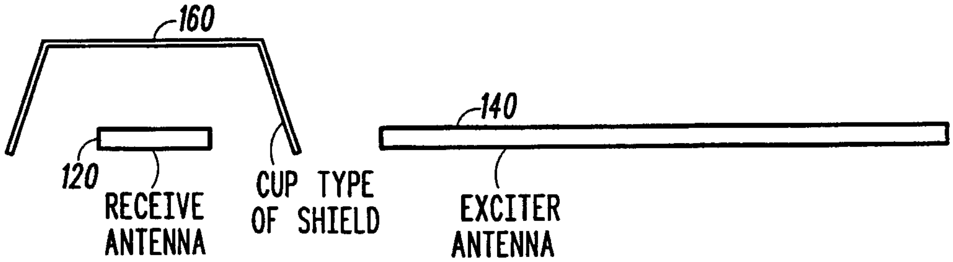
(54) Title: METHOD AND APPARATUS FOR REDUCING THE AMOUNT OF INTERFERENCE BETWEEN TWO ANTENNAE POSITIONED NEAR EACH OTHER IN AN ELECTRIC FIELD RADIO FREQUENCY IDENTIFICATION READER SYSTEM



(57) Abstract: A typical reader system has at least a receiver (110), a first antenna (120), an exciter (130) and a second antenna (140). An electrically conductive shield (160) is positioned between the first antenna (120) and the second antenna (140) in order to reduce noise generated by the second antenna (140) and received at the first antenna (120).

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METHOD AND APPARATUS FOR REDUCING THE AMOUNT OF INTERFERENCE BETWEEN TWO ANTENNAE POSITIONED NEAR EACH OTHER IN AN ELECTRIC FIELD RADIO FREQUENCY IDENTIFICATION READER SYSTEM

Field of the invention

The present invention relates generally to a method and apparatus for reducing the amount of interference between two antennae positioned near each other in an electric field radio frequency identification reader system.

Background of the Invention

FIG. 1 illustrates a cross-sectional side view of a capacitively coupled radio frequency identification (RFID) reader system 100. The reader system 100 typically comprises a variety of components, but for purposes of this discussion, only a receiver 110, a receive antenna 120, an exciter source 130 (i.e., a voltage source or electrical source) and an exciter antenna 140 are shown. The two antennae 120, 140 are used for the purpose of communicating power and information between the reader system 100 and a capacitively coupled RFID tag (also referred to as a transceiver) 150. The exciter antenna 140 is used primarily to capacitively couple power to the tag 150, but the signal on the exciter antenna 140 may also be modulated in order to communicate information from the reader 100 to the tag 150. The receive antenna 120 is used to receive information communicated to the reader 100 by the tag 150.

When the tag 150 is positioned within proximity of the reader system 100, exciter power is capacitively coupled to the tag 150 and the tag 150 responds by modulating its impedance as a function of the data being communicated back to the reader 100. The varying impedance causes a varying voltage that is capacitively coupled to the receive antenna 120 of the reader 100. In order to achieve useful operating distances between the tag 150 and the reader 100, the exciter voltage at the reader 100 is typically two to three orders of magnitude greater than the voltage across the tag 150. The resultant modulation voltage across the tag 150 is a fraction of the operating voltage of the tag 150. Under typical operating conditions, particularly when the tag 150 is at large distances from the reader 100, the amplitude of the capacitively coupled tag signal that is incident upon the receive antenna 120 is very small; being orders of magnitude smaller than the voltage across the tag 150 itself. Because the capacitively coupled tag signal is so small, the receiver 110 connected to the receive antenna 120 must have high gain in order to amplify and recover the tag signal, and to enable the tag signal to be processed by other components of the receiver 110.

In addition to the tag signal, current flows between the exciter antenna 140 and the receive antenna 120 because of the capacitance and potential difference that exists between them. At the receive antenna 120, the voltage that results from exciter coupling is many orders of magnitude greater than the voltage resulting from the tag signal. Therefore, the desired tag signal is swamped by the much larger exciter signal at the receive antenna 120. Because of this, the high-gain receiver circuitry can be easily overloaded by the much larger signal coupled from the exciter antenna 140, thereby reducing or eliminating the ability to receive and process the tag signal. Even without overloading, the large exciter component in the receiver 110 results in a low signal-to-noise ratio, which significantly reduces the read distance performance, and sometimes prevents the reader system 100 from being usable in the intended application.

Prior art systems utilize tuned networks, or filters, connected to the receive antenna 120 in order to reject signals at the exciter frequency, and to pass or enhance signals at the tag modulation frequency. Such tuned networks must often be constructed of passive components (e.g., inductors, capacitors and resistors) rather than active semiconductor-based filter circuits to prevent them from being overloaded by the large voltages coupled by the exciter antenna 140. In many cases, the tuned network must be tuned by manually adjusting one or more of the passive components to obtain the desired rejection and/or bandpass frequencies in order to compensate for component tolerances. Also, tuned network component characteristics may vary due to temperature changes, mechanically induced drift and aging. Such component variations can potentially cause shifts in the rejection and/or bandpass frequencies that are large enough to cause a significant decrease in reader system 100 performance. Therefore, important design considerations must be made during the design of such tuned networks.

Another important design consideration of tuned networks is the effective input impedance at the modulated tag signal frequency. As the input impedance at the receive antenna 120 decreases, the amplitude of the tag signal at the receive antenna

120 will also be reduced; potentially reducing system performance.

Thus, there exists a need to provide a method and apparatus for reducing the amount of interference received at the receiver 110 when the exciter and receive antennae are placed near each other in the RFID reader system 100.

Brief Description of the Drawings

A preferred embodiment of the invention is now described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 (prior art) illustrates a capacitively coupled radio frequency identification (RFID) system;

FIG. 2 illustrates a side view of a cup shield positioned over a receive antenna and the receive antenna and an exciter antenna are coplanar in accordance with the preferred embodiment of the present invention;

FIG. 3 illustrates a side view of the cup shield positioned over the receive antenna and the receive antenna and the exciter antenna are non-coplanar in accordance with the preferred embodiment of the present invention;

FIG. 4 illustrates a side view of the cup shield as depicted in FIG. 3 with the receive antenna oriented in a different position in accordance with the preferred embodiment of the present invention;

FIG. 5 illustrates a side view of an outer cup shield placed over the cup shield depicted in FIG. 3 in accordance with a first alternative embodiment of the present invention;

FIG. 6 illustrates a top view of a strip shield positioned between the receive antenna and the exciter antenna in accordance with a second alternative embodiment of the present invention; and

FIG. 7 illustrates a top view of a guard ring positioned between the receive antenna and the exciter antenna in accordance with a third alternative embodiment of the present invention.

Detailed Description of the Preferred Embodiment

Referring to the typical reader system 100 illustrated in FIG. 1, the present invention reduces the amount of interference received at the receive antenna 120 when the exciter and receive antennae 140, 120 are placed near each other in the reader system 100. The reader system 100 can be a capacitively coupled radio frequency identification (RFID) reader or a contactless smartcard reader. The present invention significantly reduces, and in some cases eliminates, performance limitations of the reader system 100 caused by excessive exciter signals coupling into the receive antenna 120. The present invention eliminates the need for tuned networks between the receive antenna 120 and receiver circuitry 110, thereby eliminating the disadvantages of tuned networks described above. Elimination of tuned networks can reduce circuit assembly area requirements, which may be necessary for miniaturized or portable reader systems. Because tuned networks can be eliminated, there is more flexibility in the choice of the reader exciter frequency. Also, a reader system 100 utilizing the present invention is more tolerant of exciter frequency variations than a tuned network system.

It should also be noted that the present invention may be utilized in conjunction with the tuned networks. Although tuned networks are not required if the present invention is utilized, tuned networks may still be used to further enhance reader system performance. Some specific applications may limit the fullest implementation of the present invention or its variations, so the additional use of tuned networks is a practical means to achieving the desired reader system performance. In such a situation, the improvement offered by the present invention allows the tuned networks to be designed with less-stringent characteristics than would be required if a tuned network were used alone without the present invention. In other words, system performance sensitivity to tuned network drift is reduced by the use of the present invention. This allows the use of non-adjustable components in the tuned networks, thus improving cost and manufacturability of the reader system.

For ease of explanation and clarification, the following description and figures only describe and depict the exciter and receive antennae 140, 120 of the typical reader system 100 depicted in FIG. 1 in order to illustrate the present invention. The exciter and receive antennae 140, 120 are electrically conductive. Different materials and compositions posses varying degrees of electrical conductivity. The minimum electrical conductivity requirements vary depending upon system performance goals, as well as other constraints such as cost, weight, etc.

The material of the exciter and receive antennae 140, 120 is selected from a variety of materials. For example, the material for the antennae 140, 120 may be metal (e.g., aluminum, copper, brass, steel, stainless steel, etc.) sheets or screens that are planar or formed into a variety of shapes. The metal screens may be a fine mesh screen (such as a window screen), a medium mesh screen or a coarse mesh screen (such as chicken wire). Additionally, the material for the antennae 140, 120 may be conductive film on an electrically non-conductive substrate material. Examples of the conductive film are aluminum, copper, steel, nickel or any other metals and alloys. Examples of the non-conductive substrate are plastic, paper, glass, wood, etc., in sheet form or various shapes. Further, the material for the antennae 140, 120 may be conductive inks or paints. The conductive ink or paint contains electrically conductive particles (such as carbon, metal, or other materials) and may be applied to a non-conductive substrate. Still further, the material for the antennae 140, 120 may be an electrically conductive composite material, such as graphite composite, conductive polymers, formed into shapes or sheets. As such, the antennae 140, 120 can be comprised of any material and manufactured in any fashion so long as the resulting antennae 140, 120 are electrically conductive.

FIG. 2 illustrates an electrically conductive shield 160 positioned over the receive antenna 120 in accordance to the preferred embodiment of the present invention. The shield 160 can take on a variety of shapes, and in the preferred embodiment, the shield 160 is formed into a cup shape. Other embodiments of the present invention illustrate the shield 160 formed in different shapes, but the illustration of various shapes is not intended to be a limitation of the present invention, but rather used as exemplary illustrations.

In FIG. 2, the exciter and receive antennae 140, 120 are coplanar. The shield 160 reduces the coupling of the unwanted exciter signal emitted from the exciter antenna 140 and picked up by the receive antenna 120. The shield 160 is electrically conductive, typically composed of a low impedance material, such as metal, although other materials can be used if appropriately selected. The shield 160 is electrically connected to the signal reference for both the exciter and receiver circuits 130, 110, and is typically system/earth ground in the capacitively coupled RFID reader system 100 of the preferred embodiment.

The shield 160 is terminated to ground, which can be equal to or very close to the natural potential of the receiver input in the absence of an exciter field or tag signal. Because of the capacitance between the exciter antenna 140 and the shield 160, and the fact that the shield 160 is terminated to ground (the same potential reference as the exciter (electrical/voltage) source), current flows between the exciter antenna 140 and the shield 160. The shield 160 and its termination, however, diverts the current flow away from the receive antenna 120. As a result, the capacitance between the exciter and the receive antennae 140, 120 is significantly reduced by the shield 160. Moreover, because of the low impedance between the shield 160 and ground, there is essentially no potential difference; namely, voltage difference, between the shield 160 and receive antenna 120. In this way, the shield 160 significantly reduces the amplitude of the exciter voltage coupled to the receive antenna 120.

The strong electric field radiated by all surfaces of the exciter antenna 140 is blocked by the shield 140 on the top and edges of the receive antenna 120. Preferably, the shield 160 is open on one surface to allow communication with the RFID tags 150 to occur on that side. A small fringe field component of the exciter field, however, may still couple around the edges of the shield 160 into the open surface of the receive antenna 120. The amplitude of the exciter fringe component incident upon the receive antenna 120, however, is significantly smaller than that of FIG. 1. Therefore, the shield 160, as taught in the present invention, prevents system overloading, increases the receiver signal-to-noise ratio, and improves system performance (read distance) over the system 100 of FIG. 1 without the shield 160.

Furthermore, the shield 160 in accordance with the preferred embodiment of the present invention prevents electric fields from extraneous noise sources from reaching the receive antenna 120 if their source is above or directly to the side of the receive antenna 120. Thus, the shield 160 helps to establish a controlled communication space between the tag 150 and reader 100, and minimizes the adverse effects caused by both internal and external unwanted noise sources.

As illustrated in FIG. 3, the exciter antenna 140 is no longer coplanar with the receive antenna 120. The relationship between the receive antenna 120 and the shield 160 is unchanged. The exciter antenna 140 offset improves the shielding effectiveness because there is more of an edge barrier between the receive antenna 120 and the exciter antenna 140, thus resulting in the shield 160 diverting more of the exciter field away from the receive antenna 120. As a result, the signal-to-noise ratio of FIG. 3 is greater than that of FIG. 2, and further improves system performance.

FIG. 4 is similar to FIGS. 2 and 3 except that the receive antenna 120 is "recessed" deeper within the shield 160 to reduce the exciter fringe coupling, first discussed in relation to FIG. 2, even further. As shown in FIGS. 2 and 3, the exciter and receive antennae 140, 120 may be coplanar or not coplanar. The shield 160 extends past the receive antenna plane in order to provide more of a side barrier to the exciter field. While this provides additional attenuation of unwanted exciter coupling into the receive antenna 120, it has the net effect of reducing the 'field of view' or lateral read zone distance (e.g., similar to putting blinders on). In systems in which lateral read zone size is not critical, it can be a very effective way to reduce exciter noise in the receiver circuitry 110. The receive antenna 120 can be positioned on a higher plane than the exciter antenna 140, and the bottom of the shield 160 can be coplanar or not coplanar with the exciter antenna 140.

FIG. 5 illustrates the use of a dual shield over the receive antenna 120 in accordance with a first alternative embodiment of the present invention. The advantage of this implementation is that the exciter current that flows through an outer shield 170 termination can flow directly to ground, while the inner shield 160 can be terminated to the ground reference for the receiver 110. Such a dual shield configuration diverts the relatively high exciter current away from the signal ground reference of the sensitive receiver circuits 110 in the reader 100; further reducing noise in the receiver 110. As described above for other configurations, the receive and exciter antennae 120, 140 can be coplanar or not coplanar.

Alternatively, the inner shield 160 could be connected to a second electrical (voltage) source (not shown). The second electrical source may be a driven shield amplifier circuit (not shown) that buffers the signals transmitted by the tag 150. The advantage of connecting the inner shield 160 to the driven shield amplifier circuit is that the effective load capacitance seen by the receive antenna 120 is reduced to nearly zero, thus optimizing the amplitude of the capacitively coupled tag signal. Such a configuration can further improve system performance.

FIG. 6 is a top view of a shield 160 placed between a monopole exciter antenna 140 and a monopole receive antenna 120 in accordance to a second alternative embodiment of the present invention. In the second alternative embodiment of the present invention, it is preferably, but not required, that the shield 160 is a strip shape and that all three elements are coplanar. This configuration is useful in applications where cup shields are either too expensive or cup shields are not practical due to physical limitations (e.g., size).

As in FIG. 6, the strip shield 160 may be grounded or connected to the exciter source 130 return or driven by a voltage approximately equal to the voltage on the receive antenna 120. Such a configuration of the shield 160 minimizes the capacitance between the receive antenna 120 and the shield 160, thus reducing the capacitive loading on the received signal.

Alternatively, a second strip shield (not shown) may be added between the first strip shield 160 and the receive antenna

120 with a different ground than the first strip shield 160. This second strip shield may also be driven to reduce capacitance to the receive antenna 120.

Although FIG. 6 shows the receive antenna 120, the exciter antenna 140, and the strip shield 160 as being coplanar, it is possible to place the elements 120, 140, 160 in three dimensions in a variety of implementations. The strip shield 160 will have most effect, however, when it is placed where the electric field lines between the antennae 120, 140 are of greatest density.

FIG. 7 is a top view of a monopole antennae configuration where the exciter antenna 140 is a "ring" and the receive antenna 120 is placed in the center of the exciter antenna 140 space. The strip shield 160 first shown in FIG. 6 is now extended into a "ring" so that it completely surrounds the receive antenna 120. Another name for a shield of this type is a "guard ring".

As in FIG. 6, the guard ring 160 illustrated in FIG. 7 may be grounded or connected to the exciter source 130 return or the guard ring 160 may be driven by a voltage approximately equal to the voltage on the receive antenna 120. As stated previously, this configuration also minimizes the capacitance between the receive antenna 120 and the guard ring 160, thus reducing the capacitive loading on the received signal.

Alternatively, a second concentric guard ring (not shown) may be added between the first guard ring 160 and the receive antenna 120 with a different ground than the first guard ring 160. Alternatively, this second guard ring may also be driven to reduce capacitance to the receive antenna 120.

Although FIG. 7 shows the receive antenna 120, the exciter antenna 140 and the guard ring 160 as being coplanar, it is possible to place the elements 120, 140, 160 in three dimensions in a variety of implementations. The guard ring 160, however, will have most effect when it is placed where the electric field lines between the antennae 120, 140 are of greatest density.

While the invention has been described in conjunction with a specific embodiment thereof, additional advantages and modifications will readily occur to those skilled in the art. For example, the shield 160 can be formed in a variety of other shapes that are not shown or described herein. Further, the placement of the actual components, in particular, the receive antenna 120, the exciter antenna 140 and the shield 160 are variable depending on the system's 100 requirements. The invention, in its broader aspects, is therefore not limited to the specific details, representative apparatus, and illustrative examples shown and described. Various alterations, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. Thus, it should be understood that the invention is not limited by the foregoing description, but embraces all such alterations, modifications and variations in accordance with the spirit and scope of the appended claims.

Claims

We claim:

1. A method for reducing interference between a first antenna and a second antenna positioned near each other in an electric field radio frequency identification reader system comprising placing a first electrically conductive shield between the first antenna and the second antenna, wherein a potential of the first electrically conductive shield is referenced to a first electrical source.

2. The method in accordance with claim 1 further comprising at least partially surrounding at least one of the first and second antennae with the first electrically conductive shield.

3. The method in accordance with claim 2 further comprising placing a second electrically conductive shield at least partially around the first electrically conductive shield, wherein the second electrically conductive shield is formed in at least a three-dimensional shape and the second electrically conductive shield has approximately equal voltage as the at least one of the first and second antennae.

4. The method in accordance with claim 2 further comprising placing a second electrically conductive shield at least partially around the first electrically conductive shield, wherein the second electrically conductive shield is formed in at least a three-dimensional shape and a potential of the second electrically

conductive shield is referenced to a different electrical source than the first electrically conductive shield.

5. The method in accordance with claim 1 wherein the first electrical source is earth-ground.

6. An apparatus for reducing interference between two antennae positioned near each other in an electric field radio frequency identification reader system comprising:

a first antenna;

a second antenna; and

a first electrically conductive shield is positioned between the first antenna and the second antenna, wherein a voltage of the first electrically conductive shield is referenced to a first voltage source.

7. The apparatus in accordance with claim 6 wherein the first electrically conductive shield is formed in at least a three-dimensional shape that at least partially surrounds at least one of the first and second antennae.

8. The apparatus in accordance with claim 6 further comprising a second electrically conductive shield positioned at least partially surrounding the first electrically conductive shield, wherein the second electrically conductive shield is formed in at least a three-dimensional shape and the second electrically conductive shield has approximately equal voltage as the at least one of the first and second antennae.

9. The apparatus in accordance with claim 8 further comprising a second electrically conductive shield positioned at least partially around the first electrically conductive shield, wherein the second electrically conductive shield is formed in at least a three-dimensional shape and a voltage of the second electrically conductive shield is referenced to a different voltage source than the first electrically conductive shield.

10. The apparatus in accordance with claim 6 wherein the first electrically conductive shield is a formed in at least a two-dimensional shape that at least partially surrounds at least one of the first and second antennae.

11. The apparatus in accordance with claim 6 wherein the electrically conductive shield has a low impedance.

12. The apparatus in accordance with claim 6 wherein the first antenna and the second antenna are coplanar.

13. The apparatus in accordance with claim 6 wherein at least one of the first and the second antennae are selected from a group consisting of: electrically conductive ink, electrically conductive paint, electrically conductive composite materials, metalized films, metal screens, and metal sheet.

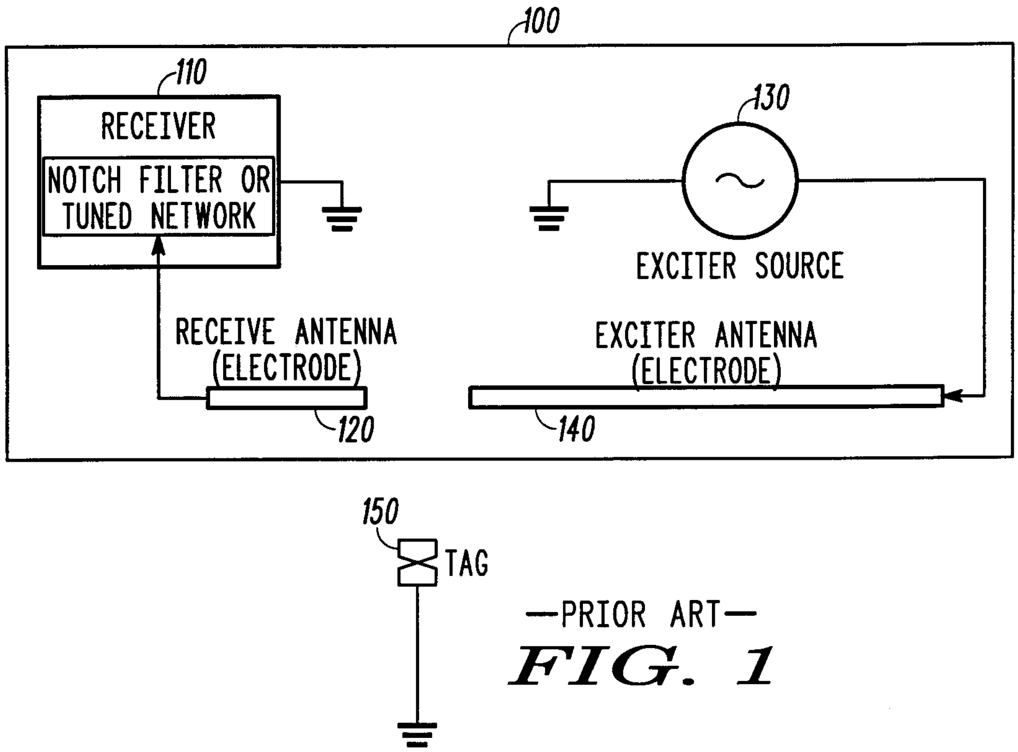
14. The apparatus in accordance with claim 6 wherein the first electrically conductive shield is selected from a group consisting of: electrically conductive ink, electrically conductive paint, electrically conductive composite materials, metalized films, metal screens, and metal sheet.

15. An improved apparatus for reducing noise components communicated between a first antenna and a second antenna in an electric field radio frequency identification communication device arranged for capacitively transmitting and receiving data via the first and second antenna characterized by:

a electrically conductive shield disposed between the first antenna and the second antenna.

16. An improved method for reducing noise components communicated between a first antenna and a second antenna in an electric field radio frequency identification communication device arranged for capacitively transmitting and receiving data via the first and second antenna wherein the improvement is characterized by the step of:

placing an electrically conductive shield between the first antenna and the second antenna.



—PRIOR ART—

FIG. 1

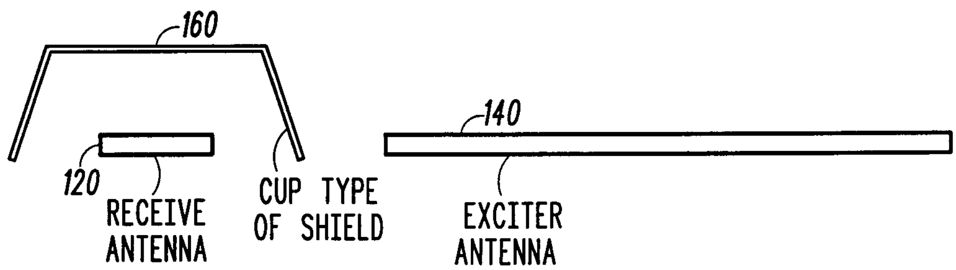


FIG. 2

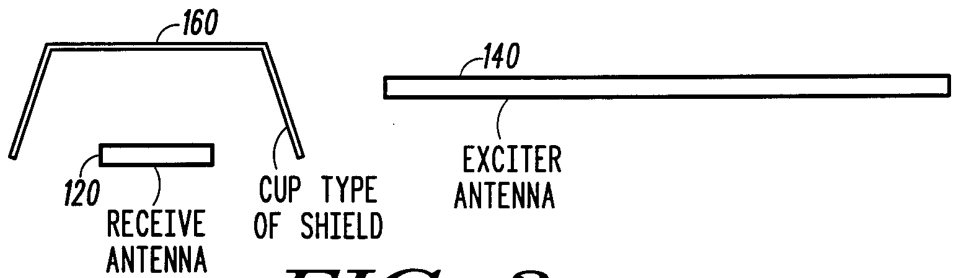


FIG. 3

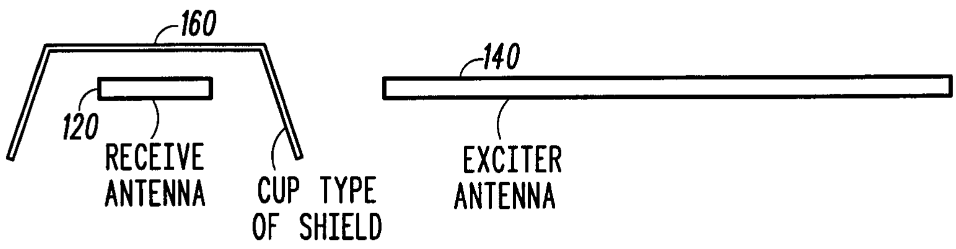


FIG. 4

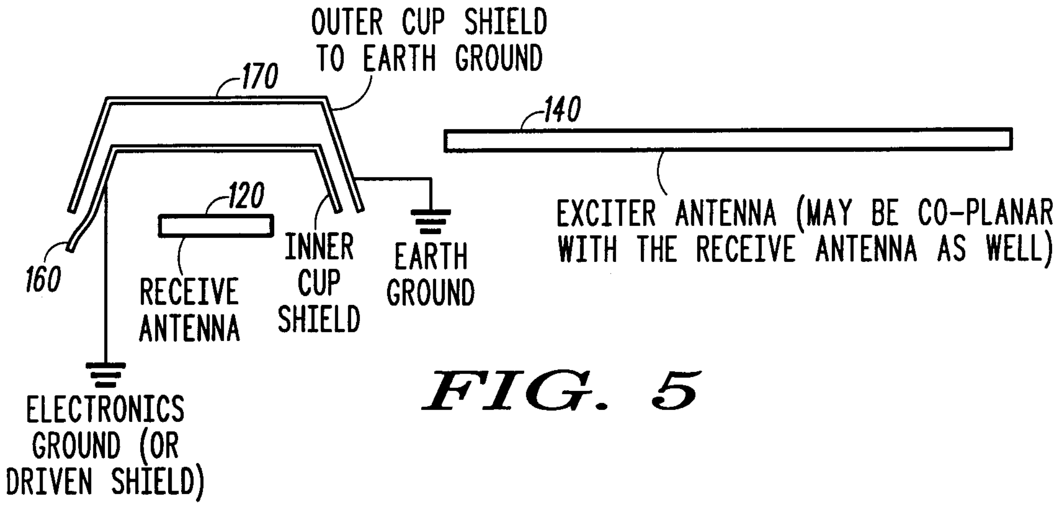


FIG. 5

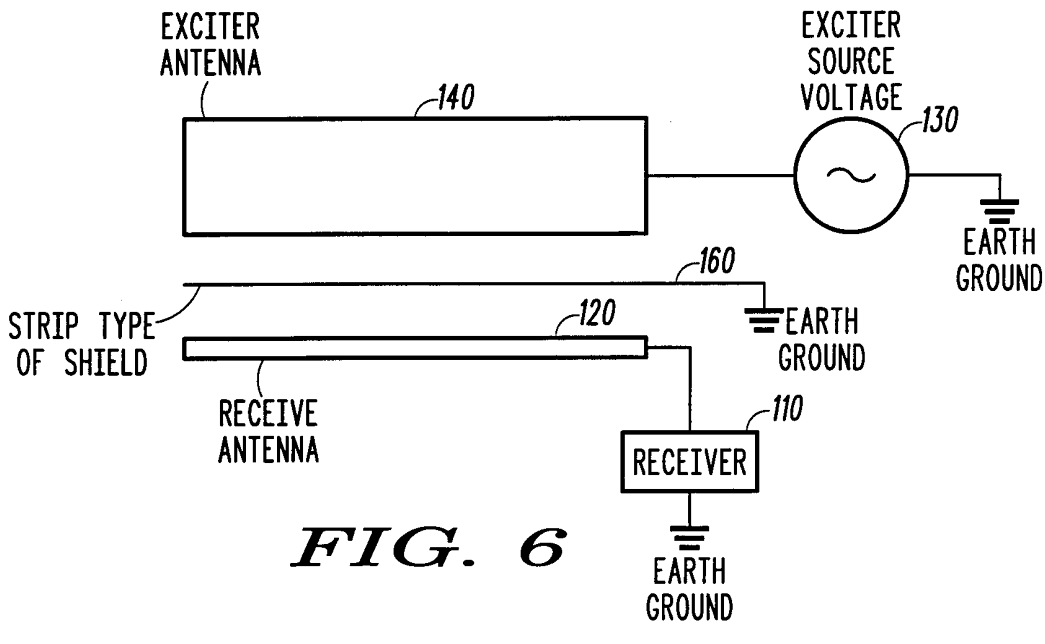


FIG. 6

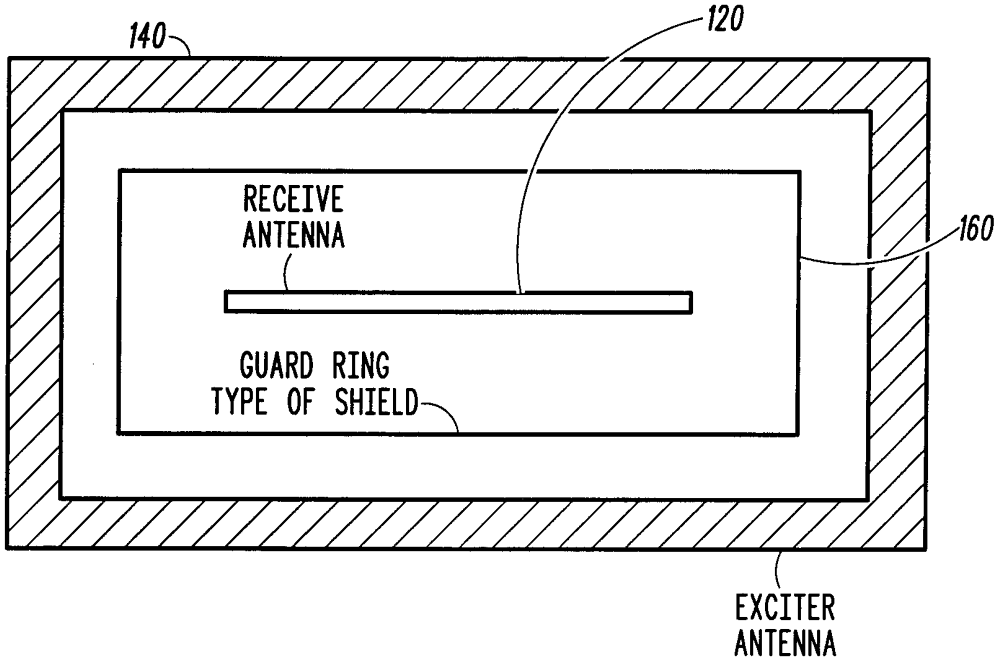

140
120
RECEIVE
ANTENNA
160
GUARD RING
TYPE OF SHIELD
EXCITER
ANTENNA

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/23396

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :H01Q 1/52
US CL :343/841, 845, 846
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)
U.S. : 343/841, 845, 846

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 3,594,809 A (DE COLA) 20 July 1971 (20.07.1971), abstract, fig. 4 and col. 2, lines 10-42.	1, 6, 10-11, 13-16 ------ 2-5, 12
Y	US 4,827,275 A (FUSINSKI) 02 May 1989 (02.05.1989), fig. 2-3 and cols. 3-4.	1-16
Y	US 4,968,984 A (KATOH et al) 06 November 1990 (06.11.1990), Fig. 3 and col. 5, lines 1-8.	1-16
A	US 5,444,866 A (CYKIERT) 22 August 1995 (22.08.1995), abstract.	1-16
A	US 5,826,201 A (GRATIAS) 20 October 1998 (20.10.1998), fig. 10 and cols. 5-6.	1-16

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
28 SEPTEMBER 2000	16 NOV 2000

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,864,323 A (BERTHON) 26 January 1999 (26.01.1999), fig. 1 and col. 2, lines 40-65.	1-16