INTERACTIVE INVENTORY MONITORING

Inventors: Stevan M. Spremo, San Jose, CA (US); Usen E. Udoh, San Francisco, CA (US)

Assignee: The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, Washington, DC (US)

(57) ABSTRACT

Method and system for monitoring present location and/or present status of a target inventory item, where the inventory items are located on one or more inventory shelves or other inventory receptacles that communicate with an inventory base station through use of responders such as RFIDs. A user operates a hand-held interrogation and display (IAD) module that communicates with, or is part of, the base station, to provide an initial inquiry. Information on location(s) of the target inventory item is also indicated visibly and/or audibly on the receptacle(s) for the user. Status information includes an assessment of operation readiness and a time, if known, that the specified inventory item or class was last removed or examined or modified. Presentation of a user access level may be required for access to the target inventory item. Another embodiment provides inventory information for a stack as a sight-impaired or hearing-impaired person passes adjacent to that stack.

9 Claims, 5 Drawing Sheets
FIG. 1
*Base Station is the termination point for each shelving system

*Selves incorporated with a RFID transponder system (N antenna's)

FIG. 2
System receives from a user request for specified information on specified inventory item

Is specified inventory item present?

Yes

Notify user that specified inventory item is present

Collect all relevant available location and status information for this item and transmit this info to the user

Cause an RFID tag at each location of specified inventory item to issue at least one of a visually perceptible signal and an audibly perceptible signal (optional)

Terminate RFID signal when a specified event occurs (optional)

No

Notify user that specified inventory item is not present

Is specified info. available for this item?

Yes

No

FIG. 3
Sense-impaired user passes adjacent to a stack while presenting an IIC, while presenting (holding) an IIC

Adjacent stack or central transceiver transmits an indicator signal that is received by the User's IIC

IIC reflects a modified version of incident signal

Adjacent stack or central transceiver receives modified signal

Adjacent stack or central transceiver estimates distance $d$ between user and adjacent stack

Adjacent stack transmits at least one of audible signal APS and visible signal VPS, announcing information on class(es) of information on inventory items in stock

FIG. 5
INTERACTIVE INVENTORY MONITORING

ORIGIN OF THE INVENTION

This invention was made, in part, by one or more employees of the U.S. government. The U.S. government has the right to make, use and/or sell the invention described herein without payment of compensation, including but not limited to payment of royalties.

FIELD OF THE INVENTION

This invention relates to interactive determination of location and/or status of a selected inventory item among an array of inventory items, for example, a book or document or equipment item or component.

BACKGROUND OF THE INVENTION

Keeping track of inventory, whether books or documents or electronic copies or goods or sensitive material, is a continual task. Determining where an inventory item is presently located, or misplaced, is increasingly time consuming as the inventory grows and items are repaired, maintained, replaced, or moved and recharacterized. Inclusion of a paper slip noting the "history" of the item is only acceptable if the item users are diligent about supplementing this history with an account of recent activities involving the item and/or the present status of the item. Where multiple copies of an inventory item are present and are kept in different locations, the tasks become correspondingly multiplied.

What is needed is a system that (1) indicates whether a selected item or category of items is present in the collection; and, if present, identifies the location(s) of the item(s) using a visually perceptible and/or auditorily perceptible signal; and (2) the present condition or status, if known, of the item(s). Preferably, the system should be flexible and should permit implementation of one or more redefined categories for subsequent searches.

SUMMARY OF THE INVENTION

These needs are met by the invention, which provides an interactive system and associated method for querying the array and for determining at least one of (i) location of a selected inventory item and (ii) present status of the inventory item.

The invention is a RFID-based system that, in one embodiment, assists a user in locating an item visually, in response to specification of the item electronically. The invention applies to more general inventory items as well. A user (not shown) enters an indicium, identifying or characterizing the item(s) being sought may be a book on a library shelf, an item from a store inventory, a legal or financial document, a medical record, a weapon system or weapon component (presumably) located in an armory, or similar item. Each such item is tagged by a weapon system or weapon component (presumably) located in an armory, or similar item. Each such item is tagged by an electromagnetic coil that is embedded in or associated with the item.

The shelving or other containment vessel or receptacle for the item(s) provides an alternating electromagnetic field to power the embedded coils and can identify the item location if the item is on or adjacent to the shelving/vessel, even if the item is not at its assigned location. Each coil includes a low power, programmable chip containing relevant information on the item (id. no., class to which item belongs, present status of the item, relevant item characteristics, recent activity affecting the item, etc.)

FIG. 1 schematically illustrates use of an RFID interrogator and display to locate an inventory item or class of such items.

FIG. 2 schematically illustrates operation of a base station RFID with an embedded multiplexer driving a plurality of RFID transponders and their associated antennas.

FIG. 3 is a flowchart of a procedure for practicing the invention.

FIG. 4 illustrates another embodiment of the invention, and FIG. 5 is a flowchart for practicing this embodiment.

FIG. 1 schematically illustrates use of an RFID interrogator and display system to locate an inventory item 11...n (n=1,...,N; N≧2) or class of such items. In this illustration, the inventory item is a book or document, but the invention applies to more general inventory items as well. A user (not shown) carries a hand held radio frequency identity detector ("RFID") interrogation and display ("IAD") system 13. The user enters an indicium, identifying or characterizing the inventory item, into the IAD system and transmits an interrogation signal IS to a collection of inventory items 11...n or to a server representing the collection, preferably using a wireless interrogation signal IS. Where access to the inventory item is restricted, the user is also required to provide one or more of a biometric indicium, or an authentication code or suitable physical indicium permitting access to and/or physical possession of the item.
The presence of each inventory item that is “in stock,” whether properly located or located elsewhere in the inventory
to or associated with an inventory receptacle 17-\(m\) that holds or is adjacent to the target inventory item 11-\(n\).

The responder 15-\(n\) receives the interrogation signal IS from the IAD system 13 and responds by transmitting, or causing to be transmitted, a response signal RS-\(n\) that is received by the IAD system. The response signal RS-\(n\) indicates the presence (or absence) of the target inventory item 11-\(n\) and the location of the receptacle 17-\(m\) where the target inventory item might be found. Optionally, a locator module 18-(\(n,m\)) provides a visually perceptible and/or audible perceptible location signal LS(\(n,m\)) that indicates the receptacle 17-\(m\) and the particular location on this receptacle where the target inventory item 11-\(n\) can be found. Optionally, if more than one qualifying target inventory item 11-\(n\) is present, a locator signal LS(\(n,m\)) is provided for one or more of all the target inventory items 11-\(n\). Optionally, the (handheld) IAD system 13 also provides visually perceptible and/or audibly perceptible information on location of the target inventory item(s) 11-\(n\) and on condition or status of each such inventory item, including one or more of the following: (1) the number of replicas of the target inventory item 11-\(n\) that should be present, (2) time and date each absent inventory item 11-\(n\) was removed from the collection, (3) user name, if item has been removed, (4) relevant information on repairs and/or maintenance and/or adjustments performed on the target inventory item(s) 11-\(n\), and (5) relevant information on any inventory item that has been substituted for or replaced the original target inventory item 11-\(n\).

FIG. 2 schematically illustrates operation of a plurality of RFID tags 14-\(n\), each tag being attached to or associated with a location associated with a particular inventory item located on the inventory receptacle 17-\(m\). Alternatively, the RFID tags 14-\(n\) may be attached to different spaced apart locations on the inventory receptacle 17-\(m\), and a tag at a given location may be activated for receiving and transmitting signals by presence or absence at that location (or within a few cm of that location) of an inventory item; where no inventory item is present at, or near to, the given location, the RFID tag is not activated and does not respond to receipt of an interrogation signal IS. Optionally, one or more RFID adjacent RFID tags 14-\(n\) \((n=0, 1, 2, 3, \ldots)\) can be activated if the inventory item physically overlaps more than on adjacent space on the inventory receptacle 17-\(m\).

An RFID base station or server 21, which may be the IAD system 11 of FIG. 1, generates and transmits an interrogation signal IS-\(n0\) for a target inventory item 15-\(n0\) that is received by the plurality of RFID tags 14-\(n\). If (and only if) the target inventory item(s) 15-\(n0\) is present, circuitry associated with the corresponding RFID tag 14-\(n0\) responds with a response signal RS-\(n0\).

A radio frequency identity detector (RFID) is a small radio transmitter, receiver and sensor that can be used, for example, to facilitate labeling, and changes thereto, in a commercial activity. An RFID can be queried, within its transmission range (25 feet in one version), by a hand held device to reveal stored information. Each RFID can have a size as small as a U.S. nickel, but is preferably somewhat larger if information in addition to presence and/or absence is to be reported. In some embodiments disclosed here, an RFID is programmed to automatically transmit selected information at a sequence of specified times, or upon demand.

One version of an RFID operates at about 433 MHz, but this frequency can be varied somewhat to provide distinguishable frequencies among a sequence of RFIDs. Presently, two RFIDs can reliably communicate with each other over a range of up to about 7 meters (approximately 23 feet) in almost any reasonable environment, in temperatures ranging from −40° F. to 185° F., at a rate of 1.8-2.2 pulses/sec. Additional communication range, up to 50-300 feet, can be obtained by supplementing the RFIDs with an external package. Two or more RFID devices use RS232 or RS485 or Ethernet TCP/IP communication protocol to communicate with each other, serial format, in simplex or half duplex modes. A signal transmitted or received by an RFID may be expressed in 256-2048 bits. A given RFID may be read/write (RW) or may be read only (RO), may have a diameter of between 0.625 and 3.75 inches, and may be used with an antenna cable of any reasonable length. Up to four antennas can be linked to a single RFID device, as presently available. Optionally, an RFID system of devices, available from RFID Inc. in Aurora, Colo, and from other suppliers, includes a handheld reader or reader-programmer, operating at 2.45 GHz, with up to 24 Mbytes of memory. RFIDs are one of several short range wireless communication systems that can be used here.

Where the RFID signal or other information reporting signal has a relatively large number of bits available (256-2048 in the present versions), an RFID signal can include protocol signals and a substantial amount of data. If a single RFID signal from a given source-RFID device cannot carry all the data, two or more RFID signals or packets can be coordinated and used to transmit the data. FIG. 2 illustrates a suitable format for an RFID signal RFIDS-\(n\) that can be used for transmitting data between the source-RFID and the C&C sub-system. An initial block of 8 bits (or more, if desired) optionally includes preamble bits (e.g., 7E or 01111110), followed by: (1) 8 bits that identify the source-RFID by number (e.g., \(n=0-255\)); (2) 12 bits that indicate the date and time (to the nearest sec) the RFID signal is initially sent by the source-RFID; (3) 8 bits that identify the RFID (no.) that last (received or generated and) transmitted this signal (the source-RFID or an intermediate RFID in the chain of signal passage); (4) 16 coded bits used to determine or estimate the location and/or spatial orientation of the ESW who wears or carries the source-RFID; (5) 8 bits indicating the estimated temperature at the source-RFID location; (6) 8 bits indicating the estimated pressure at the source-RFID location; (7) 8 bits indicating the estimated concentration of a specified chemical or compound at the source-RFID location (more than one concentration can be transmitted); (8) 8 bits indicating the estimated electromagnetic field intensity at the source-RFID location; (9) 8 bits indicating a visible light index at the source-RFID location; (10) 8 bits indicating an average noise intensity at the source-RFID location; (11) 8 bits indicating a peak noise intensity at the source-RFID location; (12) 8 bits estimating the flux of nuclear particles (alphas, betas, gammas and/or ions) at the source-RFID location; (13) 8 bits indicating the estimated oxygen content at the source-RFID location; and (14) an 8-bit pattern (e.g., 00000001) representing a post-amble or closing sequence. If a measurement, among the preceding items (5)-(13), is not included, the corresponding 8-bit field has a coded special pattern, such as 00000000. The total number of bits required for this particular format is about 132 bits. Other signal formats can also be used here, using fewer bits or more bits.

An example of a presently available RFID base station is the Texas Instruments LF Base Station IC TMS3705ADR,
which communicates with resonance frequencies in a range 129-140 kHz. Synchronous and asynchronous data transmission are supported, using a phase locked loop clock generation of 16 MHz. The operation voltage is 4.5-5 Volts, and the device operates at temperatures in a range -40° C ≤ T ≤ 85° C, with charging range current and sleep mode current of 0.8 mAmp and 15 μAmp, respectively. Minimum recovery time or dead time between responses to the same or different RFID is estimated as a few tens of μsec. Pin count is 16, and the package size is 10 mm by 6 mm.

Optionally, the RFID tag senses and transmits one or more of the following information ("status information") concerning an adjacent inventory item: (1) an indicium identifying or characterizing the item (e.g., a title and call number and copy number for a book or document, or an appliance number and copy number for an appliance or device); (2) an indication of when the item was last returned to or placed on the receptacle 17-m; (3) an indication of the present condition or status (e.g., use-ready, inactivated for maintenance, permanently inactivated, or withdrawn from use) of the item; (4) number of similar or identical inventory items present in the collection of all reporting receptacles; (5) location of other similar or identical items; and/or (6) how often the item has been removed or queried.

When the IAD system 13 in FIG. 1 requests information on a specified inventory item, an RFID tag 14-n on each receptacle 17-m for which the specified item is present optionally provides a visually perceptible signal (e.g., a light having a corresponding color, color combination, blink frequency, texture or other visual indicator signal) or an audibly perceptible signal (e.g., a sound having a corresponding audible frequency, combination of frequencies, sound intensity pattern, chirp or other audible indicator signal) at each location of the item, whether the item is correctly shelved or incorrectly shelved; the location of each such item is optionally indicated on the user’s IAD system. The user can then go to one or more of the indicated locations and retrieve the desired item.

In one embodiment, the IAD system 13 communicates with a base station or server 21 that, in turn, sequentially communicates with each RFID 14-n on each inventory receptacle 17-m (e.g., a shelf), preferably through a signal multiplexing system. For example, each receptacle 17-m may periodically transmit status information for each inventory item on that receptacle to the base station 21, for example, once every K seconds (e.g., K=5-120). The received status information is temporarily stored at the base station 21 in N memory positions (one for each reporting RFID tag on the shelf), these N memory positions are overwritten in the same manner as the IIC has a reflection coefficient (measured beforehand) of d. Assuming that the intensity I of the reflected (modified) indicator signal is located, to issue at least one of a visually perceptible signal and an audibly perceptible signal (step 35), which signal is terminated (step 36) (a) after lapse of a specified time interval (e.g., 10-120 sec) or (b) when at least one copy of the specified inventory item is removed from the receptacle shelf, whichever occurs first. The system then returns to step 31.

When the answer to the query in step 32 is "no," the system notifies the user that the specified inventory item is not present, in step 37, and returns to step 31. When the answer to the query in step 33 is "no," the system notifies the user that the specified inventory item is present (optional), notifies the user that the specified status information is not available, in step 38, and moves to step 34.

Where the inventory item is a sensitive one (e.g., a weapon system or component thereof), the invention may be configured to report the presence or absence or non-adjacency of the item at non-regular time intervals (for security purposes), may be configured to promptly report any changes in the status information for the item, and may be configured to require presentation and authentication of a level of permitted access appropriate for the item.

FIG. 4 illustrates another embodiment 41, in which a sight-impaired ("SI") person seeks either an inventory item or information concerning an inventory item. The SI user 42 passes by an inventory stack or shelving 43-i (i=1 ... , N i=1 ... N) holding an inventory interrogation card (IIC) 44 so that a selected face of the card is oriented in the general direction of one of the stacks, or in the general direction of a central transmitter 45. Periodically, each stack 43-i and/or the central transceiver 45, transmits an indicator signal to determine if an IIC 44 is present, through receipt of the indicator signal and reflection (after suitable modification) of a modified indicator signal that is subsequently received as a return signal, by the stack 43-i and/or by the central transceiver 45. Where no modified indicator signal is received, the system takes no further action.

Receipt of the modified indicator signal indicates that a user 42 is present, and the stacks are advised of the presence of a user. When the user 42 passes within a selected threshold distance d(thr) (e.g., d(thr)=6-120 inches) of one of the stacks 43-i, that stack will provide an audibly perceptible signal APS announcing the group(s) or class(es) of inventory items that are present on the shelf 43-i. The intensity of the reflected (modified) indicator signal may be used to estimate a distance of the user from the signal monitor or stack in the following manner. The intensity I of the indicator signal (assumed to be isotropic) will decrease according to an inverse square law,

\[ I(r) = \frac{I_0 d_0^2}{r^2} \]

where the quantity I_0 d_0^2 is a normalizing factor, assumed to be known, and d is the monitor-IIC distance. Assuming that the IIC has a reflection coefficient (measured beforehand) of \( \rho \), each signal-reflecting point on the IIC is treated as a new
What is claimed is:

1. A method for providing information on availability and/or status and/or location of one or more specified inventory items, the method comprising:
   a. providing an electromagnetic energy source that generates and transmits energy over a wireless energy path;
   b. providing at least one of a specified inventory item and a specified class of inventory items as a target inventory item, among an array of inventory items, with an electromagnetic mechanism that receives and utilizes electromagnetic energy from the energy source;
   c. receiving an electronic inquiry concerning information associated with the target inventory item;
   d. determining, through use of a computer, at least one of the following availability, status and location information items: (i) whether the target inventory item is located at or adjacent to at least one determinable inventory item location; and (ii) present status information for the target inventory item, where the present status information includes at least one of presence or absence of the target inventory item in the array, at least one present location, if known, of the target inventory item, and operational readiness of the target inventory item; and (iii) at least one of user name and user contact information, if the target inventory item is not located at or adjacent to the determinable inventory item location and has been removed by an identifiable user;
   e. determining and displaying for at least one time, the status, if known, of at least one of the target inventory items, where the status is characterized by the group of characteristics consisting of absent, use-ready, inactivated for maintenance, permanently inactivated, and withdrawn from use;
   f. providing information on at least one attribute associated with the target inventory item, in response to receipt of the electronic inquiry, where the at least one attribute is one or more of (1) number of replicas of the target inventory item that should be present in inventory, and (2) name or contact information for user, if the target inventory item has been removed or examined or maintained or repaired or modified or substituted or replaced;
   g. when the target inventory item is not located at or adjacent to the determinable location, providing at least one of a visibly perceptible signal and an audibly perceptible signal indicating present location of at least one of the target inventory item;
   h. when the target inventory item is not located at or adjacent to the determinable location, determining if the target inventory item is located elsewhere in the array; and
   i. when the target inventory item is determined to be located elsewhere in the array, providing an indicium indicating the present location of the target inventory item.

2. The method of claim 1, further comprising: when said target inventory item is not located at or adjacent to said determinable location and is not located elsewhere in said array, providing a second indicium indicating that said target inventory item is not present in said array.

3. The method of claim 1, further comprising terminating said at least one of said visibly perceptible signal and said audibly perceptible signal, at a time determined with reference to at least one of (i) accumulation of a time interval, after said visibly perceptible signal or said audibly perceptible signal is first provided with a time interval length at least equal to a threshold length and (ii) removal of said target inventory item from said location.

4. The method of claim 1, further comprising receiving said electronic inquiry at a radio frequency identity detector ("RFID") associated with said specified inventory item or class.

5. The method of claim 4, further comprising providing at least one of said location information and said status information for said target inventory item using said RFID.
6. The method of claim 1, further comprising providing said visually perceptible signal as a selected color signal that is distinguishable from at least one other color signal used to indicate location of another target inventory item.

7. The method of claim 1, further comprising:
   specifying, as said target inventory item, a restricted item for which at least one of access to, and use of, the restricted item is restricted and has an assigned location;
   requiring presentation, by a user who seeks at least one of access to, and use of, the restricted item, of at least one biometric indicium that establishes that the user has a right to access to and use of the restricted item;
   determining whether the restricted item is located at or adjacent to its assigned location; and
   when the restricted item is not at or adjacent to its assigned location, issuing an advisory signal and determining whether at least one of the restricted item is located at or adjacent to a location other than an assigned location.

8. The method of claim 7, further comprising:
   associating a required level for access with said restricted item;
   requiring presentation and authentication of a user access level by said user who seeks at least one of access to, and use of, said restricted item; and
   permitting access by said user to said restricted item only if said user’s authenticated access level is at least equal to the required level for access or use.

9. The method of claim 1, further comprising periodically transmitting, to a central receiver, each of said ASL information items, and receiving and storing said transmitted ASL information items in a selected memory unit associated with the central receiver; and
   overwriting said ASL information items received and stored in the selected memory unit during one time period with said ASL information items received during a subsequent time period.

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