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Radio Frequency Identification (RFID) Tags for Metallic and Three-Dimensional (3D) Objects and Methods of Making and Using Thereof

Abstract

RFID tags for use on a non-planar surface of an object, packaging around the object, or a metallic object, and methods of making and using thereof are disclosed. For 3D objects, the method comprises forming an antenna on the non-planar surface and positioning a reactive RFID strap in proximity to the antenna. The reactive RFID strap can induce a far field antenna response, wherein coupling can occur via electric fields, magnetic fields, or both. For metallic objects, an antenna is formed on the surface of a substrate. An RFID chip or strap is attached and the clip component cut. The clip components can be modified to help secure the clip component to the metallic item by adding surface deflections, adhesive fixing points, or tabs designed to engage with an existing hole or opening in the metallic item package or object.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS [0001] The present application is a division of U.S. patent application Ser. No. 17/612,401 filed Nov. 18, 2021, which is a national stage application under 35 U.S.C. § 371 of International Application No. PCT/US2020/034864 filed May 28, 2019, which claims the benefit of U.S. Provisional Patent Application Nos. 62/854,126 filed May 29, 2019 and 62/954,482 filed Dec. 28, 2019, each of which is incorporated by reference herein in their entireties.

FIELD

[0002] The present invention relates generally to (1) the production of a radio frequency identification (RFID) tags that can be generated on three dimensional (3D) objects or packages and (2) the production of a reactive radio frequency identification (RFID) strap which interacts with a metallic object and induces current flow in it. More specifically, for 3D objects, the RFID tag can be formed on the surface of the 3D object or its primary or secondary packaging by producing a conductive material on the object, compensating for its shape and position, and coupling the conductive material to a reactive RFID strap to form the RFID tag that can then induce a far field RFID antenna response. For metallic objects, the reactive RFID strap can be secured to a plastic clip for relatively easy attachment to the metallic object; and if the size and shape of the metallic object are suitable, the reactive RFID strap can induce a far field RFID antenna response.

BACKGROUND

[0003] Generally stated, radio-frequency identification is the use of electromagnetic energy to stimulate a responsive device (known as an RFID “tag” or transponder) to identify itself and, in some cases, provide additional information and/or data stored in the tag. RFID tags typically comprise a semiconductor device commonly referred to as the “chip”, upon which are formed a memory and an operating circuitry, which is connected to an antenna. Typically, RFID tags act as transponders, providing information stored in the chip memory in response to a radio frequency interrogation signal received from a reader, also referred to as an interrogator. In the case of passive RFID devices, the energy of the interrogation signal also provides the necessary energy to operate the RFID tag device.

[0004] As referenced above, RFID tags are generally formed by connecting an RFID chip to some form of antenna. Antenna types are very diverse, as are the methods of constructing the same. One particularly advantageous method of making RFID tags is to use a strap, a small device with an RFID chip connected to two or more conductors that can be coupled to an antenna. The coupling of the conductors to the antenna can be achieved using a conductive connection, an electric field connection, magnetic connection or a combination of coupling methods.

[0005] RFID tags may be incorporated into or attached to articles that a user wishes to later identify and/or track. In some cases, the tag may be attached to the outside of the article with a clip, adhesive, tape, or other means and, in other cases, the RFID tag may be inserted within the article, such as being included in the packaging, located within the container of the article, or sewn into a garment. Further, RFID tags are manufactured with a unique identification number which is typically a simple serial number of a few bytes with a check digit attached. This identification number is typically incorporated into the RFID tag during its manufacture. The user cannot alter this serial/identification number, and manufacturers guarantee that each RFID tag serial number is used only once and is, therefore, unique. Such read-only RFID tags typically are permanently

attached to an article to be identified and/or tracked and, once attached, the serial number of the tag is associated with its host article in a computer database.

[0006] Frequently, a number of retail and other items are metallic in some form. These metallic retail items typically require an RFID tag or strap to be attached to them in order to track the item. However, it is sometimes necessary for these RFID tags or straps also to be removable and/or only be active for a limited distance. Therefore, there exists in the art a long felt need to manufacture a reactive RFID strap that can be removably secured to a metallic item. There also exists in the art a long felt need for a reactive RFID strap that induces a current to flow in the metallic object. In one embodiment, the present invention discloses a reactive RFID strap that can be secured to a plastic clip for easy attachment to a metallic object; and if the size and shape of the metallic object are suitable, the reactive RFID strap can induce a far field RFID antenna response.

[0007] Additionally, a number of retail products, other items, and their associated packaging have non-planar surfaces that are not ideal for receiving traditional RFID tags thereon. For example, on a bottle, it is oftentimes necessary to form the RFID tag antenna on the flat portion of the base or top of the bottle to obtain a more secure attachment between the bottle and the RFID tag, as opposed to a curved portion of said bottle. Therefore, there also exists in the art a long felt need for a method of forming an antenna on any portion of the bottle, or any other non-planar surface, that is adapted to the shape that, when used in conjunction with a reactive RFID strap that is flexible enough to conform to the surface, a high performance RFID tag is created. More specifically, the present invention discloses a method of depositing a conductor onto a non-planar surface of an object, wherein the antenna shape may be adapted to function optimally and thereby providing the manufacturer with greater flexibility in RFID tag formation and/or placement.

SUMMARY

[0008] The following presents a simplified summary in order to provide a basic understanding of some aspects of the disclosed innovation. This summary is not an extensive overview, and it is not intended to identify key/critical elements or to delineate the scope thereof. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

[0009] RFID tags for metallic objects and three dimensional (3D) objects are described herein. For metallic objects, in some embodiments, the tags contain reactive RFID strap components containing an RFID chip or strap and a conductor component which are both secured to a plastic clip component. The reactive RFID strap component is then attached to a metallic item or object. If the size and shape of the metallic item is suitable, the reactive RFID strap component can induce a far field antenna response, wherein coupling can be between electric fields, magnetic fields, or both with coupling related to the structure of the reactive RFID strap component and its proximity to the metallic item.

[0010] The clip component of the reactive RFID strap component may be provided in multiple forms. In some embodiments, the tab of a clip component may contain an edge that is aligned with an outside edge of a frame section. In other embodiments, the tab of the clip component can be surrounded or encircled by the frame section on all edges or sides. Nonetheless, as explained more fully below, these two examples of possible types of clip components provide different mechanical properties. For example, the first example offered above is easier to fit and easier to position over an edge of a metallic item, but it is not as robust as the second example. On the other hand, while the second example of a possible clip style may be harder to attach to the metallic object, it is more robust than the first example and will likely have a longer useful life.

[0011] The reactive RFID strap component can be secured to the clip component in multiple ways. In some embodiments, the conductor component can be formed in a conductive loop with the RFID chip in series, coupling primarily by the magnetic fields. In other embodiments, the conductive component can be a generally U-shaped conductor on the frame which couples to a metallic item primarily by the electric fields. In still other embodiments, the conductive component can be a

conductive loop that is mounted on the frame and runs around or encircles the tab of the clip component.

[0012] Methods of manufacturing the reactive RFID strap component for metallic objects are also disclosed. The method generally includes forming an antenna on the surface of a suitable substrate. The substrate can be formed of any suitable material. Exemplary materials include, but are not limited to, plastic. An RFID chip or strap is then attached, and the clip component cut. The clip component may be retained in the web by a series of tabs or be positioned on a release liner and attached by an adhesive. The clip components are then formatted for use, for example, by placing them in rolls, canisters, or bags. The clip components can also be modified to help secure the clip component to the metallic item by adding surface deflections, adhesive fixing points, or tabs designed to engage with an existing hole or opening in the metallic item package or object thereby forming a more secure connection between the clip component and the metallic item.

[0013] In some embodiments, the RFID tag is formed on the surface of a 3D object or its primary or secondary packaging. In some embodiments, the RFID tag is formed by producing a conductive material on the object, compensating for its shape and position, and coupling the conductive material to a reactive RFID strap to form the RFID tag that can then induce a far field RFID antenna response. The RFID tag device is particularly suited for non-planar objects, and gives greater choice on packaging where the RFID tag must be formed and an antenna shape must be adapted to conform to the packaging's geometry to optimally function.

[0014] In some embodiments, a reactive RFID strap component contains an RFID chip or strap and a conductor component which are both secured to a plastic clip component. The reactive RFID strap component is then attached to the 3D object. If the size and shape of the 3D object is suitable, the reactive RFID strap component can induce a far field antenna response, wherein coupling can be between electric fields, magnetic fields, or both with coupling related to the structure of the reactive RFID strap component and its proximity to the 3D item.

[0015] The clip component of the reactive RFID strap component may be provided in multiple forms. For example, the tab of a clip component may contain an edge that is aligned with an outside edge of a frame section. Alternatively, the tab of the clip component can be surrounded or encircled by the frame section on all edges or sides. Nonetheless, as explained more fully below, these two examples of possible types of clip components provide different mechanical properties. For example, the first example offered above is easier to fit and easier to position over an edge of a 3D object, but it is not as robust as the second example. On the other hand, while the second example of a possible clip style may be harder to attach to the 3D object, it is more robust than the first example and will likely have a longer useful life.

[0016] Furthermore, the reactive RFID strap component can be secured to the clip component in multiple ways. For example, the conductor component can be formed in a conductive loop with the RFID chip in series, coupling primarily by the magnetic fields. Alternatively, the conductive component can be a generally U-shaped conductor on the frame which couples to a metallic item primarily by the electric fields. In a further alternative embodiment, the conductive component can be a conductive loop that is mounted on the frame and runs around or encircles the tab of the clip component.

[0017] A method of manufacturing the reactive RFID strap component is also disclosed. The method generally comprises forming an antenna on the surface of a suitable material, such as plastic. A RFID chip or strap is then attached, and the clip component cut. The clip component may be retained in the web by a series of tabs or be positioned on a release liner and attached by an adhesive. The clip components are then formatted for use, such as by placing them in rolls, canisters, or bags. The clip components can also be modified to help secure the clip component to the metallic item by adding surface deflections, adhesive fixing points, or tabs designed to engage with an existing hole or opening in the 3D item package or object thereby forming a more secure connection between the clip component and the 3D object.

[0018] In other embodiments, the method includes forming an antenna on the surface of the non-planar object, and positioning a reactive RFID strap on the surface of the non-planar object near the antenna to form the RFID tag. The reactive RFID strap is coupled to the antenna so that a far field antenna response is induced, wherein coupling can be between electric fields, magnetic fields, or both.

[0019] In other embodiments, the reactive RFID strap may be positioned before the antenna is formed on the surface of the non-planar object. The antenna may be manufactured from a conductive liquid and may be either sprayed or printed onto the surface of the non-planar object by ink jet spraying or printing. Alternatively, the antenna may be manufactured from a metal foil and positioned on the surface of the non-planar object. Further, if the surface area of the non-planar object is overly complex (e.g., contoured) at the location where the RFID antenna is formed, the method may further comprise adding a physical connection between the RFID antenna and the reactive RFID tag.

[0020] In some embodiments, a method of manufacturing a RFID tag adapted for a non-planar object is disclosed. The method preferably includes scanning a surface of the non-planar object and then selecting a suitable design for an RFID antenna at a chosen location on the surface of the non-planar object. A suitable design for a reactive RFID strap may then be selected along with a suitable position for positioning the reactive RFID strap relative to the non-planar object, and the RFID tag can then be formed on the surface of the non-planar object. More specifically, the RFID antenna may be formed on the surface of the non-planar object either before or after the reactive RFID strap is positioned on the surface. Additionally, a radio frequency (RF) performance may be measured to ensure proper performance of the RFID tag and for purposes of optimizing the design. The reactive RFID strap is coupled to the antenna so that a far field antenna response is induced, wherein coupling can be between electric fields, magnetic fields, or both.

[0021] In still other embodiments, the method of manufacturing a RFID tag adapted for a non-planar object includes first depositing a separator on a surface of a non-planar object. An antenna is then formed on the separator, and a reactive RFID strap is positioned on the separator so that the reactive RFID strap couples with the antenna to form the RFID tag. The reactive RFID strap is coupled to the antenna so that a far field antenna response is induced, wherein coupling can be between electric fields, magnetic fields, or both. The separator may be measured for thickness, and the separator thickness adapted to ensure stability of the RFID tag. The separator may further comprise a ramped portion so that the antenna may be formed on the separator, down the ramped portion, and into contact with the surface of the non-planar object. Alternatively, a base conductor may be first positioned on the surface of the non-planar object, and the separator may be deposited or positioned atop the base conductor.

[0022] To the accomplishment of the foregoing and related ends, certain illustrative aspects of the disclosed innovation are described herein in connection with the following description and the annexed drawings. These aspects are indicative, however, of but a few of the various ways in which the principles disclosed herein can be employed and is intended to include all such aspects and their equivalents. Other advantages and novel features will become apparent from the following detailed description when considered in conjunction with the drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 illustrates a top perspective view of a reactive RFID strap component in proximity to and coupled with a metallic object in accordance with the disclosed architecture.

[0024] FIG. 2A illustrates a front perspective view of one possible embodiment of the clip component of the present invention in accordance with the disclosed architecture.

[0025] FIG. 2B illustrates a front perspective view of an alternative embodiment of the clip component of the present invention in accordance with the disclosed architecture.

[0026] FIG. 3A illustrates a front perspective view of an embodiment of the tab component with the conductor component forming a conductive loop thereon in proximity to a metallic object and in accordance with the disclosed architecture.

[0027] FIG. 3B illustrates a front perspective view of an alternative embodiment of the conductor component forming a U-shaped conductor on the tab component in proximity to a metallic object and in accordance with the disclosed architecture.

[0028] FIG. 3C illustrates a front perspective view of an alternative embodiment of the conductor component forming a conductive loop mounted on the frame and encircling the tab component in proximity to a metallic object and in accordance with the disclosed architecture.

[0029] FIG. 4 illustrates a flowchart of the basic process for manufacturing the reactive RFID strap component of the present invention in accordance with the disclosed architecture.

[0030] FIG. 5A illustrates a front perspective view of the reactive RFID strap component before being modified with surface deflections in accordance with the disclosed architecture.

[0031] FIG. 5B illustrates a side perspective view of the reactive RFID strap component of FIG. 5A before being modified with surface deflections in accordance with the disclosed architecture.

[0032] FIG. 5C illustrates a front perspective view of the reactive RFID strap component after being modified with surface deflections in accordance with the disclosed architecture.

[0033] FIG. 5D illustrates a side perspective view of the reactive RFID strap component of FIG. 5C after being modified with surface deflections in accordance with the disclosed architecture.

[0034] FIG. 6A illustrates a front perspective view of an embodiment of the reactive RFID strap component modified with additional adhesive fixing points in accordance with the disclosed architecture.

[0035] FIG. 6B illustrates a front perspective view of an alternative embodiment of the reactive RFID strap component modified with additional adhesive fixing points in accordance with the disclosed architecture.

[0036] FIG. 7A illustrates a front perspective view of the reactive RFID strap component modified with tabs and designed to engage an opening already formed in the metallic object in accordance with the disclosed architecture.

[0037] FIG. 7B illustrates a side perspective view of the reactive RFID strap component modified with tabs and designed to engage an opening already formed in the metallic object in accordance with the disclosed architecture.

[0038] FIG. 7C illustrates a front perspective view of the reactive RFID strap component modified with tabs and engaging an opening formed in the metallic object in accordance with the disclosed architecture.

[0039] FIG. 8 illustrates a top perspective view of the reactive RFID strap component secured to a metallic bag in accordance with the disclosed architecture.

[0040] FIG. 9 illustrates a graph of the far field response in accordance with the disclosed architecture.

[0041] FIG. 10 illustrates a top perspective view of the reactive RFID strap component secured to a metallic box in accordance with the disclosed architecture.

[0042] FIG. 11 illustrates a graph of the far field response in accordance with the disclosed architecture.

[0043] FIG. 12 illustrates an exploded view of a reactive RFID strap and an antenna coupled together to form a RFID tag in accordance with the disclosed architecture.

[0044] FIG. 13 illustrates an exploded view of one possible embodiment of the RFID tag adapted for use on a non-planar object in accordance with the disclosed architecture.

[0045] FIG. 14 illustrates a flowchart of the basic process for assembling the RFID tag on the surface of the non-planar object in accordance with the disclosed architecture.

[0046] FIG. **15** illustrates a flowchart of a basic process for scanning a surface of a non-planar object and assembling an RFID tag on the surface of the non-planar object in accordance with the disclosed architecture.

[0047] FIG. **16** illustrates a flowchart of the basic process for manufacturing the RFID tag on the surface of the non-planar object in accordance with the disclosed architecture.

[0048] FIG. **17** illustrates a flowchart of an alternative embodiment of manufacturing a RFID tag on a surface of a non-planar object further comprising first depositing a separator on the surface of the non-planar object in accordance with the disclosed architecture.

[0049] FIG. **18** illustrates a flowchart of adapting an antenna of the RFID tag to conform to the separator of the present invention in accordance with the disclosed architecture.

[0050] FIG. **19** illustrates a flowchart of adapting the separator and then adapting an antenna of the RFID tag to conform to the separator in accordance with the disclosed architecture.

[0051] FIG. **20A** illustrates a flowchart of adapting the separator to comprise a ramped portion and then adapting an antenna of the RFID tag to conform to the separator in accordance with the disclosed architecture.

[0052] FIG. **20B** illustrates a flowchart of illustrating first depositing a base conductor on the surface of the non-planar object before the separator in accordance with the disclosed architecture.

DETAILED DESCRIPTION

[0053] The innovation is now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding thereof. It may be evident, however, that the innovation can be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to facilitate a description thereof.

I. RFID Tags

A. Metallic Items or Objects

[0054] In one embodiment, the reactive RFID strap components contain an RFID chip or strap and a conductor component which are both secured to a clip component, such as a clip component formed of plastic or some other suitable material. The reactive RFID strap component is then attached to a metallic item or object. If the size and shape of the metallic item is suitable, the reactive RFID strap component is capable of inducing a far field antenna response, wherein coupling can be between electric fields, magnetic fields, or both with the coupling related to the structure of the reactive RFID strap component and its proximity to the metallic item.

[0055] In some embodiments, the RFID chip and conductor component can be secured to the clip component in multiple ways. For example, the conductor component can be formed in a conductive loop with the RFID chip in series, with coupling primarily by the magnetic fields. Alternatively, the conductor component can be a generally U-shaped conductor on the frame which couples to a metallic item primarily by the electric fields. In other embodiments, the conductor component can be a conductive loop that is mounted on the frame and encircles the tab of the clip component. The various alternative embodiments of the clip components can be modified to help secure the clip component to the metallic item by adding surface deflections, adhesive fixing points, or tabs designed to engage with an opening or plurality of openings already formed in the metallic item or package to provide a more secure attachment thereto. Furthermore, various methods of manufacturing a RFID tag comprising an antenna and a reactive RFID strap on a three dimensional (3D) or non-planar object are also disclosed.

[0056] Referring initially to the drawings, FIG. **1** illustrates a top perspective view of a reactive RFID strap component **100** in proximity with and coupled to a metallic item **108** or other conductive object. The reactive RFID strap component **100** is typically a reactive strap which induces an antenna response into the metallic item **108**, and is integrated into a plastic clip but can be any reactive object as is known in the art. Further, reactive RFID strap component **100** can be

any suitable size, shape, and/or configuration as is known in the art without affecting the overall concept of the invention. One of ordinary skill in the art will appreciate that the shape, size and configuration of the reactive RFID strap component **100** shown in the various FIGS. is for illustrative purposes only, and that many other shapes and sizes of the reactive RFID strap component **100** are well within the scope of the present disclosure. Although the dimensions of the reactive RFID strap component **100** (i.e., length, width, and height) are important design parameters for good performance, the reactive RFID strap component **100** may be any shape, size or configuration that ensures optimal performance during use and satisfies user need or preference. [0057] Typically, the reactive RFID strap component **100** is comprised of a RFID chip or strap **102** and a conductor component **104** which are both secured to a clip component **106**. The reactive RFID strap component **100** is then attached to a metallic item **108** or other suitable conductive object as is known in the art. If the size and shape of the metallic item **108** are sufficient, the reactive RFID strap component **100** can induce a far field antenna response. For example, coupling can be via electric fields (E), magnetic fields (H), or commonly, by both electric (E) and magnetic (H) fields with coupling being related to the structure of the reactive RFID strap component **100** and its proximity to the metallic item **108**. Thus, coupling of the reactive RFID strap component **100** to the metallic item **108** in the electric (E) and magnetic (H) fields is somewhat dependent upon geometry.

[0058] The reactive RFID strap components **100** can be versatile, such that they can be altered depending on the needs and/or wants of a user. For example, the reactive RFID strap components **100** can be produced to be relatively flat so they can be used in a roll to roll process, or other suitable distribution process as is known in the art. Further, the reactive RFID strap components **100** are designed to slip over the edges of metallic items **108** and could incorporate a stop such that they only transmit a certain distance. Additionally, the reactive RFID strap components **100** of the present invention in their various possible alternative embodiments can comprise an adhesive with a release liner making the reactive RFID strap components **100** easy to attach to and remove from the metallic items **108**. The profile of the strap component **100**, or the amount of material that sticks up above the metallic item **108**, can be varied as well, depending on the needs and/or wants of a user. Overall, the reactive RFID strap components **100** are produced to be quite robust or strong and easily applied to the metallic items **108**.

[0059] As shown in FIGS. 2A-B, the RFID chip **102** and the conductor component **104** may both be secured to a clip component **106**. More specifically, FIG. 2A illustrates a front perspective view of one possible embodiment of the clip component **106**, and FIG. 2B illustrates a front perspective view of an alternative embodiment of the clip component. Typically, the clip component **106** is a plastic clip, but can also be made of any suitable material as is known in the art. Further, the clip component **106** can be any suitable size, shape, and/or configuration as is known in the art without affecting the overall concept of the invention. One of ordinary skill in the art will appreciate that the shape, size and configuration of the clip component **106** shown in FIGS. 2A-B is for illustrative purposes only, and that many other shapes and sizes of the clip component **106** are well within the scope of the present disclosure. Although the dimensions of the clip component **106** (i.e., length, width, and height) are important design parameters for good performance, the clip component **106** may be any shape or size that ensures optimal performance during use. Further, the clip component **106** can typically be utilized in two basic forms as shown, however the clip component **106** can also utilize other suitable forms as is known in the art.

[0060] As shown in FIG. 2A, the clip component **106** comprises a tab component **200** and a frame component **202**. The tab component **200** comprises an edge section **204** that is aligned with the outside edge section **206** of the frame component **202**. As shown in FIG. 2B, the clip component **106** comprises the tab component **200** surrounded by the frame component **202** on all edges. Thus, the two different forms of clip components **106** comprise different mechanical properties. For example, the clip component **106** of FIG. 2A would be easier to fit to a metallic item **108**, as at the

end of the manufacturing process, the tab component **200** can be deflected and can easily be pushed over the aligned edge sections **204** and **206**. However, the clip component **106** form of FIG. 2A is less robust than that shown in FIG. 2B. Conversely, while the form of clip component **106** of FIG. 2B is more difficult to attach to a metallic item or object **108** compared to the form of clip component shown in FIG. 2A, the clip component form of FIG. 2B is more robust than the clip component form disclosed in FIG. 2A and will typically have a longer useful life.

[0061] As shown in FIGS. 3A-C, the RFID chip **102** and the conductor component **104** are both secured to a clip component **106**. The RFID chip **102** and the conductor component **104** can be secured to the clip component **106** in multiple ways depending on the wants and/or needs of a user such as, for example, with adhesives. Further, the conductor component **104** can be any suitable size, shape, and/or configuration as is known in the art without affecting the overall concept of the invention. One of ordinary skill in the art will appreciate that the shape, size and configuration of the conductor component **104** shown in FIGS. 3A-C is for illustrative purposes only, and that many other shapes and sizes of the conductor component **104** are well within the scope of the present disclosure. Although the dimensions of the conductor component **104** (i.e., length, width, and height) are important design parameters for good performance, the conductor component **104** may be any shape or size that ensures optimal performance during use and that satisfies user need.

[0062] Further, the conductor component **104** can typically be fitted to the clip component **106** in a multitude of different ways such as those shown, for example, in FIGS. 3A-C. However, the conductor component **104** can also be fitted to the clip component **106** in any other suitable way as is known in the art. As shown in FIG. 3A, the conductor component **104** can be positioned in a conductive loop with the RFID chip **102** in series, thus coupling primarily in the magnetic (H) fields and positioned on the tab component **200**. Alternatively, as shown in FIG. 3B, the conductor component **104** can be formed as a generally U-shaped conductor on the frame component **202**, which couples to the metallic item **108** primarily by electric (E) field coupling. In a further alternative embodiment shown in FIG. 3C, the conductor component **104** may be positioned in a conductive loop with the RFID chip **102** in series and mounted on the frame component **202** such that it encircles the tab component **200**.

[0063] FIG. 4 illustrates a flowchart of a basic method of manufacturing a reactive RFID strap component **100** for use with a metallic item **108**. At **400**, the method comprises forming an antenna on the surface of a suitable material, such as plastic, for example, polyethylene terephthalate (PET). Ideally, the material is thick enough to be self-supporting as a clip component, but thin enough to be processed roll to roll, for example 0.5 mm thick, or any other suitable thickness as is known in the art. Alternatively, a thick card or corrugated material may be used, or any other suitable material as is known in the art, if the roll to roll process is not used. Specifically, the antenna may be formed via pattern printing an adhesive, laminating the foil, cutting around the pattern, and stripping the matrix.

[0064] At **402**, a RFID chip or strap is then attached to the antenna, and at **404** the clip component is die cut such that a user cuts around the critical structural elements. The clip component may be retained in the web by a series of tabs or be positioned on a release liner and attached by an adhesive. At **406**, the clip components may then be formatted for use, such as by placing the clip components in rolls, canisters, or bags. For example, at **408**, the clip components can be formatted in rolls, the rolls are then used in a printer and dispensed into a product. At **410**, the clip components are cut into single units and dropped into a bag for manual assembly. At **412**, the clip components are stacked into a tube or canister for use with an applicator gun.

[0065] As shown in FIGS. 5A-B, the reactive RFID strap component **100** may be modified via tools that apply heat and/or pressure to create deflections **500**. Alternatively, other suitable tools known in the art for making deflections **500** may be used, for example, punches. More specifically, FIGS. 5A-B illustrate front and side views of the reactive RFID strap component **100** before being shaped by the heat and/or pressure tool, or an alternative tool, to create deflections **500**.

[0066] Conversely, FIGS. 5B-C illustrate front and side views of the reactive RFID strap component **100** post-deflection creating process, namely after being shaped by a tool that uses heat and/or pressure, or other means, to form deflections **500** therein. The deflections **500** can either be 3D raised bump structures **502** or lowered bump structures **504** on the surface of the reactive RFID strap component **100**. The deflections **500** comprise surface bumps or catches which help to attach the clip component **106** to the conductor component **104** in a secure manner.

[0067] As shown in FIGS. 6A-B, the reactive RFID strap component **100** can further comprise additional grip **600** or adhesive fixing points **602** to better secure the clip component **106**. More specifically, FIG. 6A illustrates a front perspective view of an embodiment of the reactive RFID strap component **100** modified with additional adhesive grips **600** and adhesive fixing points **602**, and FIG. 6B illustrates a front perspective view of an alternative embodiment of the reactive RFID strap component **100** modified with additional grips **600** and adhesive fixing points **602**. Additional grips **600** and/or adhesive fixing points **602** may be added by printing or any other suitable form of dispensing as is known in the art. The grip **600** and adhesive fixing points **602** are typically added to the surface of the reactive RFID strap component **100**, but may also be added to any other suitable area as is known in the art.

[0068] Additionally, as shown in FIGS. 7A-C, the reactive RFID strap component **100** may further comprise a plurality of tabs **700** formed on its surface. As shown in FIG. 7A, any number of tabs **700** can be used depending on the wants and/or needs of a particular user. Specifically, the tabs **700** can be non-return flaps that are pushed out of the reactive RFID strap component **100** (see FIG. 7B). As shown in FIG. 7C, the tabs **700** engage the metallic item **108**. Typically, the tabs **700** engage a hole or opening **702** positioned in the metallic item **108**, or any other suitable area of the metallic item **108** as is known in the art. The hole or opening **702** is typically the opening already formed in the metallic item or object **108** and that is used for hanging the item **108** on a display rail or hook.

[0069] As shown in FIGS. 8, the reactive RFID strap component **100** may be secured to a metallic bag **800** to induce a far field antenna response, wherein coupling can be between electric fields, magnetic fields, or both. Further, FIG. 9 illustrates a graph of the far field response in accordance with the disclosed architecture, and which illustrates an approximate -11 dBm sensitivity over the FCC band.

[0070] As shown in FIG. 10, the reactive RFID strap component **100** may also be secured to a metallic box **902** to induce a far field antenna response, wherein coupling can be between electric fields, magnetic fields, or both. Further, FIG. 11 illustrates a graph of the far field response in accordance with the disclosed architecture, and which illustrates an approximate -10 dBm sensitivity over the FCC band.

B. Three-Dimensional (3D) Objects

[0071] FIGS. 12-14 illustrate a, RFID tag **1000** positioned on a surface **1052** of a non-planar object **1050**, and a method of manufacturing the same. The RFID tag **1000** contains an antenna **1002** and a reactive RFID strap **1004**. The reactive RFID strap **1004** further contains an RFID chip **1006**. Both the antenna **1002** and the reactive RFID strap **1004** can be any suitable size, shape, and/or configuration as is known in the art without affecting the overall concept of the invention. One of ordinary skill in the art will appreciate that the shape, size and configuration of both the antenna **1002** and the reactive RFID strap **1004** shown in the various FIGS. are for illustrative purposes only, and that many other shapes and sizes of both the antenna **1002** and the reactive RFID strap **1004** are well within the scope of the present disclosure. Although the dimensions of both the antenna **1002** and the reactive RFID strap **1004** (i.e., length, width, and height) are important design parameters for good performance, both the antenna **1002** and the reactive RFID strap **1004** may be any shape, size or configuration that ensures optimal performance during use and satisfies user need and/or preference.

[0072] Typically, the RFID tag **1000** can induce a far field antenna response. For example, coupling

of the antenna **1002** to the reactive RFID strap **1004** can be via electric fields (E), magnetic fields (H), or commonly, by both electric (E) and magnetic (H) fields with coupling being related to the structure of the RFID tag **1000**. Therefore, coupling of the antenna **1002** to the reactive RFID strap **1004** in the electric (E) and magnetic (H) fields is somewhat dependent upon geometry. The antenna **1002** is conductive and is typically formed from a variety of conductive materials, such as, but not limited to, metal foils, cut mechanically or by a laser, printed conductive inks, or vapor deposited materials. Furthermore, the RFID tag **100** is formed by positioning the antenna **1002** near the reactive RFID strap **1004**.

[0073] The generally non-planar object **1050** may be a box, bag, bottle, irregularly shaped product, or any other three dimensional object having at least one non-planar surface. It will be appreciated that the RFID tag **1000** may be formed on the surface of a product itself, or on its primary or secondary packaging as desired, any of which may serve as the non-planar object **1050**.

[0074] FIG. **14** illustrates a method **1400** of manufacturing the RFID tag **1000** on the surface **1052** of the non-planar object **1050**. The method begins at **1402** where the non-planar object **1050** for receiving the RFID tag **1000** is selected. The construction of the RFID tag **1000** begins by forming the antenna **1002** on the surface **1052** of the non-planar object **1050** at step **1410**. At step **1412**, the reactive RFID strap **1004** is then positioned on the surface **1052** of the non-planar object **1050**. The reactive RFID strap **1004** is then coupled to the antenna **1002** to induce a far field antenna response as a functioning RFID tag **1000** at step **1414**.

[0075] Alternatively, and as also illustrated in FIG. **14**, the method **1400** may begin at step **1402** wherein the non-planar object **1050** for receiving the RFID tag **1000** is selected. At step **1404**, the construction of the RFID tag **1000** may begin by forming and positioning the reactive RFID strap **1004** on the surface **1052** of the non-planar object **1050**, prior to forming the antenna **1002**. Then, at step **1406**, the antenna **1002** is formed on the surface **1052** of the non-planar object **1050**, and the reactive RFID strap **1004** is coupled to the antenna **1002** to induce a far field antenna response as a functioning RFID tag **1000** at step **1408**. More specifically, the coupling of the antenna **1002** to the reactive RFID strap **1004** can be via electric fields (E), magnetic fields (H), or by both electric (E) and magnetic (H) fields. Additionally, the reactive RFID strap **1004** may be physically coupled to the antenna **1002** if so desired.

[0076] The antenna **1002** may be deposited onto the non-planar object **1050** by spraying or printing a conductive ink to form the antenna **1002**. The ability to choose between spraying or printing to deposit a conductor onto a non-planar object, where an antenna shape may be adapted to function optimally, provides the manufacturer or other user with greater design flexibility and choice relative to the location on the non-planar object **1050** where an RFID tag may be formed. For example, on a bottle, it is common to try to form an RFID tag antenna on a flat surface on either the base or a top of the bottle. However, by using the methods **1400** depicted in FIG. **14**, a user may form the antenna **1002** on any portion of the bottle surface, and adapt the same to the shape or contour of the bottle, so that in conjunction with the reactive RFID strap **1004** that is flexible enough to conform to the surface **1052**, a high performance RFID tag **1000** may be created. It must also be appreciated that, if the reactive RFID strap **1004** is not adequately flexible to attach to a highly complex three dimensional surface area where the antenna **1002** is formed, the reactive RFID strap **1004** may be placed on a relatively flat area and the antenna **1002** sprayed to create a physical connection between the antenna **1002** and the reactive RFID strap **1004**, thereby forming the final RFID tag **1000**.

[0077] FIGS. **15** and **16** illustrate a method **1500** of manufacturing a RFID tag **1000** adapted for a surface **1052** of a non-planar object **1050** based on the object shape and/or composition. More specifically, the method **1500** utilizes a camera system and a laser grid or the like to precisely scan the non-planar object **1050** onto which the antenna will be formed to insure that the antenna is correctly created, as there may be variations in the non-planar object **1050** and/or its placement on a production line. As with the prior methods **1400** depicted in FIG. **14**, the reactive RFID strap

1004 may be placed on the surface **1052** of the non-planar object **1050** before or after creation of the antenna **1002** to form the high performance RFID tag **1000**.

[0078] More specifically, the method **1500** begins at step **1502** by determining the three dimensional position and shape of the non-planar object **1050** as the camera system scans the surface **1052**. At step **1504**, a design for an antenna **1002** suitable for a chosen location along the surface **1052** of the non-planar object **1050** is selected, compensating for surface shape and position. A design of a reactive RFID strap **1004** and a position for attaching the reactive RFID strap **1004** to the surface **1052** of the non-planar object **1050** is chosen at step **1506**. At steps **1508** and **1510**, the antenna **1002** is then sprayed or created onto the surface **1052** of the non-planar object **1050**, and coupled to the reactive RFID strap **1004** to form the RFID tag **1000** on the surface **1052** of the non-planar object **1050** to produce a far field antenna response. At step **1512**, a measurement of RF performance is conducted, either inline or offline. If the RF performance is acceptable at step **1512**, the method ends at step **1514** with the design having been successfully produced. If, on the other hand, the performance is not acceptable, the method of manufacture returns to step **1504** and the antenna design is adapted to optimize performance.

[0079] Alternatively, the reactive RFID strap **1004** may be positioned on the surface **1052** of the non-planar object **1050** before creation of the antenna **1002**. Additionally, the antenna **1002** may also be printed or otherwise positioned on the surface **1052** of the non-planar object **1050**. The coupling of the antenna **1002** to the reactive RFID strap **1004** can be via electric fields (E), magnetic fields (H), or by both electric (E) and magnetic (H) fields. Additionally, the reactive RFID strap **1004** may be physically coupled to the antenna **1002** if desired.

[0080] FIGS. **17-20B** illustrate a method **1700** of manufacturing a RFID tag **1000** adapted for a non-planar object **1050**. The method **1700** is adapted for creating a RFID tag **1000** comprising more than one layer, which is advantageous as metal and liquid objects can cause a significant drop in the performance of a standard RFID tag. As such, an RFID tag design utilizing an antenna formed on a separating material, such as a foam plastic or similar material with a high dielectric constant, for example, a flexible plastic with a ceramic dielectric powder such as, titanium dioxide or a barium titanate may be used. FIG. **17** illustrates method **1700**, wherein the RFID tag **1000** is formed on the non-planar object **1050** by first depositing a separator **1020**, then an antenna **1002**, and a reactive RFID strap **1004** to form a “surface insensitive” RFID tag **1000**.

[0081] More specifically, method of manufacturing a RFID tag **1000** adapted for a non-planar object **1050** begins at step **1702**, wherein the non-planar object **1050** for receiving the RFID tag **1000** is selected. At step **1706**, the construction of the RFID tag **1000** begins with the separator **1020** being deposited onto the non-planar object **1050**, for example, by spraying. Next, at step **1712**, an antenna **1002** is formed on the separator **1020**. As previously stated, the antenna **1002** may be sprayed, printed, or otherwise positioned atop the separator **1020**. At step **1714**, a reactive RFID strap **1004** is attached to the separator **1020**, and coupled to the antenna **1002** to create the RFID tag **1000** with a far field antenna response at step **1716**. Alternatively, the reactive RFID strap **1004** may be positioned on the separator **1020** before creation of the RFID antenna **1002**. The coupling of the antenna **1002** to the reactive RFID strap **1004** can be via electric fields (E), magnetic fields (H), or by both electric (E) and magnetic (H) fields. Additionally, the reactive RFID strap **1004** may be physically coupled to the RFID antenna **1002** if desired.

[0082] FIG. **18** illustrates an alternative version of the method **1700**, wherein the antenna shape and reactive RFID strap location are adapted to a thickness measurement **1022** of the separator **1020**. More specifically, after the separator **1020** is deposited onto the surface of the non-planar object **1050** at step **1706**, the thickness **1022** of the separator **1020** is measured at step **1708**. At step **1712**, the antenna **1002** may be sprayed, printed, or otherwise positioned atop the separator **1020**. At step **1714**, a reactive RFID strap **1004** is attached to the separator **1020**, and coupled to the antenna **1002** to create the RFID tag **1000** with a far field antenna response at step **1716** as before. It will be appreciated that the separator **1020** does not need to be applied to a larger area of the non-planar

object **1050** than the area required for the RFID tag **1000**. For example, the separator **1020** may be created only directly underneath the RFID tag **1000**, thereby blocking less of a surface **1052** of the non-planar object **1050** so as to not obscure other desirable qualities such as branding or marking. [0083] FIG. **19** illustrates a further alternative version of the method **1700**, wherein the accuracy of the initially applied material for the separator **1020** is insufficient to permit formation of a stable RFID tag **1000**. In this particular embodiment, the thickness **1022** of the separator material **1020** is adapted to insure stability of the RFID tag **1000**, and may be rolled to a required or desired thickness. Further, if the separator material **1020** is capable of curing with heat, the roller may be suitably heated for use to both roll and cure the separator material. More specifically, after the separator material **1020** is deposited onto the surface of the non-planar object **1050** at step **1706**, the desired thickness **1022** of the separator material **1020** may be achieved at step **1708** by, for example, hot roll. The separator material **1020** may also be cured if required or otherwise desired at this stage. At step **1712**, the antenna **1002** may then be sprayed, printed, or otherwise positioned atop the separator material **1020**. Then, at step **1714** (as shown in FIG. **17**), a reactive RFID strap **1004** is attached to the separator material **1020** and coupled to the antenna **1002** to create the RFID tag **1000** with a far field antenna response as previously described.

[0084] FIG. **20A** illustrates an alternative version of the method **1700**, wherein at least a portion of the antenna structure is deflected with respect to another portion of the antenna structure. The ability to create a deflected antenna structure is particularly desirable, as successfully creating conductors around sharp corners by printing is difficult. More specifically, the separator material **1020** may further comprise a ramped portion **1024**, and be sprayed or otherwise applied so that the ramped portion **1024** is sloped or tapered downwardly to meet a surface **1052** of the non-planar object **1050**. Once the separator material **1020** with the ramped portion **1024** is deposited at step **1706**, the antenna **1002** is printed or sprayed onto the separator material **1020**, including down along the ramped portion **1024** and into proximity contact with the surface **1052** of the non-planar object **1050**, as best shown in FIG. **20A** at step **1712**. The reactive RFID strap **1004** may then be attached to the separator material **1020** and coupled to the antenna **1002** to create the RFID tag **1000** with a far field antenna response at **1716** as described above. This method is particularly effective for forming “on-metal” type RFID tags, wherein the non-planar object **1050** has a metallic surface **1052**.

[0085] FIG. **20B** illustrates yet a further alternative version of the method **1700**, wherein at least a portion of the antenna structure is deflected with respect to the other part of the antenna structure and the RFID tag comprises both a top and a bottom conductor. More specifically, the method **1700** further comprises first applying a base conductor **1026** to the surface **1052** of the non-planar object **1050** at step **1704**. Then, at step **1706**, the separator material **1020** is sprayed or otherwise deposited atop the base conductor **1026** so that the ramped portion **1024** is sloped downwardly to the base conductor **1026**. Once the separator material **1020** with the ramped portion **1024** is deposited at step **1706**, the antenna **1002** and reactive RFID strap **1004** are printed or sprayed onto the separator material **1020** down along the ramped portion **1024** and into proximity contact with the base conductor **1026** to create the RFID tag **1000** with a far field antenna response at step **1712**. This allows for a RFID tag structure wherein the base conductor **1026** isolates the top conductor (i.e., antenna **1002**) acting as the radiating antenna from the non-planar object **1050**, and is particularly effective in applications in which the non-planar object **1050** contains a high loss liquid such as water.

[0086] What has been described above includes examples of the claimed subject matter. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the claimed subject matter, but one of ordinary skill in the art may recognize that many further combinations and permutations of the claimed subject matter are possible. Accordingly, the claimed subject matter is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims.

Furthermore, to the extent that the term “includes” is used in either the detailed description or the claims, such term is intended to be inclusive in a manner similar to the term “comprising” as “comprising” is interpreted when employed as a transitional word in a claim.

Claims

1. A method of manufacturing a radio frequency identification (RFID) tag adapted for a non-planar object comprising: depositing a separator on the non-planar object; forming an antenna on the separator; positioning a reactive RFID strap on the separator; and coupling the reactive RFID strap to the antenna to induce a far field antenna response.
 2. The method of manufacturing the RFID tag adapted for the non-planar object of claim 1, wherein a thickness of the separator is adapted to insure stability of the RFID tag.
 3. The method of manufacturing the RFID tag adapted for the non-planar object of claim 2, wherein the separator comprises a ramped portion and the antenna is deposited onto the separator, the ramped portion, and into proximity contact with a surface of the non-planar object.
 4. The method of manufacturing the RFID tag adapted for the non-planar object of claim 3 further comprising first applying a base conductor to a surface of the non-planar object and depositing the separator atop the base conductor.
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