US006025780A

United States Patent [19]

Bowers et al.

[11] **Patent Number: 6,025,780**

[45] **Date of Patent: Feb. 15, 2000**

[54] **RFID TAGS WHICH ARE VIRTUALLY ACTIVATED AND/OR DEACTIVATED AND APPARATUS AND METHODS OF USING SAME IN AN ELECTRONIC SECURITY SYSTEM**

[75] Inventors: **John H. Bowers**, Clarksburg, N.J.; **Thomas J. Clare**, Media, Pa.

[73] Assignee: **Checkpoint Systems, Inc.**, Thorofare, N.J.

[21] Appl. No.: **08/900,266**

[22] Filed: **Jul. 25, 1997**

[51] **Int. Cl.**[7] **G08B 13/14**

[52] **U.S. Cl.** **340/572.3**; 340/572.1; 340/825.54; 340/825.32; 705/28

[58] **Field of Search** 340/572, 825.32, 340/825.54, 572.1, 572.3; 364/478.03, 478.13, 478.15; 235/375, 382.5, 385; 705/28; 455/83

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,752,960	8/1973	Walton	340/825.3
3,816,708	6/1974	Walton	340/825.3
4,141,078	2/1979	Bridges, Jr. et al.	235/375
4,223,830	9/1980	Walton	235/380
4,567,473	1/1986	Lichtblau	340/572
4,580,041	4/1986	Walton	235/380
4,688,026	8/1987	Scribner et al.	340/572
4,745,401	5/1988	Montean	340/572
4,746,830	5/1988	Holland	310/313 D
4,827,395	5/1989	Anders et al.	364/138
4,837,568	6/1989	Snaper	340/825.54
4,857,893	8/1989	Carroll	340/572
4,881,061	11/1989	Chambers	340/563
4,924,210	5/1990	Matsui et al.	340/572
5,019,815	5/1991	Lemelson et al.	340/933
5,036,308	7/1991	Fockens	340/572
5,059,951	10/1991	Kaltner	340/572
5,099,226	3/1992	Andrews	340/572
5,099,227	3/1992	Geiszler et al.	340/572
5,103,222	4/1992	Esch et al.	340/825.54
5,111,186	5/1992	Narlow et al.	340/572
5,119,070	6/1992	Matsumoto et al.	340/572
5,151,684	9/1992	Johnsen	340/572
5,153,842	10/1992	Dlugos, Sr. et al.	364/478.15
5,214,409	5/1993	Beigel	340/572

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

0 494 114	7/1992	European Pat. Off. .
0 585 132	3/1994	European Pat. Off. .
0 598 624	5/1994	European Pat. Off. .
0 615 285	9/1994	European Pat. Off. .

OTHER PUBLICATIONS

Bowers, J. "Road To Intelligent Tagging is Paved with Opportunities," *Automatic I.D. News,* Oct. 1997, pp. 86–87.

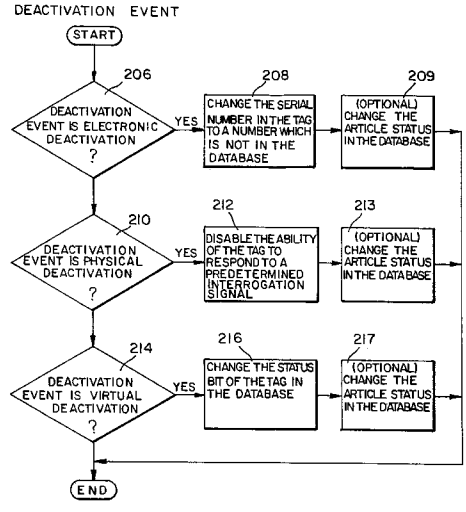
Primary Examiner—Benjamin C. Lee

Attorney, Agent, or Firm—Akin, Gump, Strauss, Hauer & Feld, L.L.P.

[57] **ABSTRACT**

An electronic security system uses a set of predefined RFID tags. Each tag is associated with, and attached to, an article or packaging for an article. Each tag includes unique tag information which is logged into a computerized database that contains a record for each of the tags in the set. A detection zone is monitored with an interrogator which detects RFID tags. When an RFID tag is detected, the database records are compared to the tag information and an appropriate database response is output. A deactivation event may be performed on the tag when legitimate access is obtained to the tagged article. The deactivation event may be electronic, physical or virtual. One type of RFID tag used in the system may physically deactivated by altering the state of a circuit element associated with the tag so that the tag cannot return a response signal. Another type of RFID tag used in the system has electronically alterable tag information. The interrogator includes circuitry for detecting the electronic alteration and causing an appropriate response therefrom without requiring any communication with a database of tags.

24 Claims, 12 Drawing Sheets



r-pac-1022
IPR2024-01416

U.S. PATENT DOCUMENTS

5,214,410	5/1993	Verster	340/572
5,218,343	6/1993	Stobbe et al.	340/572
5,260,690	11/1993	Mann et al.	340/572
5,288,980	2/1994	Patel et al.	235/381
5,339,074	8/1994	Shindley et al.	340/825.31
5,347,263	9/1994	Carroll et al.	340/572
5,353,011	10/1994	Wheeler et al.	340/572
5,430,441	7/1995	Bickley et al.	340/825.54
5,432,864	7/1995	Lu et al.	382/118
5,444,223	8/1995	Blama	235/435
5,446,447	8/1995	Carney et al.	340/572
5,448,110	9/1995	Tuttle et al.	257/723
5,450,070	9/1995	Massar et al.	340/825.35
5,450,492	9/1995	Hook et al.	380/28
5,469,363	11/1995	Saliga	364/478.13
5,471,203	11/1995	Sasaki et al.	340/825.31
5,490,079	2/1996	Sharpe et al.	705/418
5,497,140	3/1996	Tuttle	342/51
5,499,017	3/1996	Beigel	340/572
5,519,381	5/1996	Marsh et al.	340/572
5,539,394	7/1996	Cato et al.	340/825.54
5,589,820	12/1996	Robinson et al.	340/572
5,604,486	2/1997	Lauro et al.	340/572
5,608,379	3/1997	Narlow et al.	340/572
5,710,540	1/1998	Clement et al.	340/572

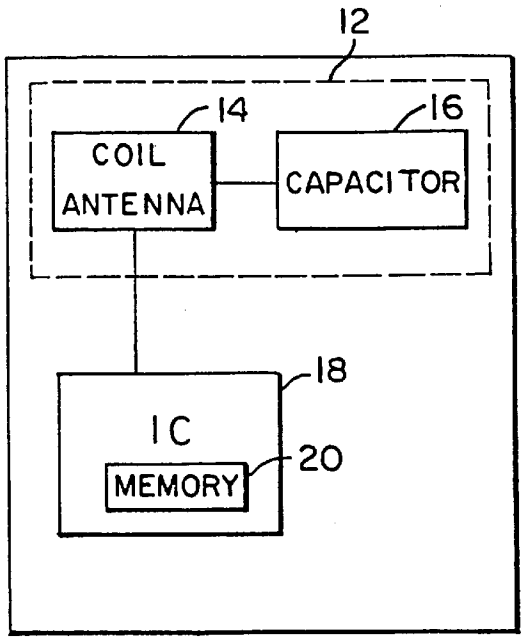

12
14
16
COIL ANTENNA
CAPACITOR
18
IC
MEMORY
20

FIG. 1

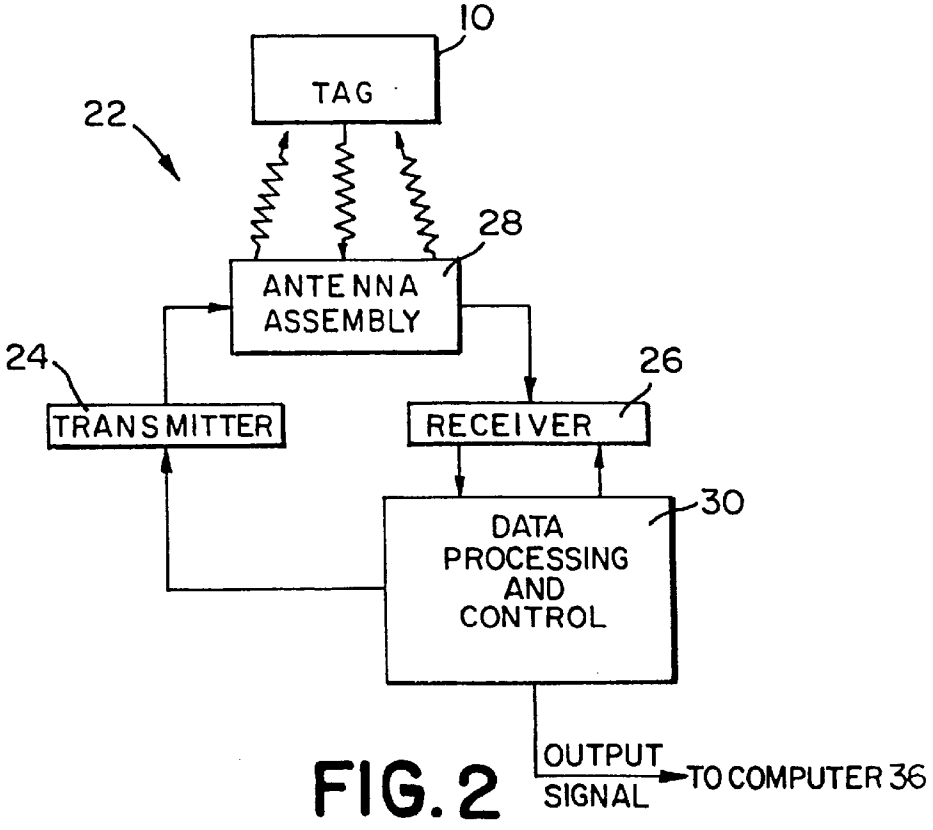

10
TAG
22
28
ANTENNA ASSEMBLY
24
26
TRANSMITTER
RECEIVER
30
DATA PROCESSING AND CONTROL
OUTPUT SIGNAL
TO COMPUTER 36

FIG. 2

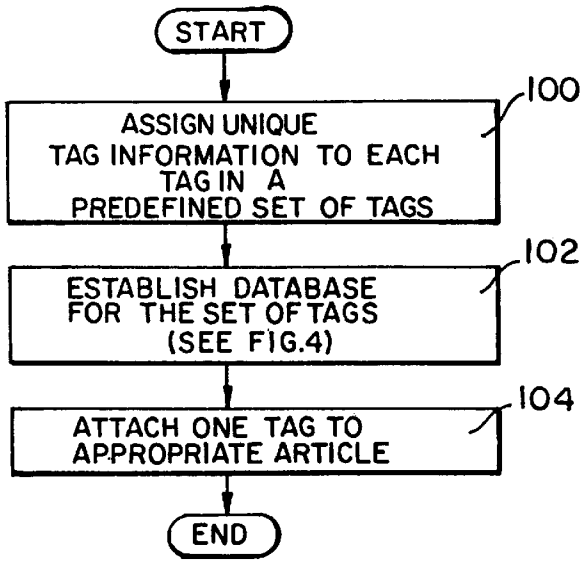

START
ASSIGN UNIQUE TAG INFORMATION TO EACH TAG IN A PREDEFINED SET OF TAGS
100
ESTABLISH DATABASE FOR THE SET OF TAGS (SEE FIG.4)
102
ATTACH ONE TAG TO APPROPRIATE ARTICLE
104
END

FIG. 3

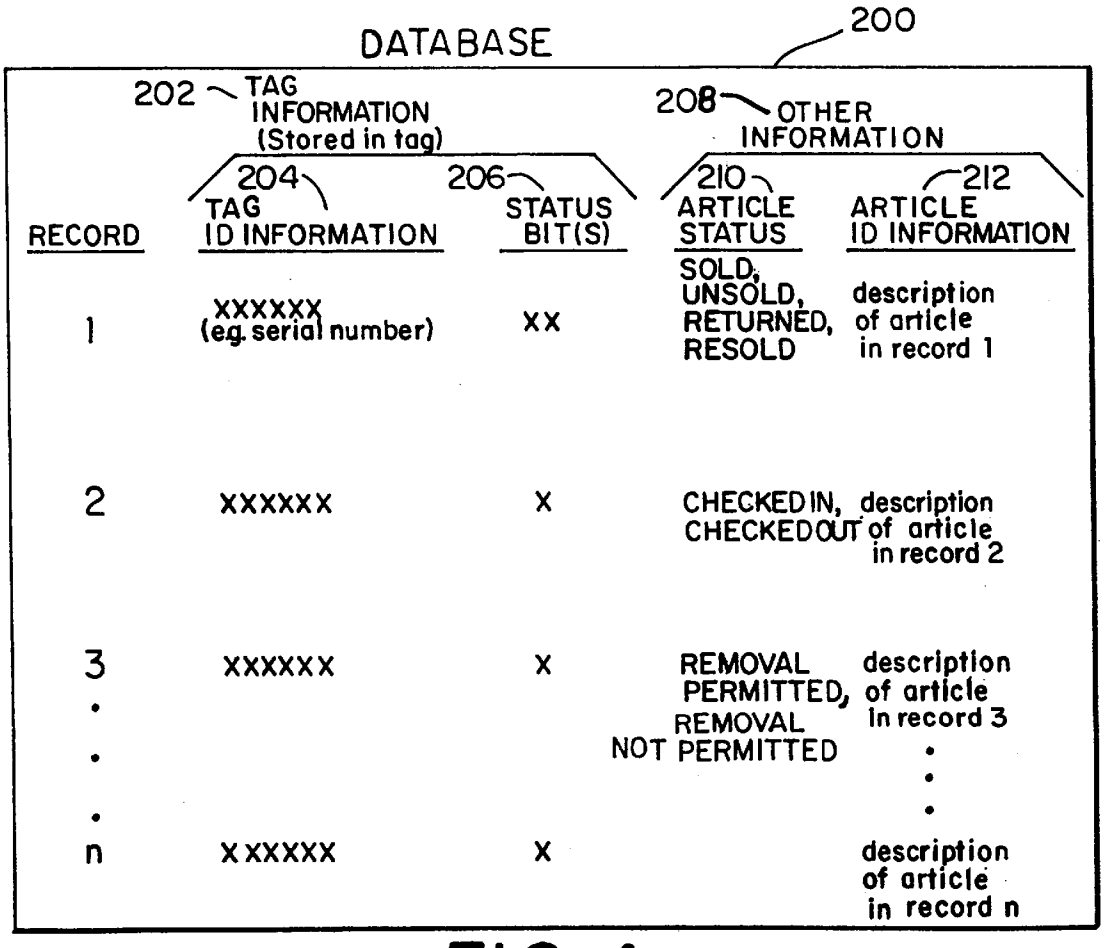

DATABASE
200
202 TAG INFORMATION (Stored in tag)
208 OTHER INFORMATION
204 TAG ID INFORMATION
206 STATUS BIT(S)
210 ARTICLE STATUS
212 ARTICLE ID INFORMATION
RECORD
1 XXXXXX (eg. serial number) XX SOLD, UNSOLD, RETURNED, RESOLD description of article in record 1
2 XXXXXX X CHECKEDIN, CHECKEDOUT description of article in record 2
3 XXXXXX X REMOVAL PERMITTED, REMOVAL NOT PERMITTED description of article in record 3
n XXXXXX X description of article in record n

FIG. 4

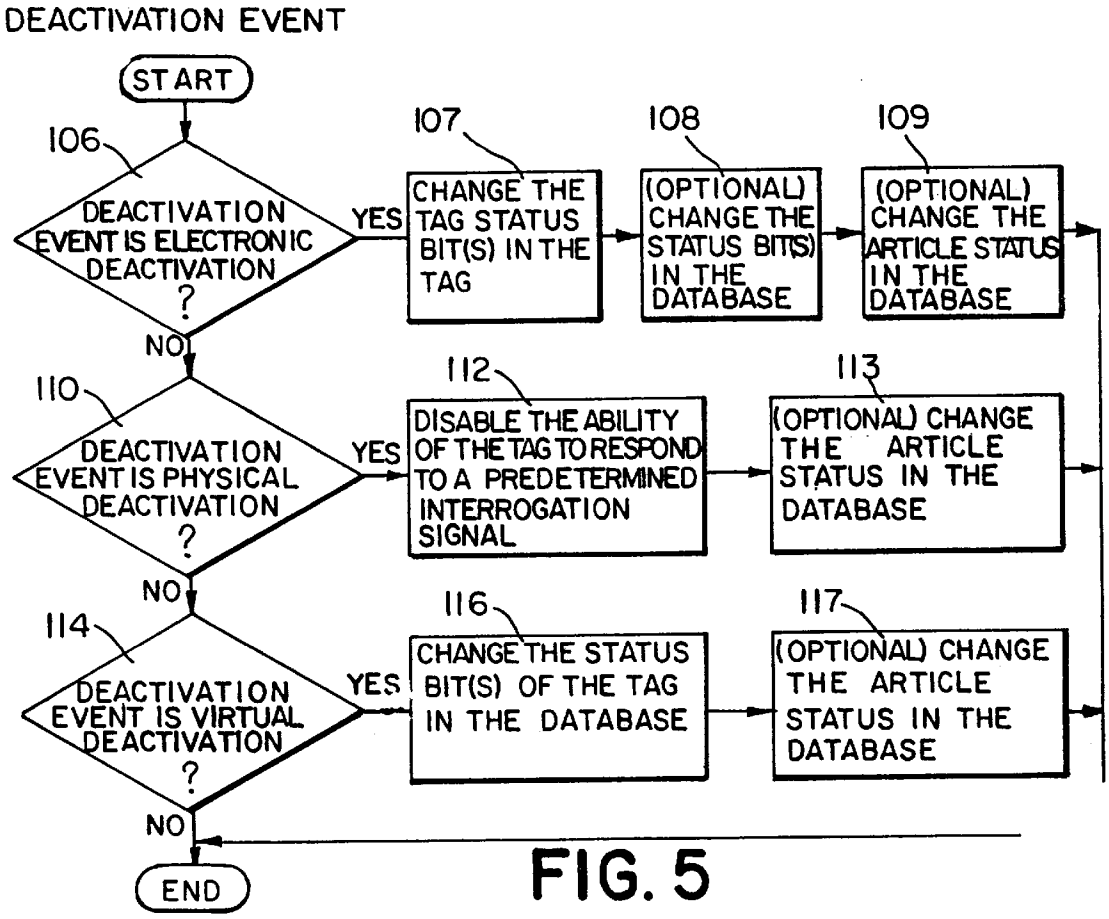


FIG. 5

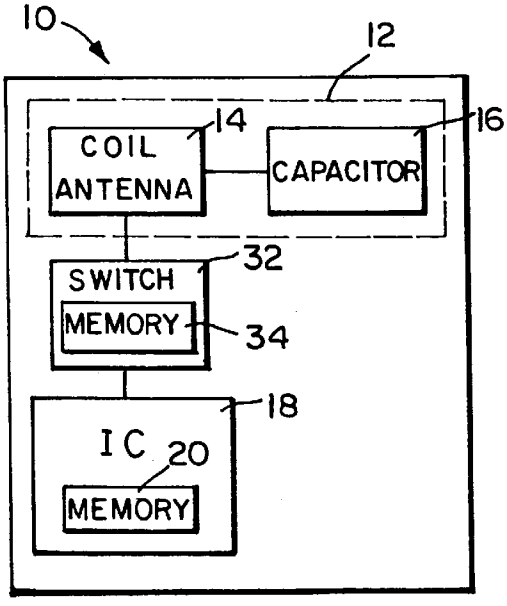


FIG. 6A

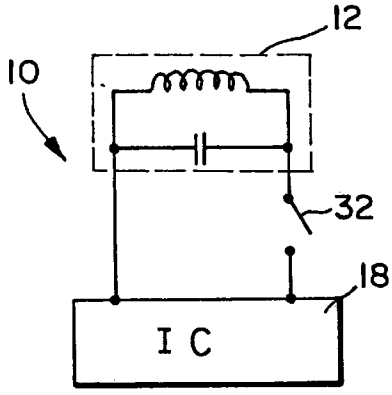


FIG. 6B

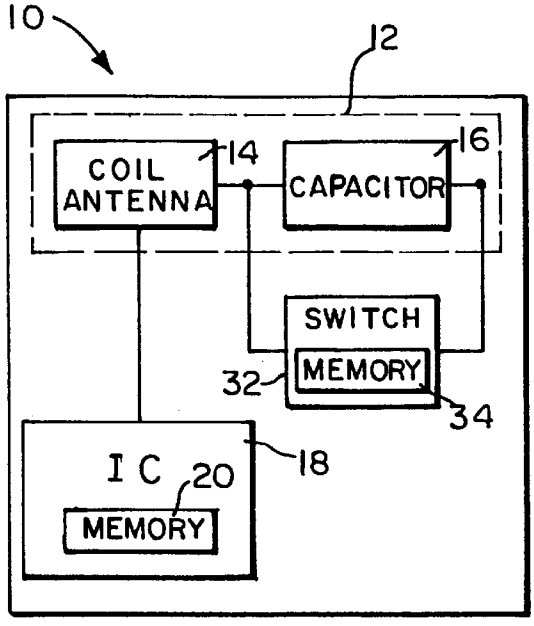


FIG. 7A

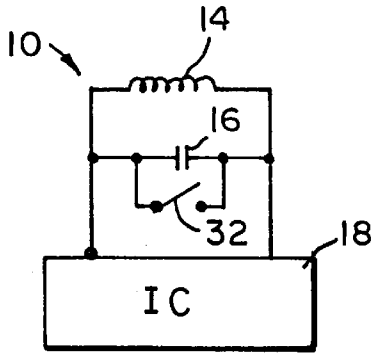


FIG. 7B

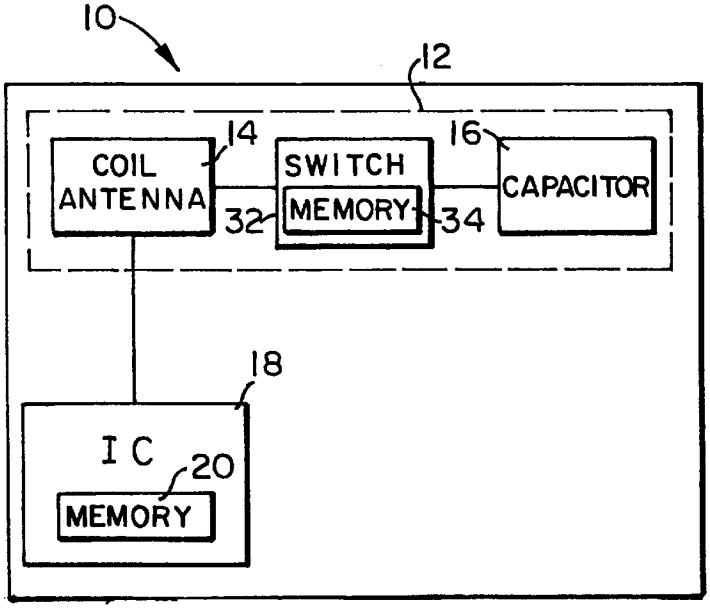


FIG. 7C

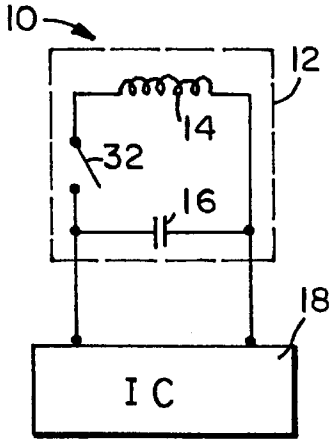


FIG. 7D

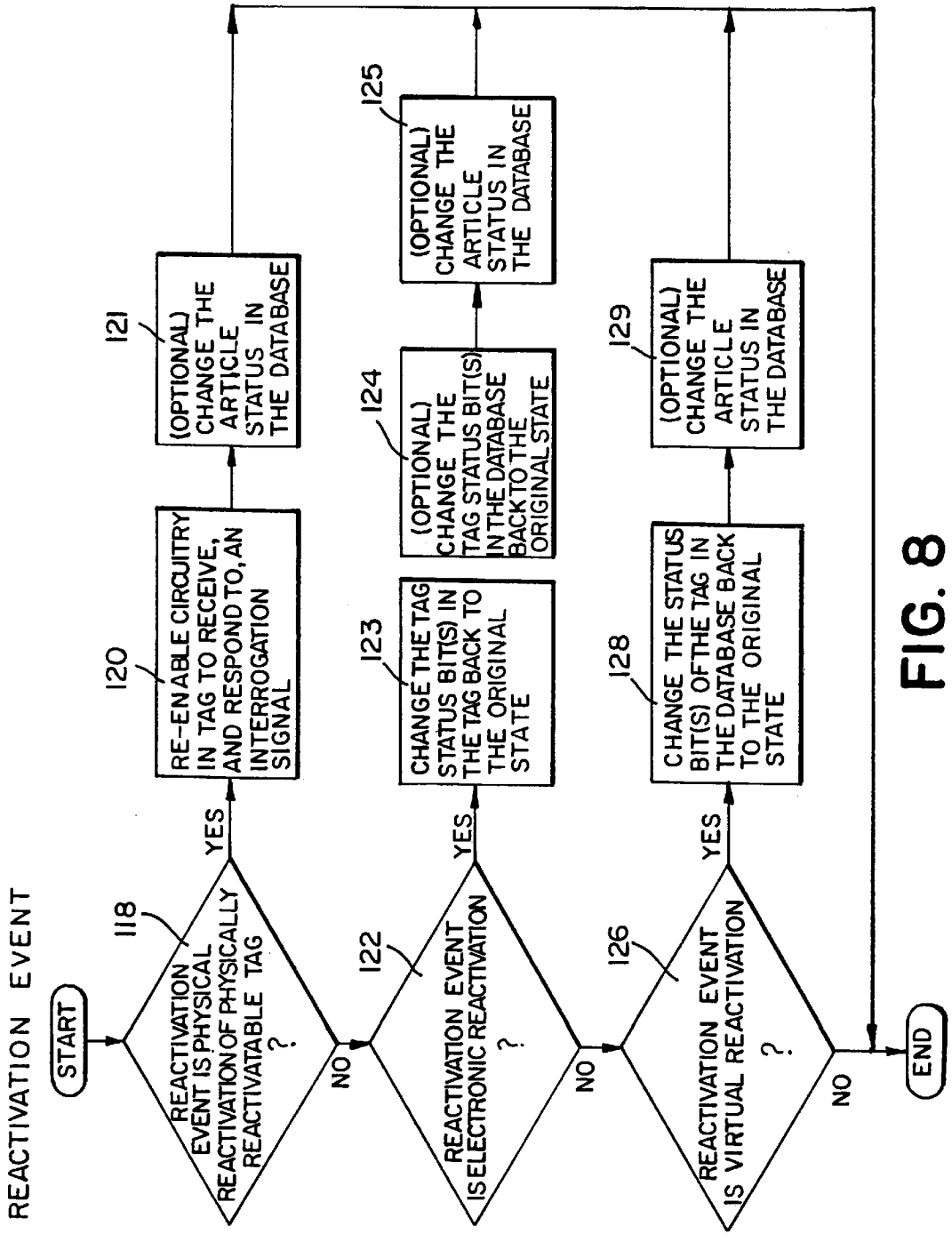

REACTIVATION EVENT
START
118
REACTIVATION EVENT IS PHYSICAL REACTIVATION OF PHYSICALLY REACTIVATABLE TAG ?
YES
NO
120
RE-ENABLE CIRCUITRY IN TAG TO RECEIVE, AND RESPOND TO, AN INTERROGATION SIGNAL
121
(OPTIONAL) CHANGE THE ARTICLE STATUS IN THE DATABASE
122
REACTIVATION EVENT IS ELECTRONIC REACTIVATION ?
YES
NO
123
CHANGE THE TAG STATUS BIT(S) IN THE TAG BACK TO THE ORIGINAL STATE
124
(OPTIONAL) CHANGE THE TAG STATUS BIT(S) IN THE DATABASE BACK TO THE ORIGINAL STATE
125
(OPTIONAL) CHANGE THE ARTICLE STATUS IN THE DATABASE
126
REACTIVATION EVENT IS VIRTUAL REACTIVATION ?
YES
NO
128
CHANGE THE STATUS BIT(S) OF THE TAG IN THE DATABASE BACK TO THE ORIGINAL STATE
129
(OPTIONAL) CHANGE THE ARTICLE STATUS IN THE DATABASE
END

FIG. 8

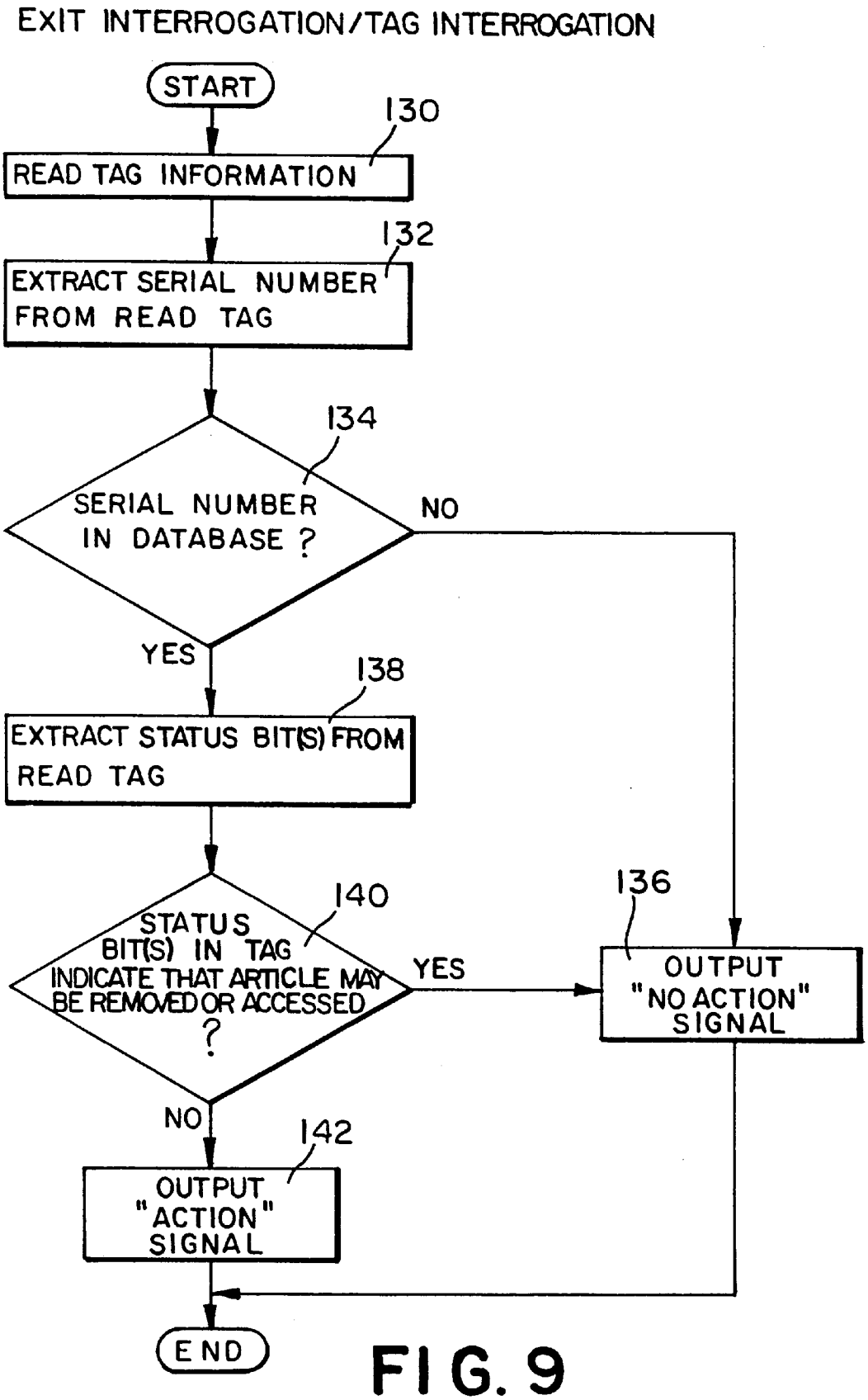

EXIT INTERROGATION/TAG INTERROGATION
START
130
READ TAG INFORMATION
132
EXTRACT SERIAL NUMBER FROM READ TAG
134
SERIAL NUMBER IN DATABASE ?
NO
YES
138
EXTRACT STATUS BIT(S) FROM READ TAG
140
STATUS BIT(S) IN TAG INDICATE THAT ARTICLE MAY BE REMOVED OR ACCESSED ?
YES
136
OUTPUT "NO ACTION" SIGNAL
NO
142
OUTPUT "ACTION" SIGNAL
END

FIG. 9

EXIT INTERROGATION/TAG INTERROGATION

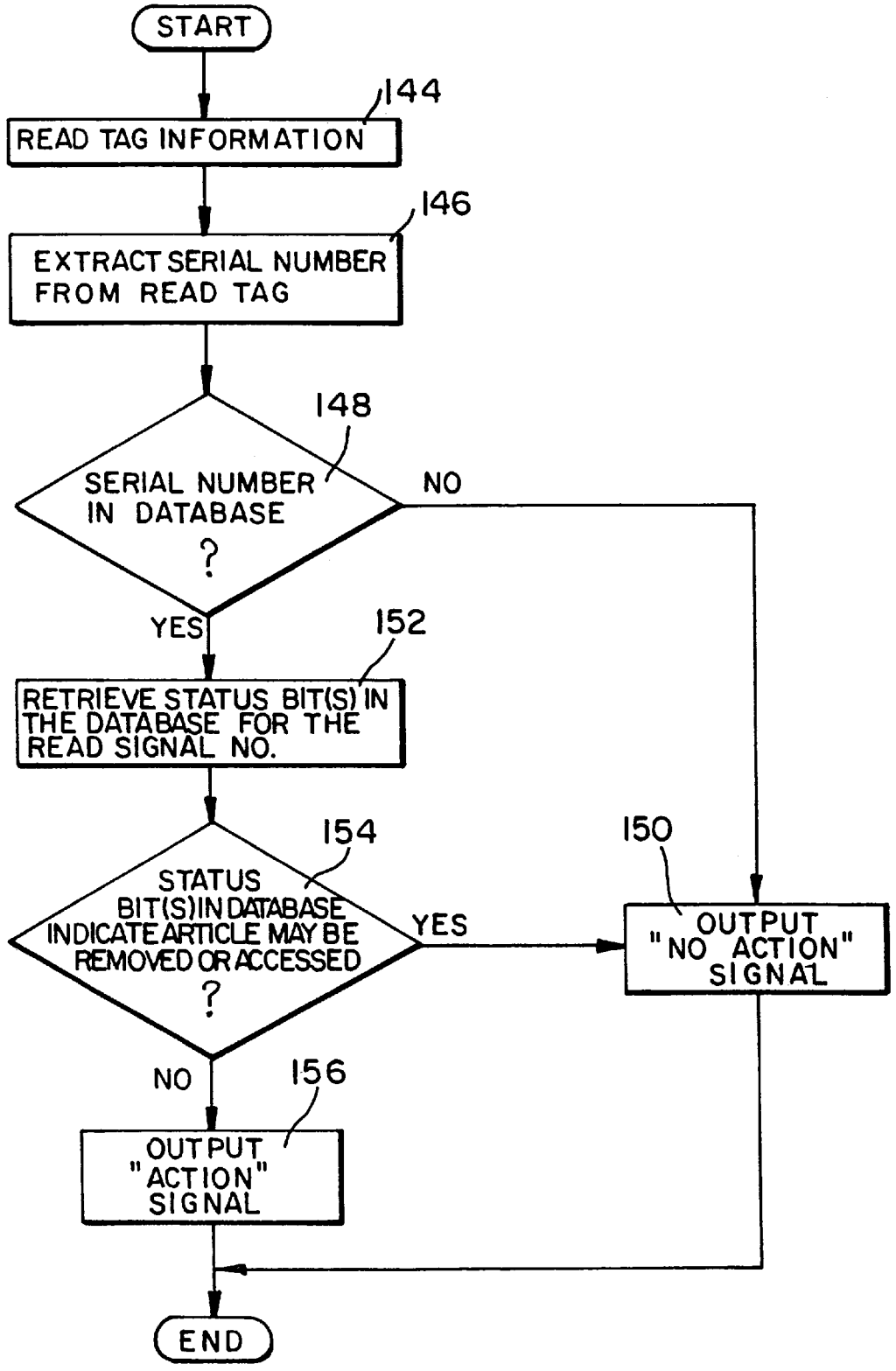


FIG. 10

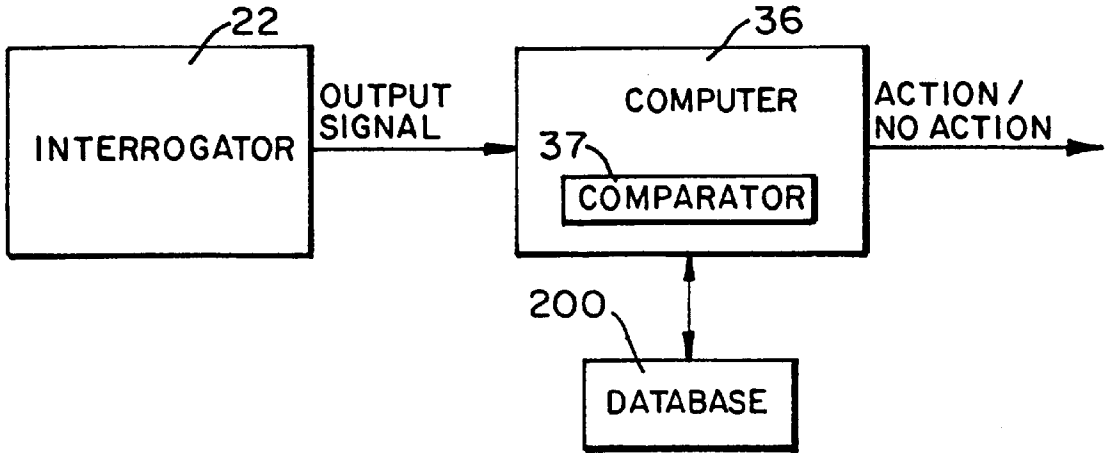

22
INTERROGATOR
OUTPUT SIGNAL
36
COMPUTER
37
COMPARATOR
ACTION / NO ACTION
200
DATABASE

FIG. 11

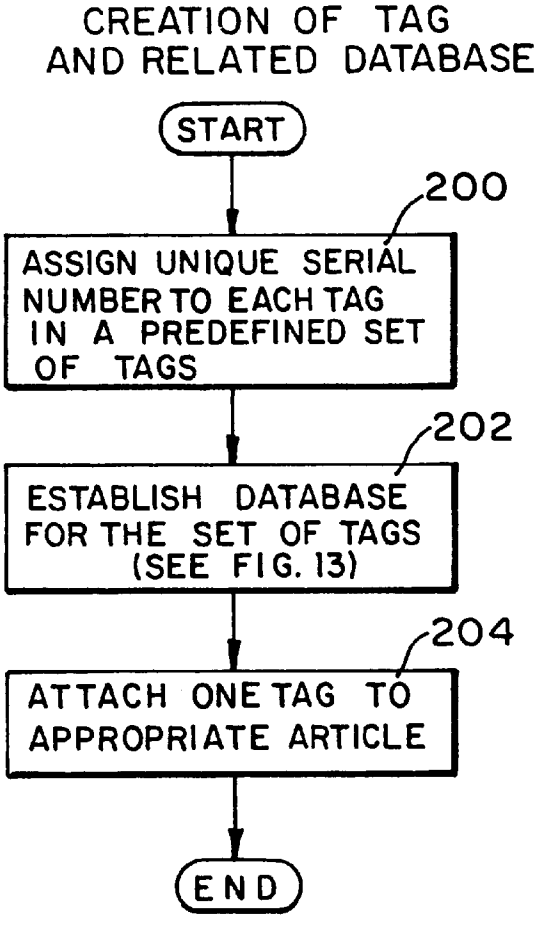

CREATION OF TAG AND RELATED DATABASE
START
200
ASSIGN UNIQUE SERIAL NUMBER TO EACH TAG IN A PREDEFINED SET OF TAGS
202
ESTABLISH DATABASE FOR THE SET OF TAGS (SEE FIG. 13)
204
ATTACH ONE TAG TO APPROPRIATE ARTICLE
END

FIG. 12

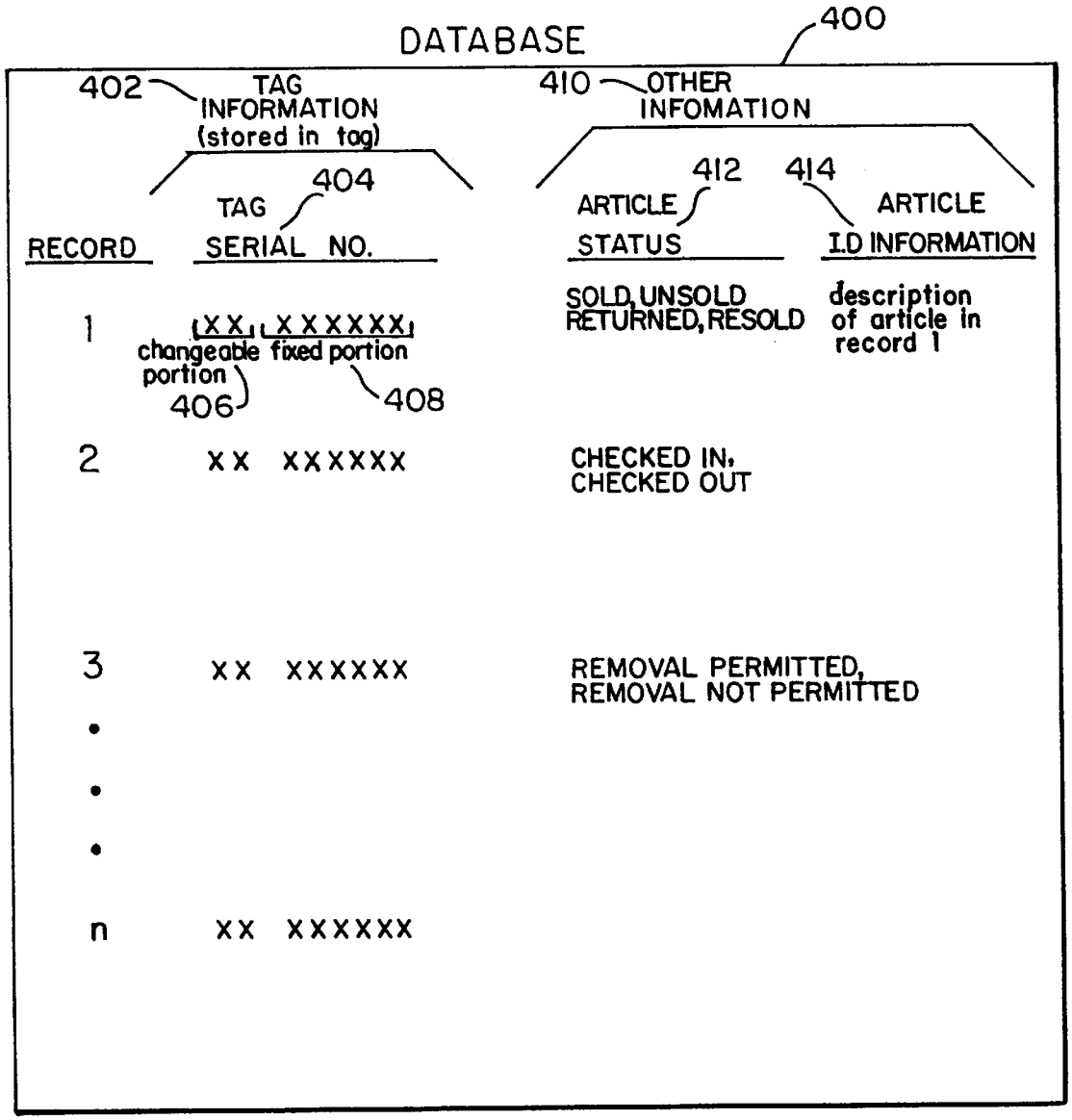

DATABASE
400
402
TAG INFORMATION (stored in tag)
410
OTHER INFOMATION
404
TAG SERIAL NO.
412
ARTICLE STATUS
414
ARTICLE I.D INFORMATION
RECORD
1
(XX, XXXXXX)
changeable portion
406
fixed portion
408
SOLD, UNSOLD RETURNED, RESOLD
description of article in record 1
2
XX XXXXXX
CHECKED IN, CHECKED OUT
3
XX XXXXXX
REMOVAL PERMITTED, REMOVAL NOT PERMITTED
n
XX XXXXXX

FIG. 13

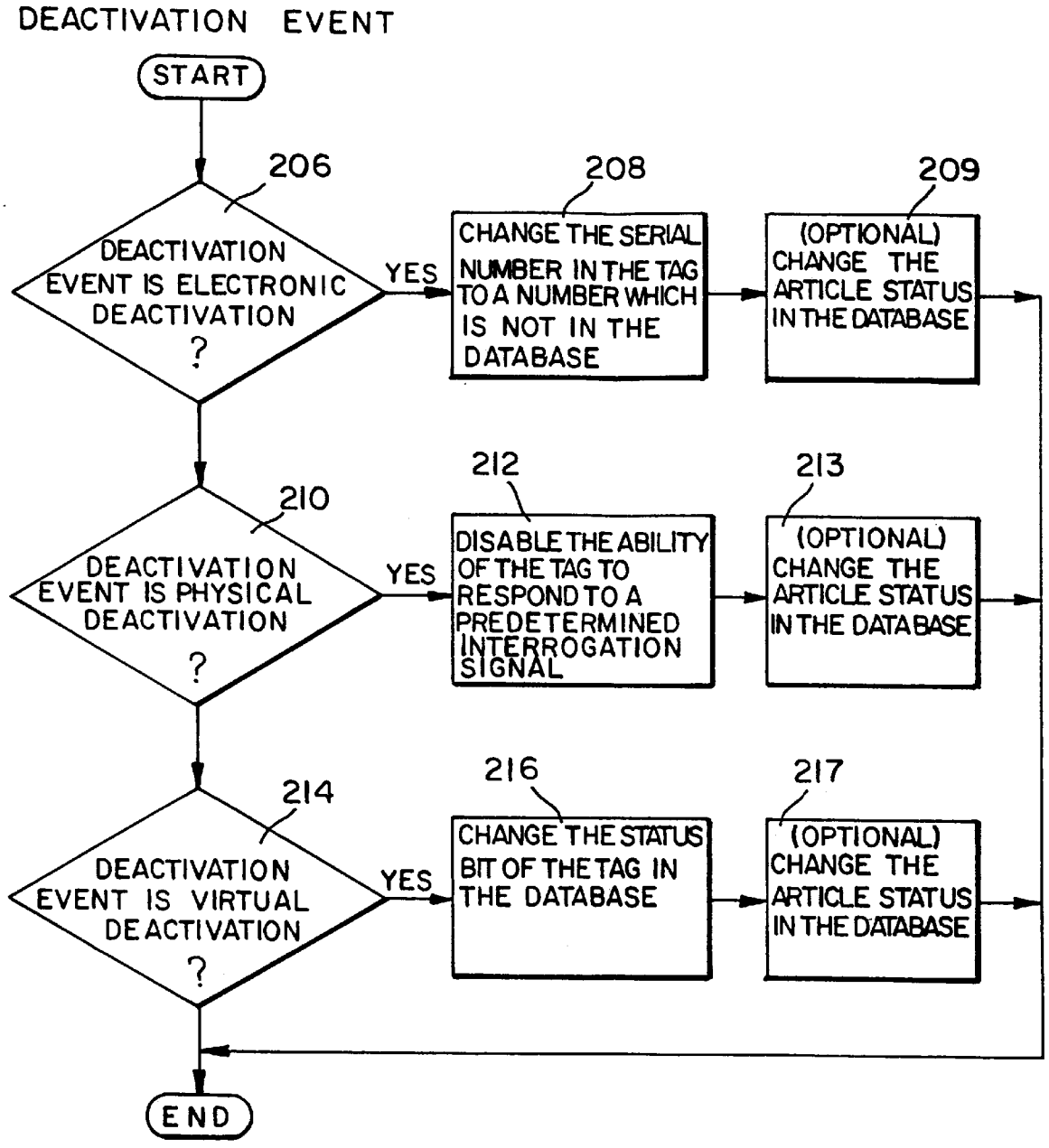

DEACTIVATION EVENT
START
206
DEACTIVATION EVENT IS ELECTRONIC DEACTIVATION ?
YES
208
CHANGE THE SERIAL NUMBER IN THE TAG TO A NUMBER WHICH IS NOT IN THE DATABASE
209
(OPTIONAL) CHANGE THE ARTICLE STATUS IN THE DATABASE
210
DEACTIVATION EVENT IS PHYSICAL DEACTIVATION ?
YES
212
DISABLE THE ABILITY OF THE TAG TO RESPOND TO A PREDETERMINED INTERROGATION SIGNAL
213
(OPTIONAL) CHANGE THE ARTICLE STATUS IN THE DATABASE
214
DEACTIVATION EVENT IS VIRTUAL DEACTIVATION ?
YES
216
CHANGE THE STATUS BIT OF THE TAG IN THE DATABASE
217
(OPTIONAL) CHANGE THE ARTICLE STATUS IN THE DATABASE
END

FIG. 14

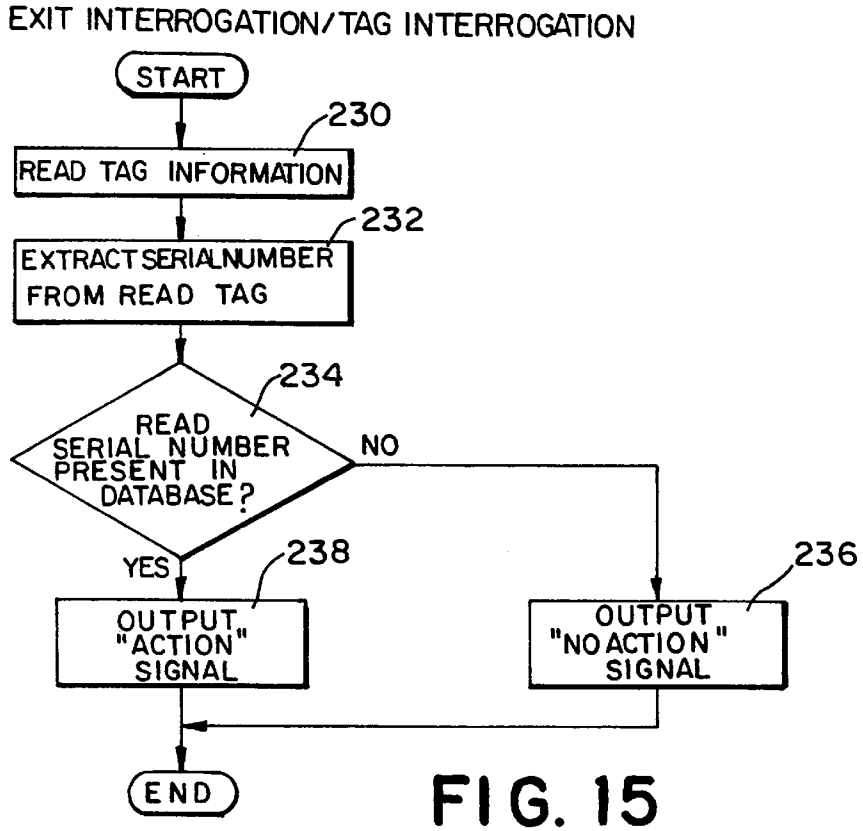

EXIT INTERROGATION/TAG INTERROGATION
START
230
READ TAG INFORMATION
232
EXTRACT SERIAL NUMBER FROM READ TAG
234
READ SERIAL NUMBER PRESENT IN DATABASE?
NO
YES
238
OUTPUT "ACTION" SIGNAL
236
OUTPUT "NO ACTION" SIGNAL
END

FIG. 15

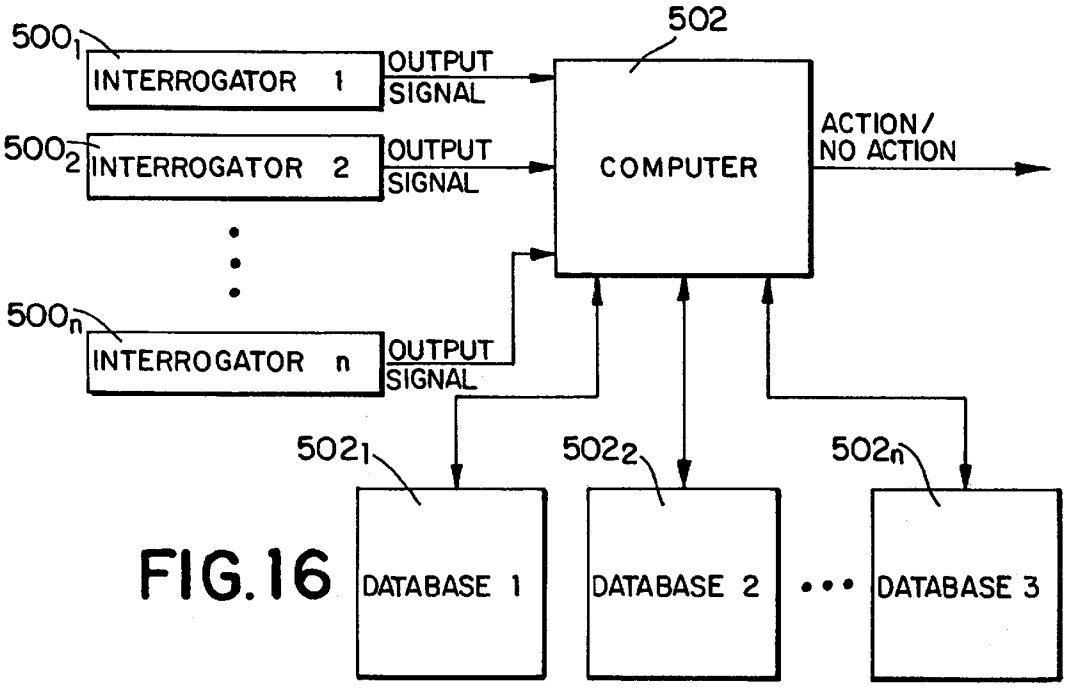

500₁
INTERROGATOR 1
OUTPUT SIGNAL
500₂
INTERROGATOR 2
OUTPUT SIGNAL
500n
INTERROGATOR n
OUTPUT SIGNAL
502
COMPUTER
ACTION/ NO ACTION
502₁
502₂
502n
DATABASE 1
DATABASE 2
DATABASE 3

FIG. 16

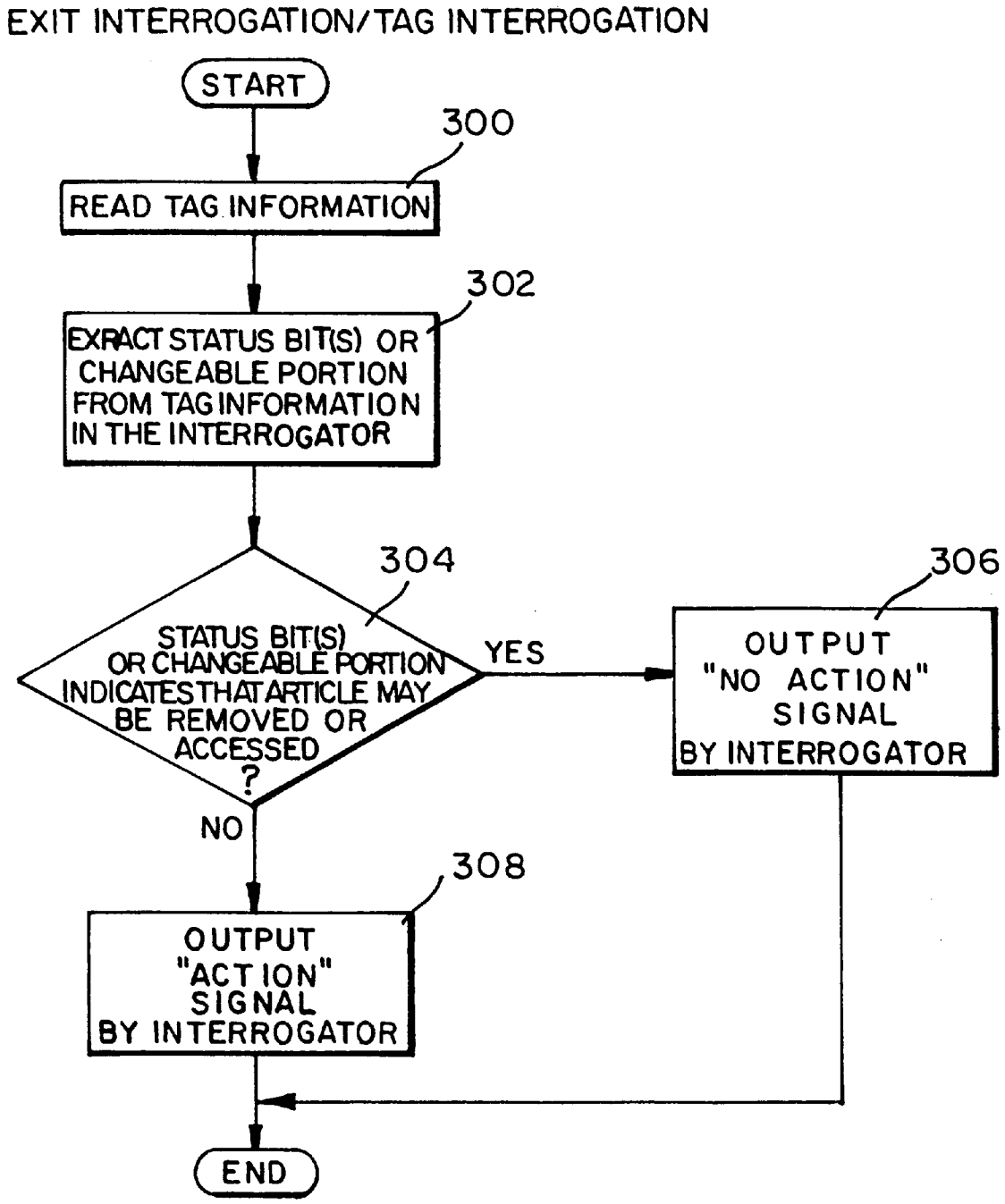

EXIT INTERROGATION/TAG INTERROGATION
START
300
READ TAG INFORMATION
302
EXRACT STATUS BIT(S) OR CHANGEABLE PORTION FROM TAG INFORMATION IN THE INTERROGATOR
304
STATUS BIT(S) OR CHANGEABLE PORTION INDICATES THAT ARTICLE MAY BE REMOVED OR ACCESSED ?
YES
306
OUTPUT "NO ACTION" SIGNAL BY INTERROGATOR
NO
308
OUTPUT "ACTION" SIGNAL BY INTERROGATOR
END

FIG. 17

RFID TAGS WHICH ARE VIRTUALLY ACTIVATED AND/OR DEACTIVATED AND APPARATUS AND METHODS OF USING SAME IN AN ELECTRONIC SECURITY SYSTEM

BACKGROUND OF THE INVENTION

Electronic article security (EAS) systems for detecting and preventing theft or unauthorized removal of articles or goods from retail establishments and/or other facilities, such as libraries, have become widespread. In general, such security systems employ a security tag which is secured to or associated with an article (or its packaging), typically an article which is readily accessible to potential customers or facility users and, therefore, is susceptible to unauthorized removal. In general, such EAS systems are employed for detecting the presence (or the absence) of a security tag and, thus, a protected article within a surveilled security area or detection zone. In most cases, the detection zone is located at or around an exit or entrance to the facility or a portion of the facility.

One type of EAS system which has gained widespread popularity utilizes a security tag which includes a self-contained, passive resonant circuit in the form of a small, generally planar printed circuit which resonates at a predetermined detection frequency within a detection frequency range. A transmitter, which is also tuned to the detection frequency, is employed for transmitting electromagnetic energy or an interrogation signal into the detection zone. A receiver, tuned to the detection frequency, is positioned proximate to the detection zone. Typically, the transmitter and a transmitter antenna are located on one side of an exit or aisle and the receiver and a receiver antenna are located on the other side of the exit or aisle, so that a person must pass between the transmitter and receiver antennas in order to exit the facility. When an article having an attached security tag moves into or passes through the detection zone, the security tag is exposed to the transmitted energy (the security tag is interrogated), resulting in the resonant circuit of the tag resonating to provide an output signal detectable by the receiver. The detection of such an output signal by the receiver indicates the presence of an article with a security tag within the detection zone and the receiver activates an alarm to alert appropriate security or other personnel.

Existing EAS systems of the type described above and of other types have been shown to be effective in preventing the theft or unauthorized removal of articles.

Security tags of the type described used in a particular store or chain of stores are typically identical. Thus, all articles, regardless of size or value, which include the securi:y tag return an identical signal to the receiver. Recently, passive resonant security tags which return unique or semi-unique identification codes were developed. U.S. Pat. No. 5,446,447 (Carney et al.), U.S. Pat. No. 5,430,441 (Bickley et al.), and U.S. Pat. No. 5,347,263 (Carroll et al.) disclose three examples of such security tags. These security tags typically include an integrated circuit to generate the identification code. Such "intelligent" security tags provide additional information about the article detected in the zone of the interrogator.

When it is desired to deactivate a security tag, such as when a tagged article is purchased, the usual approach with the prior art EAS systems is to physically deactivate or physically disable the security tag so that the tag does not respond to an interrogation signal sent out by the interrogator or transmitter when the tag passes through the detection zone. One common technique for physically deactivating a security tag is to destroy some portion of the resonant circuit, such as a capacitor. Another technique involves covering the tag with a shield on either a permanent or temporary basis to prevent the tag from being exposed to an interrogation signal. A third technique involves surrounding a portion of the tag coil with a magnetizable and demagnetizable metallic element which, according to whether the element is magnetized or demagnetized, changes the tag Q so that it becomes either detectable or undetectable by an interrogator.

Despite the widespread use of such security tags, and, more recently, RFID tags, there is still a need to expand the functional capabilities of EAS and other systems which use RFID tags. Specifically, it would be desirable to create databases which interact with interrogators and RFID programming equipment to identify and track the status of individually tagged articles. It would also be desirable to "deactivate" RFID tags in a manner which allows the tags to be conveniently reactivated. It would also be desirable to deactivate and reactivate RFID tags in a manner which does not require physically or electronically altering the tag itself. The present invention addresses these needs by providing a method of using deactivatable and reactivatable RFID tags which are tracked by a database so that the status of the tagged article may be tracked throughout its life cycle.

BRIEF SUMMARY OF THE INVENTION

An electronic security system is provided which comprises a predefined set of radio frequency identification tags, an interrogator, a computerized database containing a record for each of the tags in the set, and a computer which compares tag information obtained from the interrogator with the database records of tags. Each of the tags in the set includes an antenna and an integrated circuit. The antenna detects the presence of the article by receiving an interrogation signal and returning a response signal. The integrated circuit is connected to the antenna. The integrated circuit stores tag information and outputs the tag information with the response signal upon interrogation of the tag. Each tag is associated with, and attached to, an article or packaging for an article and is programmed with unique tag information. The interrogator monitors a detection zone for detecting disturbances in the form of a response signal caused by the presence of a tag within the zone. The interrogator outputs an interrogator output signal when a tag is detected in the zone. Each interrogator output signal includes the tag information stored in the integrated circuit. Each record in the computerized database includes tag information. The computer includes a comparator for receiving the database records and the tag information from the interrogator and comparing the database records to the tag information, and outputting an appropriate response.

Furthermore, a method is provided of using a predefined set of tags in an electronic RFID security system. Each tag is associated with, and attached to, an article or packaging for an article. Each tag includes an antenna for use in detecting the presence of the article by receiving an interrogation signal and returning a response signal, and an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag. The method comprising the steps of programming each of the tags with unique tag information, establishing a computerized database containing a record for each of the tags in the set, each record including the tag information and other information about the article having the tag associated therewith, and

monitoring a detection zone with an interrogator for detecting disturbances in the form of a response signal caused by the presence of a tag within the zone. The interrogator outputs an interrogator output signal when a tag is detected in the zone. Each interrogator output signal includes the tag information stored in the integrated circuit. The database records are then compared to the tag information and an appropriate database response is output. A deactivation event may be performed on the tag when legitimate access is obtained to the tagged article. The deactivation event may be electronic, physical or virtual.

Another embodiment of the invention provides a radio frequency identification tag comprising an antenna and an integrated circuit connected to the antenna. The antenna receives an interrogation signal and returns a response signal. The integrated circuit stores tag information and outputs the tag information with the response signal upon interrogation of the tag. The tag includes at least one circuit element that has a physically activated state which allows the tag to return a response signal, and a physically deactivated state which prevents the tag from returning a response signal.

Yet another embodiment of the invention provides an electronic security system comprising a predefined set of radio frequency identification tags and an interrogator. Each tag is associated with, and attached to, an article or packaging for an article. Each tag includes an antenna for detecting the presence of the article by receiving an interrogation signal and returning a response signal, and an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag. The tag is programmed with unique tag information, and at least a portion of the tag information is electronically alterable so as to allow the tag to be electronically activated and deactivated. The interrogator monitors a detection zone and detects disturbances in the form of a response signal caused by the presence of a tag within the zone. The interrogator outputs an interrogator output signal when a tag is detected in the zone. Each interrogator output signal includes the tag information stored in the integrated circuit. The interrogator includes circuitry for detecting the electronically alterable portion of the tag information and determining an appropriate response therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary, as well as the following detailed description of preferred embodiments of the invention, will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there are shown in the drawings embodiments which are presently preferred. It should be understood, however, that the invention is not limited to the precise arrangements and instrumentalities shown. In the drawings:

FIG. **1** is a block diagram schematic of an RFID tag suitable for use with the present invention;

FIG. **2** is a functional block diagram schematic of an interrogator suitable for use with the present invention;

FIG. **3** is a flowchart of the steps for initiating a first embodiment of the present invention;

FIG. **4** is a sample database created for use with the first embodiment of the present invention;

FIG. **5** is a flowchart of deactivation event options of "electronic deactivation," "physical deactivation," or "virtual deactivation," in accordance with the first embodiment of the present invention;

FIG. **6A** is a block diagram schematic of a first embodiment of a physically reactivatable tag suitable for use with the present invention;

FIG. **6B** is an equivalent electrical circuit diagram of one preferred implementation of the tag of FIG. **6A**;

FIG. **7A** is a block diagram schematic of a second embodiment of a physically reactivatable tag suitable for use with the present invention;

FIG. **7B** is an equivalent electrical circuit diagram of one preferred implementation of the tag of FIG. **7A**;

FIG. **7C** is a block diagram schematic of a third embodiment of a physically reactivatable tag suitable for use with the present invention;

FIG. **7D** is an equivalent electrical circuit diagram of one preferred implementation of the tag of FIG. **7C**;

FIG. **8** is flowchart of the decision process for a reactivation event in accordance with the first embodiment of the present invention;

FIG. **9** is a flowchart of an exit interrogation/tag interrogation procedure useful for EAS systems which use electronic deactivation in accordance with the first embodiment of the present invention;

FIG. **10** is a flowchart of an exit interrogation/tag interrogation procedure useful for EAS systems which use virtual deactivation in accordance with the first embodiment of the present invention;

FIG. **11** is a schematic block diagram of the elements which perform the steps in FIGS. **9** and **10**;

FIG. **12** is a flowchart of the steps for initiating a second embodiment of the present invention;

FIG. **13** is a sample database created for use with the second embodiment of the present invention;

FIG. **14** is a flowchart of deactivation event options of "electronic deactivation," "physical deactivation," or "virtual deactivation," in accordance with the second embodiment of the present invention;

FIG. **15** is a flowchart of an exit interrogation/tag interrogation procedure useful for EAS systems which use electronic or virtual deactivation in accordance with the second embodiment of the present invention;

FIG. **16** is a schematic block diagram of large scale application of the present invention which links together plural entities; and

FIG. **17** is a flowchart of an exit interrogation/tag interrogation procedure useful for EAS systems which use electronic deactivation in accordance with a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Certain terminology is used herein for convenience only and is not be taken as a limitation on the present invention. In the drawings, the same reference numerals are employed for designating the same elements throughout the several figures.

FIG. **1** shows general details of a sample RFID tag **10** suitable for use with the present invention. The RFID tag **10** becomes an intelligent security tag when used in embodiments wherein the tag **10** is attached to articles. The tag **10** includes a passive resonant radio frequency (RF) circuit **12** for use in detecting when the tag **10** is within a zone monitored by a reader or interrogator, as is well-known in the art. One well-known type of circuit **12** has a coil antenna **14** and a capacitor **16** which together form a resonant circuit

with a predetermined resonant frequency i.e., the selected radio frequency determined by the values of the coil and the capacitor. Power for the tag **10** is derived from the antenna **14** in a conventional manner. Furthermore, the tag **10** includes an integrated circuit (IC) **18** for providing "intelligence" to the tag **10**. The IC **18** is electrically connected to the resonant circuit **12**. (The capacitor **16** may be either external to the IC **18**, or the capacitor **16** may be within the IC **18**, depending upon the desired implementation of the circuit **12**.) The IC **18** includes a programmable memory **20**, such as a 20 bit memory, for storing bits of identification data. The IC **18** outputs a data stream comprised of the stored data (i.e. 20 bits in the present embodiment) when sufficient power from the antenna **14** is applied thereto. In one embodiment of the invention, the data stream creates a series of data pulses by switching an extra capacitor (not shown) across the coil antenna **14** for the duration of the data pulses. The addition of the extra capacitor changes the resonant frequency of the RF circuit **12**, detuning it from the operational frequency. Thus, instead of the RF circuit **12** returning a simple single frequency response signal, it returns a signal containing a packet of preprogrammed information. The packet of information (data pulses) is received and processed by interrogator receiving circuitry and is decoded (if necessary) to provide identification information about an article to which the tag **10** is secured. Other methods of using the data in the IC memory **20** to output identification data from the tag **10** are within the scope of the invention. The IC **18** is preferably also a passive device and is powered in the same manner as the RF circuit **12** (i.e., by using energy received at the antenna **14** from the interrogator transmitter signal). The tag **10** is thus a so-called "radio frequency identification (RFID) tag" (RFID tag). Other types of RFID tags may be used with the present invention. Examples of other RFID tags which are suitable for use as the tag **10** are shown in U.S. Pat. No. 5,446,447 (Carney et al.), U.S. Pat. No. 5,430,441 (Bickley et al.), and U.S. Pat. No. 5,347,263 (Carroll et al.). Typically, RFID tags are not physically deactivatable. In other words, no physical change or change of magnetic state occurs to the state of the coil, capacitor or any other element comprising the antenna circuit of such RFID tags. An RFID tag which is not physically deactivatable has significant advantages over physically deactivatable magnetic security tags and/or prior art physically deactivatable RF security tags which are commonly used today because such RFID tags are more difficult to bypass. In some embodiments of the present invention, nonphysically deactivatable RFID tags are used. In other embodiments of the present invention, physically deactivatable RFID tags are used.

The preferred embodiment of the RFID tag includes a resonant circuit having a coil antenna and a capacitor, and an IC. However, the scope of the invention includes an RFID tag which has only a coil antenna and an IC.

FIG. **2** is a block diagram schematic of a reader or interrogator **22** suitable for use with the tag **10** described in FIG. **2**. The interrogator **22** and the tag **10** communicate by inductive coupling, as is well-known in the art. The interrogator **22** includes a transmitter **24**, receiver **26**, antenna assembly **28**, and data processing and control circuitry **30**, each having inputs and outputs. The output of the transmitter **24** is connected to a first input of the receiver **26**, and to the input of the antenna assembly **28**. The output of the antenna assembly **28** is connected to a second input of the receiver **26**. A first and a second output of the data processing and control circuitry **30** are connected to the input of the transmitter **24** and to a third input of the receiver **26**, respectively. Furthermore, the output of the receiver **26** is connected to the input of the data processing and control circuitry **30**. Interrogators having this general configuration may be built using circuitry described in U.S. Pat. Nos. 3,752,960, 3,816,708, 4,223,830 and 4,580,041, all issued to Walton, all of which are incorporated by reference in their entirety herein. The interrogator **22** may be physically implemented, for example, as a pair of pedestals (not shown), a checkout pad, or as a portable RFID scanner (not shown), all of which are capable of communicating with RFID tags, depending upon the needs of the specific application.

FIG. **3** is a flowchart of the steps for initiating a first embodiment of the present invention, and FIG. **4** is a sample database created for use with the first embodiment. Referring to FIG. **3**, a predefined set of tags **10** are prepared to be applied to a predefined set of articles (not shown), unique tag information is assigned to each tag **10** within the tag set and each of the tags are programmed accordingly using a tag programmer (step **100**). This step includes assigning unique identification information and an initial status to each tag, as described in more detail below. Next, a database is established for the set of tags **10** (step **102**). Lastly, one of the tags **10** is attached directly to each article or to the packaging of each article (step **104**). In the disclosed embodiment, one tag **10** is associated with each article. Steps **100** and **102**, or all three steps **100**, **102** and **104**, may be performed at a factory or at the site of article access. The steps in FIG. **3** may be performed in any order.

FIG. **4** shows a sample database **200** established in step **102** of FIG. **3**. Each numbered record in the database **200** includes a field for tag information **202** comprising tag identification information **204** and variable information in the form of one or more status bits **206** (hereafter, "status bits"). Optionally, there may be additional fields for other information **208** pertaining to the record, such as article status **210** and article identification information **212**. The tag information **202** is stored in the tag **10**. Optionally, some or all of the other information **208** is also stored in the tag **10**.

One example of tag information **202** is a serial number which is unique to the set of tags **10** in the database **200**. Preferably, none of the serial numbers in the database **200** are used in dazabases or EAS systems of other entities which use tags **10** readable by the same interrogation equipment. In this manner, there is no chance that a tag used by another entity (e.g., another chain of stores) can be confused with any of the tags **10** in the database **200**.

One example of article status **210** is a human readable string of characters indicating the meaning of the status bits. If the tagged articles are retail items, the article status **210** indicates whether the article is sold, unsold, returned or resold. If the tagged articles are books, videotapes, or other types of articles which are borrowed and returned, the article status **210** indicates whether the article is checked in or checked out, and may also indicate whether the article is or is not permitted to be removed from the premises. In the preferred embodiment of the invention, the article status **210** is a human readable form of the status bit(s) **206**. If no article status field exists, the status bit(s) **206** may be decoded to obtain the article status information.

Article identification information **212** is a description of the article associated with the record in human readable form (e.g., SONY 19" TV, Model No. KV1926; PERT Shampoo/Conditioner, 16 oz.)

Once all of the articles are tagged and the database **200** is established, the articles are made accessible to customers or patrons within predefined surroundings. The predefined sur-

roundings have one or more exits which have detection zones that are monitored with the interrogator **22** for detecting disturbances in the form of a response signal caused by the presence of a non-deactivated tag **10** within the zone. The interrogator **22** outputs an interrogator output signal when a non-physically deactivated tag **10** is detected in the zone. Each interrogator output signal includes the tag information **202** stored in the integrated circuit **18**. The exit interrogation/tag interrogation process is described in more detail below with respect to FIGS. **9** and **10**.

When legitimate access is obtained to an article having a tag **10** associated therewith, the tag **10** is deactivated before the tagged article can be removed from the predefined surroundings. FIG. **5** is a flowchart showing the various options associated with a deactivation event. Deactivation may be characterized as being either "electronic," "physical," or "virtual," as defined below:

electronic deactivation—one or more of the status bits in the tag **10** are electronically changed or reprogrammed, and, optionally, one or more of the security tag status bits **206** may be changed in the database **200**. In the retail environment example shown in FIG. **4**, the tag status bits could be changed from "01" to "00" to indicate that the article was sold. The electronic change can take place at the cash register or at a merchandise pick-up area by any suitable equipment. If the article is subsequently returned by the customer, the store could either change the tag status bits to another code, such as "10", until the article is further processed, or could change the status bits back to "01" if the article is immediately reshelved for subsequent purchase. The equipment for electronically changing or reprogramming the tag status bits may be the same or modified versions of the equipment (e.g., a tag programmer) used to initially program the tag information **202**.

physical deactivation—the tag **10** is physically changed or disabled so that it does not output an interrogator output signal within the detection frequency range when passing through the detection zone (i.e., it does not respond to an interrogation signal sent out by the interrogator **22** or does not respond in a detectable manner). Tags **10** may be physically disabled in a reversible or nonreversible manner. A tag **10** may be non-reversibly disabled by destroying one cr more circuit elements or circuit connections within the tag **10** which are needed to either receive an interrogation signal or respond to an interrogation signal. One example is to break down the capacitor **16** of the resonant circuit **12**, such as by using a dielectric breakdown mechanism, thereby creating a short across the capacitor **16** and preventing resonance of the tag **10**. Alternatively, the tags **10** may be reversibly disabled. For example, referring to FIGS. **6A**, **6B** and **7A–7D**, the tag **10** may include a built-in electronic switch **32** connected to the resonant circuit **12** in such a way as to disable the resonance, or receipt of the resonance, when the state of the switch **32** is changed.

FIGS. **6A** and **6B** show a first embodiment of reversibly physically deactivatable tag **10** wherein the electronic switch **32** may be placed in series between the resonant circuit **12** and the IC **18** so that the resonant circuit **12** is disconnected when the switch **32** is open.

Alternatively, the switch **32** may be placed across the capacitor **16** or coil antenna so that resonance is prevented when the switch **32** is closed. FIGS. **7A** and **7B** show such an embodiment wherein the switch **32** is placed across the capacitor **16**, thereby shorting out the capacitor **16** and preventing resonance.

FIGS. **7C** and **7D** show a third embodiment of a reversibly physically deactivatable tag **10** wherein the switch **32** is placed in the series loop of the resonant circuit **12**. When the switch **32** is open, no resonance occurs. The tags in FIGS. **7A** and **7C** are preferred over the tag in FIG. **6A** because there is less induced voltage impressed on the switch **32** in the tags of FIGS. **7A** and **7C** than in the tag in FIG. **6A**.

The electronic switch **32** may be any suitable device, such as a Field Effect Transistor (FET). Preferably, the switch **32** has a memory **34** so that the state of the switch **32** is maintained whether or not power is applied to the tag **10**. One example of such a switch **32** is an FET with a charge storage mechanism associated with its gate electrode, similar to that used in an EEPROM storage cell. The state of this switch may be changed using the same or modified versions of the equipment used to initially program the security tag information.

virtual deactivation—one or more of the tag status bits **206** are changed in the database **200**, but no change is made to the status bits in the tag **10** nor is any other change made to the tag **10**. The types of changes to the status bits **206** in the database **200** are the same as those described above with respect to the status bits in the tag **10**. One advantage of virtual deactivation is that it is not necessary to use deactivatable or reprogrammable tags **10**, or equipment to perform either function, in the EAS system.

FIG. **5** is a flowchart of the decision process for a deactivation event. If the deactivation event is electronic deactivation (YES output from step **106**), one or more of the tag status bits are changed in the tag **10** (step **107**), and, optionally, one or more of the tag status bits are changed in the database **200** (step **108**). If an article status field exists in the database **200**, the article status **210** is changed too (step **109**). If the deactivation event is a physical deactivation (YES output from step **110**), the tag **10** is physically disabled so that it does not respond to a predetermined interrogation signal (step **112**) and the article status **210** is changed in the database **200** (step **113**), if such a field exists. If the deactivation event is a virtual deactivation (YES output from step **114**), the status bits **206** associated with the tag **10** are changed in the database **200** (step **116**) and the article status **210** is also changed in the database **200** (step **117**), if such a field exists.

It may sometimes be desired to reactivate a reversibly physically deactivated tag **10**, or an electronically or virtually deactivated tag **10**. (A non-reversibly physically deactivated tag **10** cannot be reactivated.) Reactivation is achieved by reversing the deactivation process.

FIG. **8** is flowchart of the decision process for a reactivation event. If the reactivation event is a physical reactivation (YES output from step **118**), the circuitry in the tag **10** which receives, and responds to, an interrogation signal is re-enabled (step **120**), such as by changing the state of the electronic switch **32** back to its original state using suitable equipment, and the article status **210** is changed in the database **200** (step **121**), if such a field exists. If the reactivation event is an electronic reactivation (YES output from step **122**), the status bits in the tag **10** are changed back to their original state (step **123**), and the article status **210** in the database **200** is changed back to its original state (step **125**), if such a field exists. If the optional step **108** in FIG. **5** was performed during deactivation, then the status bits in the database **200** are changed back to their original state (step **124**). If the reactivation event is a virtual reactivation (YES output from step **126**), the status bits **206** associated with the tag **10** in the database **200** are changed back to their original state (step **128**), and the article status **210** in the database **200** is changed back to its original state (step **129**),

if such a field exists. If the article contains a physically deactivated tag **10** which cannot be reactivated, a new tag **10** may be attached to the article and a new entry would be made in the database **200** for the new tag **10**.

FIG. **9** is a flowchart of an exit interrogation/tag interrogation procedure useful for EAS systems which use electronic deactivation. FIG. **10** is a flowchart of an exit interrogation/tag interrogation procedure useful for EAS systems which use virtual deactivation. (If an EAS system uses physical deactivation, the tag **10** will not respond to an interrogation signal. Thus, the procedures in FIGS. **9** and **10** cannot be used for physically deactivated tags.) FIG. **11** is a schematic block diagram of the elements which perform the steps in FIGS. **9** and **10**.

Referring to FIGS. **9** and **11**, as the tagged article enters the detection zone, the article's tag **10** outputs a signal in response to an interrogation signal from the interrogator **22**. Next, the interrogator **22** outputs a signal which contains the tag information and sends it to a computer **36** which contains a comparator **37** (step **130**). The computer **36** extracts the serial number from the tag information or obtains the serial number from the interrogator output signal (step **132**). For this example, the identification information stored in the IC memory is referred to as the tag's "serial number." The computer **36** accesses the database **200** and, using the comparator **37**, searches through the database for a serial number **204** which matches the serial number of the interrogated tag **10** (step **134**). If no match is found, the computer **36** outputs a "no action" signal. If the EAS system operates in a retail environment, the likely explanation when no match occurs is that the tag **10** is similar in kind to those used by the store that the customer is exiting from, but belongs to an article associated with a different store, or different chain of stores. Thus, that particular tag **10** may exist in a different database than the one accessed for the particular store. The store can thus assume that the article is not being improperly removed therefrom. Of course, there is a possibility that the article belongs to the particular store, but that nobody entered it into the database **200** when it was received into inventory. The present system cannot detect such human errors. However, a log may be kept of tags **10** which are read, but not found in the database **200**, so that errors like this can be tracked if other inventory control procedures detect shortfalls at a later date.

Still referring to FIGS. **9** and **11**, if the serial number is found in the database **200**, the computer **36** extracts the status bits from the read tag **10** (step **138**), and uses the status bits to decide whether the article may be removed from the premises (in the case of a retail article or borrowed article) or accessed (in the case of an on-site use) (step **140**). This step is performed by comparing the read status bits to a predefined table of status bits maintained in a separate portion of the database **200**, or in a separate memory (not shown). A sample table for a two bit status code in a retail environment may be as follows:

00—SOLD
01—UNSOLD
10—RETURNED
11—RESOLD

A sample table for a one bit status code in a library or rental environment may be as follows:

0—CHECKED IN or REMOVAL PERMITTED
1—CHECKED OUT or REMOVAL NOT PERMITTED

If removal or accessing is permitted, a "no action" signal is output by the computer **36** (step **136**). For example, if the status bits in the read tag **10** indicate that a retail article was sold (code=00), the customer is free to exit the store with the article. Likewise, if the status bits in the read tag **10** indicate that a videotape was properly checked out by a renter (code=1), the customer is free to exit the store with the videotape. If removal or accessing is not permitted, as in the case of an unsold article (code=01) or an article which is not properly checked out (code=0), an "action" signal is output from the computer **36** (step **142**). The "action" signal may trigger an alarm which is audible or visible to either a customer or employee. Alternatively, or in addition to an alarm, other action may be taken, such as capturing an image of the detection zone.

The flowchart in FIG. **10** is used for EAS systems which rely upon virtual deactivation of tags **10**. Referring to FIG. **10**, the first four steps of reading tag information, extracting a serial number therefrom, matching the serial number to a serial number in the database **200**, and outputting a "no action" signal if no match is found (steps **144**, **146**, **148**, **150**, are identical to steps **130**, **132**, **134**, **136**, respectively, of FIG. **9**. The remaining steps in FIG. **10** differ from those in FIG. **9**. If the serial number is located in the database **200**, the status bits **206** of the associated serial number are retrieved from the database **200** (step **152**). The status bits **206** are compared to a predefined table of status bits to determine whether the article may be removed from the premises or whether access to the article is permitted (step **154**). Step **154** is thus similar to step **140** in FIG. **9**, except that the status bits examined in FIG. **10** are the status bits **206** in the database **200**, whereas the status bits examined in FIG. **9** are the status bits in the tag **10**. The remaining step in FIG. **10** of outputting either a "no action" or "action" signal depending upon the result of the comparison (step **156**) is the same as step **142** of FIG. **9**.

FIGS. **12–15** illustrate a second embodiment of the present invention. The second embodiment differs from the first embodiment in one significant way. In the first embodiment, the serial number and status bits are read out of the tag **10** and are processed as separate pieces of information. In the second embodiment, there are no separate status bits. Instead, a portion of the serial number is used to perform some of the functions performed by the status bits of the first embodiment, and the article status field is used to perform other functions.

FIG. **12** is a flowchart of the steps for initiating a second embodiment of the present invention, and FIG. **13** is a sample database created for use with the second embodiment. Referring to FIG. **12**, a predefined set of tags **10** are prepared to be applied to a predefined set of articles (not shown), unique tag information is assigned to each tag **10** and the tags are programmed accordingly (step **200**). Next, a database is established for the set of tags **10** (step **202**). Lastly, the tags **10** are attached directly to each article or to the packaging of each article (step **204**). In the disclosed embodiment, one tag **10** is associated with each article. The steps in FIG. **12** may be performed in any order.

FIG. **13** shows a sample database **400** established in step **202** of FIG. **12**. Each record in the database **400** includes a field for tag information **402** comprising a tag serial number **404**. The serial number **404** includes a variable or changeable portion **406** of one or more bits and a fixed portion **408** of a plurality of bits. Each record in the database **400** may optionally includes a field for other information **410** pertaining to the record, such as article status **412** and article identification information **414**. The tag serial number **404** is stored in the tag **10**. Optionally, some or all of the other information **408** is also stored in the tag **10**. Preferably, each serial number **404** is unique. In this manner, there is no

chance that a tag used by the same or another entity (e.g., another chain of stores) can be confused with one another.

The article status **412** and article identification information **414** are the same as in the first embodiment of the invention.

Once all of the articles are tagged and the database **400** is established, the articles are made accessible to customers or patrons within predefined surroundings. The predefined surroundings have one or more exits with detection zones monitored by the interrogator **22** in the same manner as in the first embodiment.

When legitimate access is obtained to an article having a tag associated therewith, the article is deactivated before it can be removed from the predefined surroundings. FIG. **14** is a flowchart showing the various options associated with this deactivation event. As in the first embodiment, deactivation may be either "electronic," "physical," or "virtual." Physical deactivation in the second embodiment is the same as physical deactivation in the first embodiment. However, electronic and virtual deactivation in the second embodiment differ from the first embodiment in some respects, as described below:

electronic deactivation—the serial number in the tag **10** is electronically changed or reprogrammed. Also, the article status **412** is changed in the database **400** (step **209**), if such a field exists. The new serial number in the tag **10** is a number which is not in the database **400**, and which preferably is not in any other databases of tags **10** of similar construction. The serial number in the tag **10** is changed by altering the changeable portion thereof. For example, in the retail environment example described above, an initial serial number of 01234567 would be changed to 00234567 upon sale of the tagged article. The electronic change can take place at the cash register or at a merchandise pick-up area. If the article is subsequently returned by the customer, the store would either change the serial number to 10234567 until the article is further processed, or would change the serial number back to 01234567 if the article is immediately reshelved for subsequent purchase.

physical deactivation—same as physical deactivation in the first embodiment (steps **210**, **212**, **213** of FIG. **14**).

virtual deactivation—the changeable portion **406** of the tag serial number **404** is changed in the database **400**, but no change is made to any part of the serial number in the tag **10** (steps **214**, **216**). Also, the article status **412** is changed in the database **400** (step **217**), if such a field exists.

Tags **10** tray also be reactivated in the second embodiment of the invention by reversing the steps performed during deactivation. The decision process for a reactivation event is similar to the decision process of the first embodiment shown in FIG. **8**, except for the previously highlighted differences regarding how tag information is changed.

FIG. **15** is a flowchart of an exit interrogation/tag interrogation procedure useful for EAS systems which use electronic or virtual deactivation in accordance with the second embodiment of the invention. (As noted above, if an EAS system uses physical deactivation, the tag **10** will not respond to an interrogation signal. Thus, the procedures in FIG. **15** cannot be used for deactivated tags.) The interrogator **22** of the schematic block diagram in FIG. **11** is also used to perform the steps in FIG. **15**.

Referring to FIGS. **11** and **15**, as the tagged article enters the detection zone, the article's tag **10** outputs a signal in response to an interrogation signal from the interrogator **22**. Next, the interrogator **22** outputs a signal which contains the tag information, and sends it to a computer **36** (step **230**). The computer **36** extracts the tag's serial number from the tag information (step **232**). The computer **36** accesses the database **400** and searches through the database for a serial number **404** which matches the serial number of the interrogated tag **10** (step **234**). If no match is found, the computer **36** outputs a "no action" signal (step **236**).

If the EAS system operates in a retail environment and uses electronic deactivation, the most likely explanations when no match occurs are:

(a) the tag **10** belongs to an article purchased at the present store, but the serial number in the tag **10** was electronically altered upon purchase of the article; or

(b) the tag **10** is similar in kind to those used by the store that the customer is exiting from, but belongs to an article associated with a different store, or different chain of stores. Thus, that particular tag **10** may exist in a different database than the one accessed for the particular store.

In both instances, the store can assume that the article is not being improperly removed. As discussed in the first embodiment of the invention, there is a possibility that the article belongs to the particular store, but that nobody entered it into the database **400** when it was received into inventory. The present system cannot detect such human errors. However, a log may be kept of tags **10** which are read, but not found in the database **400**, so that errors like this can be tracked if other inventory control procedures detect shortfalls at a later date.

Still referring to FIGS. **11** and **15**, if the serial number is found in the database **400**, the computer **36** outputs an "action" signal (step **238**). The "action" signal may trigger an alarm which is audible or visible to either a customer or employee. Alternatively, or in addition to an alarm, other action may be taken, such as capturing an image of the detection zone. The most likely explanations for when a read serial number matches a serial number in the database **400** are as follows:

(a) a customer or patron is improperly attempting to remove an article from the premises; or

(b) an employee did not properly electronically deactivate the tag **10** of the article.

In either instance, the "action" signal alerts the appropriate person to investigate the matter further.

The flowchart in FIG. **15** may also be used for EAS systems which rely upon virtual deactivation of tags **10**. If the EAS system operates in a retail environment and uses virtual deactivation, the most likely explanations when no match occurs are:

(a) the tag **10** belongs to an article purchased at the present store, but the serial number **404** of the tag **10** in the database **400** was changed upon purchase of the article; or

(b) the tag **10** is similar in kind to those used by the store that the customer is exiting from, but belongs to an article associated with a different store, or different chain of stores. Thus, that particular tag **10** may exist in a different database than the one accessed for the particular store.

In both instances, the store can assume that the article is not being improperly removed.

The most likely explanations for a read serial number to match a serial number in the database **400** are as follows:

(a) a customer or patron is improperly attempting to remove an article from the premises; or

(b) an employee did not properly virtually deactivate the tag **10** of the article (i.e., the employee did not change the serial number **404** in the database **400** upon purchase of the article.)

In either instance, the "action" signal alerts the appropriate person to investigate the matter further.

The main difference between the electronic and virtual deactivation schemes is that the electronic deactivation

scheme requires the use of equipment which can electronically alter the serial number in the tag, whereas the virtual deactivation scheme requires only that the serial number **404** in the database **400** be changed. Once the tagged article is read, the virtual deactivation scheme may thus be executed entirely in software.

An alternative version of the electronic deactivation scheme in the second embodiment of the invention is to change the article status **412** in the database upon an appropriate event (e.g., purchase of a tagged article), as well as the serial number **404** in the database. The serial number **404** is changed by altering the changeable portion **406** in the same manner as the security tag **10**. In this alternative embodiment, all interrogated security tags **10** which are originally logged into the database **400** will match during the interrogation scheme. An additional step would then be required to examine the article status **412** to determine whether removal is permitted. In this alternative embodiment, the only tags **10** which will not cause a match are those which belong to other stores, or chains of stores, and which are thus not present in the database **400** of the present store or chain of stores.

An alternative version of the virtual deactivation scheme in the second embodiment of the invention is to change the article status **412** in the database **400** upon an appropriate event (e.g., purchase of a tagged article), instead of changing the serial number **404** in the database **400**. In this alternative embodiment, all interrogated tags **10** which are originally logged into the database **400** will match during the exit interrogation scheme. An additional step would then be required to examine the article status **412** to determine whether removal is permitted. In this alternative embodiment, the only tags **10** which will not cause a match are those which belong to other stores, or chains of stores, and which are thus not present in the database **400** of the present store or chain of stores.

In both embodiments of the invention, a common coding bit scheme should be adopted by all users of the same type of tag **10** to avoid conflicts among different databases. For example, the scheme in FIG. **4** allows for changes to be made to the status bits, whereas the tag identification information (e.g., serial number) is permanently fixed. Likewise, the scheme of FIG. **13** allows for changes to be made to the first two digits of the serial number, whereas the remaining six digits are permanently fixed. Thus, in the scheme of FIG. **4**, the tag identification information of all tags **10** should be unique, and in the scheme of FIG. **13**, the last six digits of all tag serial numbers should be unique. If these rules are followed, no conflicts will arise between EAS systems of different entities. For example, if a customer walks out of a SEARS store with a properly deactivated tagged article, carries the tagged article into neighboring stores that use the same EAS system as the SEARS store, and exits the neighboring stores carrying the tagged article purchased at SEARS, the databases in the neighboring stores will not contain any serial numbers that match the SEARS article. Accordingly, none of the computers in the neighboring stores will output an "action" signal upon detection of the article in their interrogation zones.

An eight bit serial number is used to illustrate the principles of the present invention. In a practical commercialized system, the total number of bits will be much greater than eight to allow for a large number of articles from a plurality of entities (e.g., individual stores, chains of stores, libraries, etc.) to be uniquely tagged. For example, the IC **18** stores 20 bits of data.

FIG. **16** is a schematic block diagram of a large-scale application of the present invention which allows plural entities to detect unauthorized removal or access of articles from any of each other's premises. For example, a large shopping complex may have hundreds of individual stores, each of which use the same EAS system and the same type of tag **10**. If a shoplifter successfully defeats the EAS system of one store by somehow removing a tagged, non-deactivated article from the store, the shoplifter may freely walk into and out of other stores carrying the stolen article without triggering an alarm at the interrogators of the other stores. While the interrogators of the other stores will detect the stolen tagged article, the article will not trigger an alarm because it does not appear in the database of the other stores. In the system of FIG. **16**, each store has an interrogator $\mathbf{500}_1$, $\mathbf{500}_2$, . . . , $\mathbf{500}_n$, and a database $\mathbf{502}_1$, $\mathbf{502}_2$, . . . , $\mathbf{502}_n$, of articles in its inventory. Each of the interrogators $\mathbf{500}_1$, $\mathbf{500}_2$, . . . , $\mathbf{500}_n$ and the databases $\mathbf{502}_1$, $\mathbf{502}_2$, . . . , $\mathbf{502}_n$ are connected to a central computer **504**. Whenever a tagged article is detected, the central computer **504** checks all of the databases to determine whether the article has been properly removed from wherever it originated. If a stolen article is detected, appropriate action may then be taken by security personnel affiliated with the shopping complex and the victimized store. The interrogators and the databases of the individual stores communicate with the computer **504** by any suitable wired or wireless electronic means.

Referring to FIGS. **11** and **16**, the signal output from the interrogator **22** (i.e., the tag information) contains the serial number. As described above, the computers in these figures extract the serial number from the tag information and interact with respective databases. Serial number "extraction" may be required if the interrogator output includes other information, or if the tag information includes other information that is passed to the interrogator output. However, it should be understood that the serial number need not necessarily be "extracted from" the interrogator output since the interrogator output may provide only the serial number, or the interrogator itself may extract the serial number from the tag information. If this is the case, the computer merely transfers the serial number directly from its input to a database query.

FIG. **17** is a flowchart of an exit interrogation/tag interrogation procedure useful for EAS systems which use electronic deactivation in accordance with a third embodiment of the present invention. This embodiment of the invention does not require accessing a database to obtain the article status information. Instead, the interrogator extracts or detects the electronically alterable portion of the tag information and determines an appropriate response therefrom.

Referring to FIG. **17**, the interrogator **22** reads the tag information **202** or **402** (step **300**). Next, the interrogator **22** extracts the status bit(s) **206** from the tag information **202** or extracts the bits of the changeable portion **406** from the tag information **402** (step **302**). The status bit(s) **206** or the bits of the changeable portion **406** are examined and a determination is made as to whether the tagged article may be removed or accessed (step **304**). This step is similar to step **140** of FIG. **9**. If the output of the decision block in step **304** is YES, then a "no action" signal is output by the interrogator **22** (step **306**). If the output of the decision block in step **304** is NO, then an "action" signal is output by the interrogator **22** (step **308**). Thus, steps **306** and **308** are similar to steps **136** and **142** of FIG. **9**. The "action" signal may trigger an alarm which is audible or visible to either a customer or employee. Alternatively, or in addition to an alarm, other action may be taken, such as capturing an image of the detection zone.]

The scheme in FIG. **17** is simpler than the scheme in FIG. **9** which requires accessing a database. The scheme in FIG.

9 includes a precheck of the serial number in the database to determine whether the status of the tagged article needs to be examined any further (see step **134**). However, as noted above, there is a possibility that the tagged article belongs to the particular store or entity, but that nobody entered it into the database when it was received into inventory. The scheme in FIG. **9** may log this event, but will not further examine the status bits to determine if the tagged article may be removed or accessed. In contrast, since there is no such precheck in the scheme of FIG. **17**, the status of all tagged articles will be checked, including articles which were not properly inventoried, as well as articles from other stores or entities which use tags of the same type and resonant frequency.

The tag status bit(s) **206** and the changeable portion **406** of the tag serial number **404** may be located at any position within the tag information. The locations shown in respective FIGS. **4** and **13** need not match the actual location within the tag.

One advantage of virtual deactivation is that access to the tagged article is not required to perform the deactivation. That is, the article need not be physically present. It is only necessary to obtain valid access to the database to virtually deactivate the tag.

Virtual deactivation may be used for removal of tagged articles from a secure area, wherein like tagged articles have the same serial number, and the tagged articles are carried out of a secure area past an interrogator. Consider a secure area such as a store, tool cage, repair shop, or the like. A customer or worker enters the secure area to select a plurality of articles for removal, such as a plurality of merchandise items to be purchased, or a plurality of tools required for performing a repair task. A computer is used to enter the plurality of articles, either individually, or by a job or lot number, and the computer keeps a record of the entered articles. For example, one job or lot number may represent a plurality of articles required for a particular repair task. The tag database is updated to virtually deactivate the plurality of articles. The customer or worker may now walk through the interrogation zone carrying all of the articles without triggering an alarm. After the customer or worker exits the secure area, the virtually deactivated articles are reactivated so that the next user cannot exit with the same articles unless that user also has them entered into the computer. One advantage of this scheme is that since identical articles are provided with an identical tag, the time and expense associated with tagging articles is reduced.

Virtual and electronic deactivation may also be used to set up multi-level complex security states which provide different types of alarms depending on information obtained from plural databases. Thus, the decision to trigger an alarm need not be simply "yes" or "no." Likewise, different types of alarms may be triggered depending upon database information.

Consider a secure area which has a plurality of different zones, such as a sports stadium. A tagged article, or a person carrying a tagged badge may be permitted to enter only specific zones based on information stored in the database. To carry out such an embodiment, the interrogators which monitor each zone must provide location information to the database along with the tag information (e.g., "I am an interrogator for women's locker room2. Is serial number 12345678 permitted access to this room?"). The database or databases in such a system will have more fields than those shown in FIGS. **4** and **13** to accommodate the additional information. Furthermore, if access is not permitted, there may not necessarily be a visual or audible alarm at the entrance to the zone. Instead, the database may be programmed to send out a silent alarm to a monitoring station, or to remotely notify a predetermined party that a particular article or person is now in a restricted zone. Additional databases may be linked to the tag database to provide such auxiliary functions.

A system which uses virtual deactivation provides significant advantages over prior art resonant tag systems. For example, virtual deactivation minimizes false alarms because only verified serial numbers trigger an alarm. Environmental resonances and RF devices may interfere with tag readings, but cannot generate the sequences needed to create a bona fide serial number at the interrogator. Thus, unless a human error has been made in the database, false alarms will be rare. Since false alarms are minimized, the RFID tags may be permanently embedded in products, rather than being removably affixed to the article or its packaging. This saves time and effort by store personnel and improves overall security.

Furthermore, if the RFID tag is used for article sensing, such as at a point-of-sale terminal, virtual deactivation may be automatically performed by sending an output signal from the article sensor/reader to the tag database. Also, as noted above, the RFID tag need not be read or sensed to perform deactivation. Thus, the status of articles in inventory, or the like, may be altered without requiring physical access to the articles.

It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular embodiments disclosed, but it is intended to cover modifications within the spirit and scope of the present invention as defined by the appended claims.

We claim:

1. An electronic security system comprising:

(a) a predefined set of passive radio frequency identification tags, each tag being associated with, and attached to, an article or packaging for an article, each tag including:

(i) an antenna for detecting the presence of the article by receiving an interrogation signal and returning a response signal, and

(ii) an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag, the tag being programmed with unique tag information so that no two tags within the predefined set of passive tags have exactly the same tag information;

(b) an interrogator for monitoring a detection zone for detecting disturbances in the form of a response signal caused by the presence of a tag within the zone, the interrogator outputting an interrogator output signal when a tag is detected in the zone, each interrogator output signal including the tag information stored in the integrated circuit;

(c) a computerized database containing a record for each of the tags in the set, each record including the tag information;

(d) a computer including a comparator for receiving the database records and the tag information from the interrogator and comparing the tag information to the database records, and outputting an appropriate response,

wherein a portion of the tag information in the database is variable information which is changed in the database

without any physical or electronic altering of the tag or the tag information stored in the integrated circuit, the change in the database thereby causing a virtual deactivation of the tag.

2. A system according to claim **1** wherein the variable information is one or more status bits which indicate the status of the tagged article.

3. A system according to claim **1** wherein the tag information comprises a tag serial number and the variable information is a changeable portion of the serial number.

4. A system according to claim **1** wherein each database record includes article identification information.

5. A system according to claim **1** wherein the response output from the comparator includes the following responses:

(i) a response indicating that legitimate access to the article is permitted, or

(ii) a response indicating that legitimate access to the article is not permitted, or

(iii) a response that no article having the detected tag information exists in the database.

6. A system according to claim **1** wherein the tag information indicates that the article associated with the tag is either sold or unsold, or checked in or checked out.

7. A system according to claim **1** wherein the tag information indicates whether or not the article associated with the tag may be removed from a facility.

8. An electronic security system comprising:

(a) a predefined set of passive radio frequency identification tags, each tag being associated with, and attached to, an article or packaging for an article, each tag including:

(i) an antenna for detecting the presence of the article by receiving an interrogation signal and returning a response signal, and

(ii) an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag, the tag being programmed with unique tag information so that no two tags within the predefined set of passive tags have exactly the same tag information;

(b) an interrogator for monitoring a detection zone for detecting disturbances in the form of a response signal caused by the presence of a tag within the zone, the interrogator outputting an interrogator output signal when a tag is detected in the zone, each interrogator output signal including the tag information stored in the integrated circuit;

(c) a computerized database containing a record for each of the tags in the set, each record including the tag information;

d) a computer including a comparator for receiving the database records and the tag information from the interrogator and comparing the tag information to the database records, and outputting an appropriate response,

wherein each record in the database further includes changeable article status information, and wherein virtual deactivation of a tag is performed by changing the article status in the database, but not physically or electronically altering the tag or the tag information stored in the integrated circuit.

9. A method of using a predefined set of passive radio frequency identification tags in an electronic security system, each tag being associated with, and attached to, an article or packaging for an article, each tag including (i) an antenna for detecting the presence of the article by receiving an interrogation signal and returning a response signal, and (ii) an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag, the method comprising the steps of:

(a) programming each of the tags with unique tag information so that no two tags within the predefined set of passive tags have exactly the same tag information;

(b) establishing a computerized database containing a record for each of the tags in the set, each record including the tag information;

(c) monitoring a detection zone with an interrogator for detecting disturbances in the form of a response signal caused by the presence of a tag within the zone, the interrogator outputting an interrogator output signal when a tag is detected in the zone, each interrogator output signal including the tag information stored in the integrated circuit;

(d) comparing the database records to the tag information, and outputting an appropriate database response; and

(e) performing a deactivation event on a tag when obtaining legitimate access to the article having the tag associated therewith, wherein the step of performing a deactivation event includes virtually deactivating the tag by changing at least a portion of the tag information in the database, but not physically or electronically altering the tag or the tag information stored in the integrated circuit.

10. A method according to claim **9** further comprising the step of:

(f) virtually reactivating a tag which was previously virtually deactivated by changing the portion of the tag information in the database which was changed for virtual deactivation to recreate the original tag information stored in the database, but not physically or electronically altering the tag or the tag information stored in the integrated circuit.

11. A method according to claim **9** wherein step (b) includes providing each database record with article identification information.

12. A method according to claim **9** wherein the database response includes one of the following responses:

(i) a response indicating that legitimate access to the article is permitted, or

(ii) a response indicating that legitimate access to the article is not permitted, or

(iii) a response that no article having the detected tag information exists in the database.

13. A method according to claim **9** wherein the tag information indicates that the article associated with the tag is sold or unsold.

14. A method according to claim **9** wherein the tag information indicates that the article associated with the tag has been checked in or checked out.

15. A method according to claim **9** wherein the tag information indicates whether or not the article associated with the tag may be removed from a facility.

16. A method of using a predefined set of passive radio frequency identification tags in an electronic security system, each tag being associated with, and attached to, an article or packaging for an article, each tag including (i) an antenna for detecting the presence of the article by receiving an interrogation signal and returning a response signal, and (ii) an integrated circuit connected to the antenna for storing

tag information and for outputting the tag information with the response signal upon interrogation of the tag, the method comprising the steps of:

(a) programming each of the tags with unique tag information so that no two tags within the predefined set of passive tags have exactly the same tag information;

(b) establishing a computerized database containing a record for each of the tags in the set, each record including the tag information;

(c) monitoring a detection zone with an interrogator for detecting disturbances in the form of a response signal caused by the presence of a tag within the zone, the interrogator outputting an interrogator output signal when a tag is detected in the zone, each interrogator output signal including the tag information stored in the integrated circuit;

(d) comparing the database records to the tag information, and outputting an appropriate database response; and

(e) performing a deactivation event on a tag when obtaining legitimate access to the article having the tag associated therewith, wherein each record in the database further includes article status information, and the step of performing a deactivation event includes virtually deactivating the tag by changing the article status in the database, but not physically or electronically altering the tag or the tag information stored in the integrated circuit.

17. A method according to claim **16** further comprising the step of:

(f) virtually reactivating a tag which was previously virtually deactivated by changing the article status information in the database which was changed for virtual deactivation to recreate the original article status information stored in the database, but not physically or electronically altering the tag or the tag information stored in the integrated circuit.

18. A method of using a predefined set of passive radio frequency identification tags in an electronic security system, each tag being associated with, and attached to, an article or packaging for an article, each tag including (i) an antenna for detecting the presence of the article by receiving an interrogation signal and returning a response signal, and (ii) an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag, the method comprising the steps of:

(a) programming each of the tags with unique tag information so that no two tags within the predefined set of passive tags have exactly the same tag information, wherein the tags are programmed with unique tag information including a tag serial number having a changeable portion and a fixed portion;

(b) establishing a computerized database containing a record for each of the tags in the set, each record including the tag information;

(c) monitoring a detection zone with an interrogator for detecting disturbances in the form of a response signal caused by the presence of a tag within the zone, the interrogator outputting an interrogator output signal when a tag is detected in the zone, each interrogator output signal including the tag information stored in the integrated circuit;

(d) comparing the database records to the tag information, and outputting an appropriate database response; and

(e) virtually deactivating the tag when obtaining legitimate access to the article having the tag associated therewith by changing the changeable portion of the serial number in the database, but not physically or electronically altering the tag or the tag serial number stored in the integrated circuit.

19. A method of using a predefined set of passive radio frequency identification tags in an electronic security system, each tag being associated with, and attached to, an article or packaging for an article, each tag including (i) an antenna for detecting the presence of the article by receiving an interrogation signal and returning a response signal, and (ii) an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag, the method comprising the steps of:

(a) programming each of the tags with unique tag information so that no two tags within the predefined set of passive tags have exactly the same tag information, wherein the tags are programmed with unique tag information including a tag serial number and one or more status bits representing the status of the article having the tag associated therewith;

(b) establishing a computerized database containing a record for each of the tags in the set, each record including the tag information;

(c) monitoring a detection zone with an interrogator for detecting disturbances in the form of a response signal caused by the presence of a tag within the zone, the interrogator outputting an interrogator output signal when a tag is detected in the zone, each interrogator output signal including the tag information stored in the integrated circuit;

(d) comparing the database records to the tag information, and outputting an appropriate database response; and

(e) virtually deactivating the tag when obtaining legitimate access to the article having the tag associated therewith by changing one or more of the status bits in the database, but not physically or electronically altering the tag, the tag serial number, or the status bits stored in the integrated circuit.

20. An electronic security system for a plurality of entities, each tag being associated with, and attached to, an article or packaging for an article associated with one of the entities, the system comprising:

(a) a predefined set of passive radio frequency identification tags, each tag including:

(i) an antenna for detecting the presence of the article by receiving an interrogation signal and returning a response signal, and

(ii) an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag, each tag being programmed with unique tag information so that no two tags within the predefined set of passive tags have exactly the same tag information;

(b) a plurality of interrogators, each interrogator monitoring a detection zone of one of the entities for detecting disturbances in the form of a response signal caused by the presence of a tag within the zone, the interrogator outputting an interrogator output signal when a tag is detected in the zone, each interrogator output signal including the tag information stored in the integrated circuit;

(c) a computerized database containing a record for each of the tags in the set, each record including the tag information; and

(d) a computer including a comparator for receiving the database records and the tag information from the plurality of interrogators and comparing the tag information to the database records, and outputting an appropriate response, wherein a portion of the tag information in the database is variable information which is changed in the database without any physical or electronic altering of the tag or the tag information stored in the integrated circuit, the change in the database thereby causing a virtual deactivation of the tag.

21. A system according to claim **20**, wherein the computerized database includes a plurality of individual databases, each database storing records for tags associated with articles for a respective entity.

22. A radio frequency identification tag comprising:

(a) an antenna for receiving an interrogation signal and returning a response signal; and

(b) an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag, wherein the tag includes at least one circuit element that has a physically activated state which allows the tag to return a response signal, and a physically deactivated state which prevents the tag from returning a response signal, wherein the tag has a resonant circuit for receiving the interrogation signal and returning the response signal, wherein the integrated circuit is connected to the resonant circuit and the antenna is part of the resonant circuit, the resonant circuit of each tag including a capacitor connected in series with the antenna, the at least one circuit element being a reversible switch connected across either the capacitor or antenna, the activated and deactivated states depending upon the position of the reversible switch, the tag being physically deactivated by opening the reversible switch thereby preventing operation of the resonant circuit, and wherein the reversible switch is a field effect transistor having a charge storage mechanism associated with its gate electrode.

23. A radio frequency identification tag comprising:

(a) an antenna for receiving an interrogation signal and returning a response signal; and

(b) an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag, wherein the tag includes at lease one circuit element that has a physically activated state which allows the tag to return a response signal, and a physically deactivated state which prevents the tag from returning a response signal, wherein the tag has a resonant circuit for receiving the interrogation signal and returning the response signal, wherein the tag has a resonant circuit for receiving the interrogation signal and returning the response signal, wherein the integrated circuit is connected to the resonant circuit and the antenna is part of the resonant circuit, the resonant circuit of each tag including a capacitor connected in series with the antenna, the at least one circuit element being a reversible switch connected between the integrated circuit and the antenna, the activated and deactivated states depending upon the position of the reversible switch, the tag being physically deactivated by opening the reversible switch, thereby disconnecting the antenna from the integrated circuit, and wherein the reversible switch is a field effect transistor having a charge storage mechanism associated with its gate electrode.

24. A radio frequency identification tag comprising:

(a) an antenna for receiving an interrogation signal and returning a response signal; and

(b) an integrated circuit connected to the antenna for storing tag information and for outputting the tag information with the response signal upon interrogation of the tag, wherein the tag includes at least one circuit element that has a physically activated state which allows the tag to return a response signal, and a physically deactivated state which prevents the tag from returning a response signal, wherein the tag has a resonant circuit for receiving the interrogation signal and returning the response signal, wherein the tag has a resonant circuit for receiving the interrogation signal and returning the response signal, wherein the integrated circuit is connected to the resonant circuit and the antenna is part of the resonant circuit, the resonant circuit of each tag including a capacitor connected in series with the antenna, the at least one circuit element being a reversible switch connected in series with the capacitor and the antenna, the activated and deactivated states depending upon the position of the reversible switch, the tag being physically deactivated by opening the reversible switch, thereby disabling the resonant circuit, wherein the reversible switch is a field effect transistor having a charge storage mechanism associated with its gate electrode.

* * * * *