Title: APPARATUS FOR AND METHOD OF TRACKING STORED OBJECTS

Abstract: An apparatus for and method of providing a storage system and tracking stored objects is disclosed. In accordance with a preferred embodiment of the invention, the storage system is composed of one or more storage shelves and dividers or partitions, any one of which may include one or more reader antennae used to track or detect the presence of objects or items tagged with radio frequency identification (RFID) tags. In exemplary implementations, the shelves and partitions of the storage system incorporate one or more reader antennae having "figure-eight" or loop geometries.
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APPARATUS FOR AND METHOD OF TRACKING STORED OBJECTS


BACKGROUND

[0002] Radio frequency identification (RFID) systems typically use one or more reader antennae to send radio frequency (RF) signals to items tagged with RFID tags. The use of such RFID tags to identify an item or person is well known in the art. In response to the radio frequency (RF) signals from a reader antenna,
the RFID tags, when excited, produce a disturbance in the magnetic field (or
electric field) that is detected by the reader antenna. Typically, such tags are
passive tags that are excited or resonate in response to the RF signal from a
reader antenna when the tags are within the detection range of the reader
antenna.

[0003] The detection range of the RFID systems is typically limited by signal
strength to short ranges, for example, frequently less than about one foot for
13.56 MHz systems. Therefore, portable reader units may be moved past a group
of tagged items in order to detect all the tagged items, particularly where the
tagged items are stored in a space significantly greater than the detection range of
a stationary or fixed single reader antenna. Alternately, a large reader antenna
with sufficient power and range to detect a larger number of tagged items may be
used. However, such an antenna may be unwieldy and may increase the range of
the radiated power beyond allowable limits.

[0004] Known RFID reader antennae are designed so that a maximum read
range may be maintained between the antenna and associated tags, without
running afoul of FCC limitations regarding radiated emissions. In a warehouse,
"backroom," or in other types of storage areas, items are packed into shelves or
drawers, where large amounts of products may be stored, and where visual
contact with the items is not essential. Often times, when tagged items are
packed or stacked together, the read range of an antenna is impeded due to "masking" that occurs through the stacking. As a result, the masking limits the number of tags that an antenna may read through, and consequently affect the number of products that may be read. Furthermore, due to FCC limitations on radiated emissions, the reader antenna sizes cannot be adjusted to resolve such problems.

SUMMARY

[0005] An apparatus for and method of providing a storage system and tracking stored objects is disclosed. In accordance with a preferred embodiment of the invention, the storage system is composed of one or more storage shelves and dividers or partitions, any one or more of which may include one or more reader antennae used to track or detect the presence of objects or items tagged with radio frequency identification (RFID) tags. In exemplary implementations, the shelves and partitions of the storage system incorporate one or more reader antennae having "figure-eight" or loop geometries.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a drawing of a backplane RFID reader antenna, along with an item having an RFID tag.

[0007] FIG. 2 is a drawing of an exemplary proximity RFID reader antenna.
[0008] FIG. 3 is a perspective drawing of a storage system in accordance with a preferred embodiment of the invention.

[0009] FIGs. 4a-4d illustrate top views of alternative configurations of the storage system shown in FIG. 3 in accordance with preferred embodiments of the invention.

[0010] FIG. 5 illustrates another exemplary implementation of a storage system in accordance with a preferred embodiment of the invention.

[0011] FIGs. 6, 7 and 8 illustrate alternative form factors incorporated in exemplary implementations of a storage system in accordance with a preferred embodiment of the invention.

[0012] FIGs. 9a-9c illustrate alternative configurations of storage trays in accordance with preferred embodiments of the invention.

[0013] FIG. 10 illustrates an alternative configuration of an antenna in accordance with a preferred embodiment of the invention.

[0014] FIG. 11 illustrates another alternative form factor incorporated in an exemplary implementation of a storage system in accordance with a preferred embodiment of the invention.
[0015] FIGs. 12 and 13 illustrate exemplary implementations of reader antennae in accordance with preferred embodiments of the invention.

DETAILED DESCRIPTION

[0016] Preferred embodiments and applications of the invention will now be described. Other embodiments may be realized and changes may be made to the disclosed embodiments without departing from the spirit or scope of the invention. Although the preferred embodiments disclosed herein have been particularly described as applied to the field of RFID systems used to track objects such as DVDs and DVD packaging material, it should be readily apparent that the invention may be used to track any suitable object and can be embodied in any technology or application to address the same or similar problems.

[0017] FIG. 1 shows an example of a practical antenna configuration used to read stored objects or items 100 (e.g., in the form of products such as a DVD or a DVD box) in which an RFID tag 101 is commonly placed in predetermined locations (typically in a corner of the DVD box), as disclosed in the '024 application. The antenna configuration of FIG. 1 is referred to as a "backplane" antenna as the antennae are placed in a "backplane" structure 102 behind items that would typically rest on a shelf. The backplane structure 102 supports a plurality of ("figure eight-type") antenna loops 103 that have feed points 104. As described in the '024 application, this arrangement may be used, for example, in
retail store displays or other structures that are referred to in the art as "fixtures," "gondolas," "modules," "mods," etc. Under the FIG. 1 configuration, the antenna-tag geometry would allow the RFID reader antenna to detect product tags even when the product is placed onto the fixture in non-standard positions (e.g., upside-down).

[0018] FIG. 2 shows an exemplary close proximity RFID reader antenna 110, where the reader antenna is composed of a single ("figure eight-type") antenna having conductive traces 111 and a center feed point 112, as also described in the '024 application. In an exemplary implementation, the antenna may be approximately 52" long and 5" wide (the approximate size of a shelf that may hold DVD's). The design of this size has relatively low radiated emissions, and has been found to pass FCC and ETSI requirements. It is understood by those skilled in the art that a multitude of different sizes may be implemented, depending on the needs of the user. As shown in FIG. 2, the design is incorporated into the horizontal surface of a shelf. Tags 101 are preferably placed near the bottom of the item 100. The closer in proximity the tags are relative to the reader antenna, the better the likelihood that the tags will be read. For optimum results, the items are preferably placed in a "face forward" orientation 115 or in a "spine-forward" orientation 116, slanted at about 45 degrees.
[0019] FIG. 3 illustrates a storage system in accordance with a preferred embodiment of the invention using a plurality of antennae configured to read a plurality of items 200 supported on a storage shelf 201. In this preferred embodiment, the items 200 may be DVDs (or particularly DVDs contained within boxes, cases or other packaging material). In this illustrative embodiment, the RFID tags 202 are preferably located near an edge of the item 200 that may be disposed near a divider plane 210 (or other partition), which contains one or more reader antennae 211. (In this exemplary implementation, the divider plane 210 has one or more antennae having a “figure eight-type” geometry.) Depending on the size of the shelf 201, one or more additional divider planes 220-223 may be disposed along the horizontal surface of shelf 201 creating (uniform/non-uniform) divided spaces between planes (210-223), where each divider plane may optionally bear one or more reader antennae (not shown). Connections of the reader antennae to other circuitry (not shown) such as tuning components, switch components, or one or more RFID readers may be made through the shelf 201 (or other structure not shown, e.g., upper shelf), a backplane 230, one of dividers 220, 221, 222, 223, or through some other wired/wireless connection.

[0020] Preferably the items 200 will each have RFID tag 202 located near an edge that will be in close proximity to at least one divider plane (e.g., 210) having
a reader antenna 211. When each of the divider planes in FIG. 3 has reader antennae 211, optimum results can be achieved when items 200 are placed into stacks (212-215) having a predetermined tag configuration (e.g., all RFID tags to the left). With this exemplary configuration, the reader antennae 211 can read from each stack (212, 213, 214, 215), and examine respective RFID tags, e.g., (202) to determine item stack location and approximate elevation within the stack for any given RFID tag. As used with regard to FIG. 3, the term "stack" may be considered to be all the DVD's between two adjacent dividers. It should be understood that the exemplary design of FIG. 3 may be adjusted or altered according to the needs of the user.

[0021] Divider planes such as 210, having an RFID antenna 211, may preferably be made of a nonmetallic material such as plastic or fiberglass. Additional structures such as plane 216 (shown in cutaway) may be provided for example to give strength and support to the design. In another embodiment, plane 216 may be made of a metallic material, provided that there is sufficient space between plane 216 and plane 210, in order not to unduly interfere with the RF field from antenna 211. The use of a metallic plane, suitably spaced from the antenna, may improve the antenna performance. In an exemplary implementation, for example, the space may be approximately 3/8 inch, and may be partly or completely filled with a material such as plastic foam that does not
interfere with the RF field in order to achieve optimum results. Likewise metal planes or structures (not shown) may be used elsewhere in the design. For example, if the shelf 201 is metallic, then preferably a non-metallic spacer may be placed between shelf 201 and the DVDs 200 resting on the shelf 201. Such a non-metallic spacer would be particularly useful if RFID tag 202 is situated underneath the DVD 200, since without the non-metallic spacer, the RFID tag would be in direct contact with the metallic shelf. Thus, for optimum results, any metal structures can be at least slightly separated from antennae or tags so as not to unduly interfere with RF transmissions.

[0022] FIGS. 4a-d illustrate cross-sectional views of RFID-tagged items (shown as DVDs 200) from the vantage point of the top of an exemplary implementation of a storage shelf in accordance with a preferred embodiment of the invention. In FIG. 4a, divider planes 231 – 235 are equipped with reader antennae (depicted by the solid coloring within the divider plane). Items 200 may be placed alongside, and preferably between, divider planes 231-235.

[0023] FIG. 4a particularly shows one DVD between each pair of divider planes, but it should be understood that there may be more than one DVD, and the DVDs may occupy space in an area (e.g., one or more DVDs placed one deep) or in a volume (e.g., one or more stacks each having one or more DVDs). An RFID tag 202 is attached to each DVD 200, preferably near an edge that will be
situated adjacent to one of the divider planes that is provided with one or more reader antennae. In the exemplary orientation shown in FIG. 4a, the RFID tag 202 is located near the longer major edge (length) of the DVD. For optimum results, the spacing between dividers should be slightly more than the shorter major edge (width) of the DVD. For example, if the DVD cases are 5.5” wide by 7.5” long, then for optimum results the spacing between dividers may be slightly more than 5.5.” Thus, for optimum results, the RFID tag 202 will be situated in proximity to reader antennae within a divider. Furthermore, as there are reader antennae in every divider in this exemplary implementation, the DVD may be rotated 180 degrees and the RFID tag will still be in proximity to a reader antenna within a divider from the other side. If, however, the DVDs are stacked in an orderly fashion (e.g., with all RFID tags to the left), the reader antennae can examine the RFID tags to determine the stack in which a given DVD is located.

[0024] FIG. 4b shows another exemplary implementation similar to FIG. 4a, having divider planes 236-239 equipped with reader antennae (shown by the solid fill within the divider plane). In this exemplary implementation, divider plane 240 does not have a reader antenna. As divider plane 240 has no reader antenna, its presence is optional but it may be preferable to have such a divider plane for example for structural or cosmetic reasons, or to help enforce an orderly placement of DVDs. For optimum results, in one embodiment, DVDs 200
adjacent to divider plane 240 will preferably be oriented with respective RFID tags 202 in close proximity to divider plane 239 that is equipped with a reader antenna. The DVD placement may be orderly as shown in FIG. 4a, or may be staggered as shown in FIG. 4b.

[0025] FIG. 4c shows yet another exemplary implementation, wherein divider planes 241, 243, and 245 are not equipped with any reader antenna. Divider planes 242 and 244, however, are equipped with reader antennae (shown by the solid fill in FIG. 4c). When every other divider plane is equipped with a reader antenna, the number of reader antennae may effectively be reduced. For optimum results, however, the DVDs 200 should be stored in a manner to place RFID tags 202 in close proximity to a divider equipped with a reader antenna, as shown in FIG. 4c.

[0026] In accordance with preferred embodiments of the invention, the divider planes may be oriented to accommodate any desired configuration. As shown in FIG. 4d, for example, divider planes 246-249 are spaced apart far enough to allow DVDs 203 to be positioned lengthwise between the divider planes. Preferably, the RFID tag 202 may be located near an edge of the DVD so that it will be read by one of the reader antennae within one of the divider planes. This exemplary implementation requires more exacting placement of the DVDs in order to achieve optimum readings, as the spacing between dividers allows
DVD 204, which is rotated 90 degrees relative to DVD 203, to be placed between dividers such that its associated RFID tag may not be proximate to a reader antenna.

[0027] It should be understood that FIGs. 4a-4d are meant as examples only and that other combinations and spacings of dividers and orientations of items may be used, with various divider/antenna configurations. In addition, the shape of the divider planes used in the configurations may take any desired form. As shown, for example, by the exemplary implementation illustrated in FIG. 5.

[0028] In FIG. 5, the upper front corner of the divider 260 is left open, which may be desirable, for example, to provide better access for a user to add or remove items (e.g., DVDs) from between the dividers. Depending on the size and shape of divider 260, it may have one or more reader antennae, including a longer reader antenna 261 and a shorter reader antenna 262.

[0029] It should be noted that placing items between dividers as shown in FIGs. 3-5 may limit access for adding or removing those items. In accordance with a preferred embodiment of the invention, additional structures may be added to the system to facilitate the storage of items. As shown in FIG. 6, for example, trays 280 are incorporated into the configuration between vertical divider planes 270, where divider planes 270 are equipped with reader antennae 271 in a manner similar to that described above. Although any number, size,
shape, or other configuration of trays (or other structures) or combinations thereof may be utilized, this illustrative implementation uses uniform trays 280 each having sides 281, internal partitions 282, handholes 283, and other features including bottom, back or top surfaces (not shown). Trays 280 may contain items 285 positioned so that their associated RFID tags (not shown) are in proximity to reader antennae 271 in dividers 270. In FIG. 6, the DVDs 285 are shown in a “face up” orientation. The trays 280 may be partly or completely removable in order to provide access for adding and removing items 285. Horizontal divider planes 275 may also be used to provide stability or act as guides for the trays 280. Alternatively, guides 276 may be used in place of some or all the horizontal divider planes, to support the trays 280 without obstructing the interior of the structure. Therefore, either the design in Figure 5, using guides 276 could utilize either trays 280 or simple stacks as in the previous Figures. A top plane 277 may be used in this, or any of the designs herein. Alternately, the next shelf up may provide a top for the structure. For optimum results, items are preferably placed into tray 280 in an ordered fashion (e.g., with all RFID tags to the left) to allow the system to determine which tray 280 contains a given item 285.

[0030] As shown in FIG. 7, where desired, one or more reader antennae 295 may be incorporated into one or more horizontal plane structures (e.g., bottom shelf 290; top shelf 296; dividers 291, etc.) in lieu of (or combination with)
antennae in vertical dividers 292. To facilitate adding or removing items, trays 300 are used, which have sides 301, internal partitions 302, handholes 303, and other features including bottom, back or top surfaces (not shown), any one or more of which may include one or more reader antennae. Trays 300 may contain items (e.g., DVDs) 305 positioned so that their associated RFID tags (not shown) are in proximity to reader antennae 295 in storage shelf 290 or horizontal dividers 291. In FIG. 7, the items are shown in a front-to-back “spine-up” orientation. The trays 300 may be partly or completely removable in order to provide access for adding and removing DVDs 305. While not necessary for the FIG. 7 configuration, vertical dividers 292 are used to provide stability or act as guides for the trays 300. As an alternative to vertical dividers 292, guides 293 may be used, generally in contact with the top edges, the bottom edges, or both edges of trays 300. A top plane 296 may also be used in this or any of the designs herein. Alternately, the next shelf up may provide a top for the structure. For optimum results, items are preferably placed into tray 300 in an ordered fashion (e.g., with all RFID tags to the bottom of the tray) to allow the system to determine which tray 300 contains a given item 305.

[0031] The configurations of reader antennae described herein in a horizontal (as well as those in a vertical) plane (e.g., within a shelf, divider, etc.) may have any orientation. As shown, for example, in FIG. 8, horizontal planes 310 may
contain one or more reader antennae 311 in a cross-ways orientation. Trays 320 may be used to facilitate storage of items (e.g., DVDs) 325 in close proximity to one or more of the horizontal planes 310. Trays 320 may have sides 321, internal partitions 322, handholes 323, and other features including bottom, back or top surfaces (not shown). Within trays 320, items 325 are positioned so that their associated RFID tags (not shown) are in proximity to reader antennae 311 in horizontal plane 310. In FIG. 8, the items are shown in a “spine-up” cross-ways orientation. The trays 320 may be partly or completely removable in order to provide access for adding and removing DVDs 325. Not shown are additional horizontal planes, vertical dividers, and trays that may be added to make up a complete structure. For optimum results, DVDs are preferably placed into tray 320 in an orderly fashion (e.g., with all RFID tags to the bottom of the tray) to allow the system to determine approximately how far back in a tray a given DVD is located.

[0032] FIGs. 9a-9c show exemplary embodiments of trays for use in a storage system in accordance with a preferred embodiment of the invention. For comparison purposes, FIG.9a is a redrawing of tray 280 previously shown in FIG. 6. FIG.9b shows an alternative embodiment as tray 284, which is provided with an open side. This may facilitate access to the contents of the tray. This or other trays may furthermore be constructed (in part or in whole) of transparent
materials, or may have additional openings (not shown) for viewing the contents. FIG. 9c shows an alternative embodiment as tray 286 that may be provided with openings or holes 287 and 288, suitable, for instance, for using one’s fingers to help remove the contents from tray 286. For optimum results, the DVDs may be fitted snugly within the tray, in order to ensure that RFID tags located near an edge of the DVD container may be as close to the wall of the tray as possible, and hence as close to an RFID reader antenna as possible.

[0033] The RFID reader antennae shown in the previous Figures are shown in exemplary configurations. Alternative embodiments are possible for the Figure-eight antennae. For example in Figure 10, an embodiment of a divider plane 120 is shown. Tabs 121 and 122 may be provided for attaching the divider plane 120 into a supporting structure. Other means may likewise be used to attach the divider plane into a supporting structure. RFID reader antenna 130 is shown, according to the proximity antenna design discussed previously, having a conductive trace 131 in a “Figure-eight” form, with a feed point 132 and attachment wires or conductors to additional circuitry (not shown). In an exemplary implementation, RFID reader antenna 130 may be approximately 22 inches long and 2.75 inches wide, and additional antennae may be placed on divider plane 120 spaced apart approximately four inches center to center. An alternative RFID reader antenna 140 is also shown, which incorporates a balanced
feed design. RFID reader antenna 140 includes a first conductive trace 141 on one surface of the divider plane 120, and having a gap 142 as shown. On the opposite surface of the divider plane is a second conductive trace 143, approximately coincident with portions of the first conductive trace 141. For optimum results, the dimensional relationship of the first 141 and second 143 conductive traces is a significant factor. The traces form a transmission line medium referred to in the art as “microstrip.” The impedance of this transmission line is dependant upon the line width of the second trace 142, the thickness of the divider plane 120 and the dielectric constant of the divider plane. Microstrip typically will have a solid metallization on the opposite surface of the first conductive trace 141. This metallization though may be reduced to approximately three times the width of the trace width of the first conductive trace 141 and will still behave as a microstrip transmission line such that the structure will not radiate. The first conductive trace 141 will radiate independently of the microstrip due to how the balun (e.g., as previously disclosed in U.S. Provisional Application No. (60/466,721), filed 5/1/03, entitled, “APPARATUS FOR AND METHOD OF PROVIDING AN ANTENNA INTEGRAL BALUN,” which is incorporated herein by reference in its entirety) provides for the excitation in the trace 141. In an exemplary implementation, for example, first conducting trace 141 may be approximately ¼ inch wide, and provide a radiating structure which generally is not directly connected to any other circuitry, while second conducting trace 143
may be approximately 0.050" wide and be connected to external circuitry (not shown). Any of the conductive traces in antennae 130 or 140 may be covered by a non-conducting coating, film, sheet, laminated material, etc. Likewise antennae with geometry similar to antennae 130 and 140 may be fabricated with other materials, for instance, wire or coaxial cable components.

[0034] While the specific embodiments illustrated herein have shown the use of antennae having a "figure eight-type" geometry, it should be apparent that additional embodiments incorporating one or more different types of antenna geometry may similarly be used in the manner described herein. As illustrated, for example, in FIG. 11, a reader antenna 420 may be used in or as part of a storage system (e.g., shelf 400, backplane 404, top plane (not shown), divider planes 405-407, etc.) such that reader antenna 420 includes an upper loop 421, a lower loop 423, a connecting conductor 422, and a feed point 424. The feed point need not be located exactly as shown in FIG. 11. Preferably, the feed point is located along the connecting conductor 422. Antenna 420, with feed point 424, preferably has the upper loop 421 and lower loop 423 connected in parallel. Both loops may read RFID tags, with the lower loop 423 better located for reading tags on DVDs near the bottom of a stack of DVDs, and the upper loop 421 better located for reading tags on DVDs near the top of a stack. One or more back loops 425 may optionally be provided along the connecting conductor 423; such back
loops 425 may read tags on DVDs near the middle of a stack. In this case back loop 425 extends only from one side of the connecting conductor, but it could likewise extend from both sides. Because the back loop 425 is relatively small, it may function as a proximity antenna, reading primarily RFID tags associated with DVDs in the back stack of DVDs, which could typically be higher than the stacks in front of it, as the forward stacks may be shorter to provide better access to the back stacks. Connections of the reader antennae to other circuitry (not shown) such as tuning components, switch components, or one or more RFID readers may be made via feed point 424. Another antenna design 430 is also shown, likewise having an upper loop 431, lower loop 433, connecting conductor 432, feed point 434, and optional back loop 435, which in this case extends from both sides of the connecting conductor 432, but it could likewise extend only from one side. Antenna 430, with feed point 434 located as shown, has the upper loop 431 and lower loop 433 connected in series. In implementing this embodiment, it should be readily apparent that the upper (421, 431) and lower loops (423, 433) may be respectively incorporated in top and bottom planes of a storage system, as well as in adjacent (or spaced apart, alternating, or otherwise non-adjacent) horizontal planes (e.g., shelves). The loops may be further implemented within vertical planes (e.g., dividers) in a similar manner.
[0035] Methods of providing a storage apparatus or system and of tracking objects stored therein in accordance with preferred embodiments of the invention are inherent in and should be readily apparent from the mere description of the inventive storage apparatus and system embodiments as made herein. No additional description of such methods therefore has been made (nor is deemed required).

[0036] While preferred embodiments of the invention have been described and illustrated, it should be apparent that many modifications to the embodiments and implementations of the invention can be made without departing from the spirit or scope of the invention. For example, although embodiments have been described in connection with the use of a shelf or storage structure or system, it should be readily apparent that any structure that may be used in selling, marketing, promoting, displaying, presenting, providing, retaining, securing, storing, or otherwise supporting an item or product may be used in implementing embodiments of the invention. Moreover, it should be apparent to those of ordinary skill in the art that the items, products or objects described herein can be any other product or type of item (e.g., DVD, CD, book, etc.) or packaging therefor that is capable of having RFID tags affixed, embedded, incorporated into, or otherwise associated with the items or packaging for the items. Although the embodiments described herein illustrate the use of a single
type of item (e.g., DVD boxes) stored together in a single storage system, it
should be apparent that any number of different types (with varying sizes,
shapes, etc.) of items may be stored together in a single (or multiple) storage
system(s) when implementing the invention.

[0037] Although the embodiments illustrated in FIGs. 3, 5 and 9 depict only a
single storage shelf with items stacked thereon, any number of shelves may be
added above (or below) the storage shelf depicted, where each additional shelf
may optionally have one or more reader antennae (of any orientation or
configuration, the same as or different from that used in other shelves).
Moreover, implementations of the invention may include modification of the
shelf depicted in FIGS. 3, 5 and 9 into a vertical plane with items supported by
the dividers and/or hung or otherwise secured onto the shelf through devices not
shown.

[0038] Whether or not specifically illustrated herein, it should be readily
apparent that any one or more of the component portions of the storage systems
illustrated herein (e.g., backplanes 230, 404; dividers 210, 220, 221, 222, 223, 260,
270, 275, 291, 405, 406, 407; shelves 201, 276, 290, 296, 310, 400; trays 280, 300, 320;
or tray components 281, 282, 301, 302, 321, 322) may include one or more
antennae in any variation or combination of geometries or orientations.
[0039] Although some of the implementations described herein have illustrated physical spaces between dividers or within trays that allow only predetermined orientations for the items, the dividers or trays may be provided with extra space beyond the dimensions of the item, to provide for the physical placement and removal of the item. To further secure the items, resilient material may be used to fill any gaps that exist beyond the physical dimension of the item. Exemplary resilient materials include plastic foam, or devices such as leaf springs or ridges, or spring-loaded devices, to urge the items closer to or against the divider planes having reader antennae. Such resilient material, leaf springs, ridges, or the like may then allow a user to physically access an item and also urge the items to be proximate to the divider planes with their associated reader antennae when not being accessed.

[0040] The RFID reader antennae described (or apparent from the disclosure) herein may be connected to an RFID reader through any tuning and switching circuitry, including, for example, that disclosed in U.S. Provisional Application No. 60/469,024, filed May 9, 2003. Figure 12, for example, shows how an exemplary implementation of the antennae connection. RFID reader 500 is connected to a number of storage units 501-518, where the storage units may, for example, take the forms shown in Figure 3, 5, 6 or 7. The RFID reader 500 may have associated with it controlling circuitry such as a primary controller (not
shown). In the exemplary implementation, the RFID antennae within the storage units are designed with a 50 ohm characteristic impedance. A quarter wavelength of 75 ohm coaxial cable 520 runs from RFID reader 500 to connection point 521. From connection point 521, a quarter wavelength of 50 ohm coaxial cable 522 runs to connection point 523. From connection point 523, a terminating 50 ohm resistor 524 is incorporated for circuit component protection when RF power is supplied without any antennae switched on. The parallel combination of the 50 ohm resistor 524 and any one of the antennae (50 ohm input impedance) results in an effective impedance of 25 ohms at the connection point 523. The quarter wavelength cables 520 and 522 transform the 25 ohms to 50 ohms at the reader side of the 75 ohm cable 520 and provide for the required match (50 ohms) of the reader.

[0041] In the exemplary implementation shown in Figure 12, the storage units may be considered to be in three groups 531-533. Group 531 includes storage units 501-506, group 532 includes storage units 507-512, and group 533 includes storage units 513-518. Connection point 523 in the example is proximate to group 531, and half-wavelength intergroup 50 ohm coaxial cable 525 connects from connection point 523 to a corresponding connection point 526 in each of groups 532 and 533.
[0042] Taking group 531 as an example, units 503 and 504 may be proximate to connection point 523, and may be connected thereto with short coaxial cables (shown but not numbered) while units 501-502, and 505-506, may be further from connection point 523 and may be connected thereto using half-wavelength intergroup 50 ohm coaxial cables 527. In Figure 12, the storage units are shown spaced apart for clarity in drawing the cables, and the spacings shown on the figure are not to scale. It will be understood that the storage units may be closer together, or further apart, than illustrated in Figure 12. Obviously the design may utilize more or fewer units or groups of units.

[0043] The RF cables or coaxial cables shown in the exemplary implementation of Figure 12 are in a branched parallel configuration. In the exemplary implementation no switches are used with the cable runs as illustrated in Figure 12. However, RF switches may be incorporated within the storage units themselves as described below. Control wiring or circuitry is not shown in Figure 12, but is understood to be included, for example, as described in previously referenced earlier applications.

[0044] Figure 13 shows an exemplary implementation of how RF signals may be routed within a storage unit such as storage unit 501. From the proximate connection point 523, a connection such as a coaxial cable 540 is made to one or more secondary controllers 541, 542 as were described in previously referenced
earlier applications. The secondary controllers may each comprise a switch 543 that may either allow RF energy to pass through to one or more RFID antennae, or may block RF energy from passing through to the RFID antennae. For example, coaxial cable 544 may connect from secondary 541 to one or more tuning circuits 545, and thence to one or more RFID antennae 546. The tuning circuits 545 in addition to having circuitry to tune the antennae 546 may also each include a switch (not shown) to select an antenna 546. In Figure 13, secondary controller 541 is connected in parallel to two series-connected groups of four antennae each. Other combinations may be used, for example, a parallel connection to two and six antennae, or a single series connection to eight antennae. Furthermore a number of antennae other than eight may be used per secondary controller, and a number of secondary controllers other than two may be used per storage unit. Each secondary may receive control commands from external circuitry, and in turn control the switches within tuning circuits 545.

[0045] Although no specific circuitry, components, or modules (e.g., tuning circuit, impedance matching circuit, RF switch, etc.) may have been explicitly disclosed herein in connection with exemplary embodiments of the invention, it should be readily apparent that any tracking, inventory control, security, or other circuit(s), component(s) or module(s) may be utilized in implementing the various embodiments of the invention.
[0046] It is to be understood therefore that the invention is not limited to the particular embodiments (or implementations thereof) disclosed (or apparent from the disclosure) herein, but only limited by the claims appended hereto.
CLAIMS

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A storage apparatus, comprising:
   
a shelf for supporting at least one item having an RFID tag; and

   at least one partition, coupled to said shelf, having at least one reader antenna used to detect presence of the RFID tag.

2. The storage apparatus as recited in claim 1, wherein said shelf is in a horizontal plane supporting a plurality of items in stacks, each item having an RFID tag; and

   wherein said at least one partition is one of a plurality of vertical dividers disposed along a horizontal surface of the shelf, and wherein the plurality of items are placed in divided spaces on the horizontal surface of the shelf as defined by the plurality of vertical dividers.

3. The storage apparatus as recited in claim 2, wherein alternating ones of the plurality of vertical dividers are reader antenna bearing dividers which contain
at least one reader antenna for detecting presence of an RFID tag in proximity to such reader antenna bearing divider.

4. The storage apparatus as recited in claim 2, wherein each of the plurality of vertical dividers are reader antenna bearing dividers which contain multiple reader antennae for detecting presence of an item having an RFID tag.

5. The storage apparatus as recited in claim 1, wherein said at least one partition is a vertical divider plane having a plurality of reader antennae, wherein at least one of the plurality of reader antennae has a figure-eight geometry.

6. The storage apparatus as recited in claim 5, wherein all of the plurality of reader antennae in the vertical divider have figure-eight geometries, and at least one of the plurality of reader antennae differs in horizontal length relative to another one of the plurality of reader antennae.

7. The storage apparatus as recited in claim 1, wherein said shelf incorporates at least one reader antenna in the form of a lower loop reader antenna for detecting presence of an RFID tag.

8. The storage apparatus as recited in claim 7, further comprising:
a horizontal plane substantially parallel to said shelf, wherein said horizontal plane incorporates an upper loop reader antenna;

a backplane, coupled to said horizontal plane and said shelf, wherein said backplane incorporates a connecting conductor that connects to both the upper loop reader antenna and the lower loop reader antenna, and further incorporates a back loop reader antenna.

9. The storage apparatus as recited in claim 1, wherein said at least one reader antenna has a balanced feed design.

10. The storage apparatus as recited in claim 9, wherein said at least one reader antenna has disposed parallel to the reader antenna an RF blocking plane separated from the reader antenna by a distance between about 1/8 to ½ inches.

11. A method of detecting the presence of products having associated therewith RFID tags, the method comprising the steps of:

providing at least one product support structure for supporting at least one item having an RFID tag, wherein the at least one product support structure has at least one partition having at least one reader antenna used to detect presence of the RFID tag; and
detecting the presence of the at least one item on the at least one product support structure.

12. The method as recited in claim 11, wherein said providing step further comprises, providing the at least one product support structure in a horizontal plane supporting the at least one item in stacks, providing the at least one partition as one of a plurality of vertical dividers disposed along a horizontal surface of the shelf, and placing the at least one item in divided spaces on the horizontal surface of the shelf as defined by the plurality of vertical dividers.

13. The method as recited in claim 12, wherein said providing step further comprises providing alternating ones of the plurality of vertical dividers as reader antenna bearing dividers which contain at least one reader antenna for detecting presence of an RFID tag in proximity to such reader antenna bearing divider.

14. The method as recited in claim 12, wherein said providing step further comprises providing each of the plurality of vertical dividers as reader antenna bearing dividers which contain multiple reader antennae for detecting presence of the at least one item.

15. The method as recited in claim 11, wherein said providing step further comprises providing the at least one partition as a vertical divider plane having a
plurality of reader antennae, wherein at least one of the plurality of reader antennae has a figure-eight geometry.

16. The method as recited in claim 15, wherein said providing step further comprises providing all of the plurality of reader antennae in the vertical divider with figure-eight geometries, and wherein at least one of the plurality of reader antennae differs in horizontal length relative to another one of the plurality of reader antennae.

17. The method as recited in claim 11, wherein said providing step further comprises incorporating at least one reader antenna in the form of a lower loop reader antenna for detecting presence of an RFID tag.

18. The method as recited in claim 17, wherein said providing step further comprises:

- providing the at least one product support with a horizontal plane substantially parallel to said shelf, wherein said horizontal plane incorporates an upper loop reader antenna; and

- a backplane, coupled to said horizontal plane and said shelf, wherein said backplane incorporates a connecting conductor that connects to both the upper loop
reader antenna and the lower loop reader antenna, and further incorporates a back
loop reader antenna.

19. The method as recited in claim 11, wherein said providing step further
comprises providing at least one reader antenna with a balanced feed design.

20. The method as recited in claim 19, wherein said providing step further
comprising providing at least one reader antenna having disposed parallel to the
reader antenna an RF blocking plane separated from the reader antenna by a
distance between about 1/8 to 1/2 inches.
Figure 5