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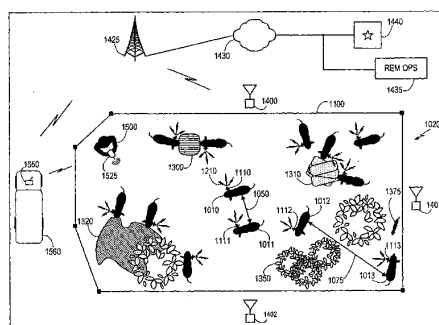


FIG. 1

(57) Abstract: An RF intelligent active tag and an RF tag reader system with an intelligent active tag is attached to a monitored subject, and an intelligent RF transponder, with sensor, and energy harvesting modules, and which exchanges a tag message using a selected communication technique. The processing module stores selected subject data pertaining to the monitored subject, and the intelligent active tag communicates by exchanging a tag message with a remote transceiver. The tag reader system includes an interrogator coupled to a host. The interrogator includes a transceiver exchanging a tag message with an active tag, using a selected communication technique. The interrogator can exchange subject data with an active tag, or may transmit a command to the active tag. The host can provide perceptible representations of subject data, and can communicate with a remote transceiver. Tag reader protocol methods and an active tag operation method are provided.

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**SUBJECT MANAGEMENT SYSTEM USING INTELLIGENT ACTIVE RF TAG AND TAG
READER SYSTEM, AND METHODS THEREFOR**

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CROSS-REFERENCE TO RELATED APPLICATION

- 10 [0001] This application is related to, and claims the benefit of, co-pending International Patent Application No. PCT/US 07/63332, filed 5 March 2007, which itself is related to, and claims the benefit of, co-pending Provisional Application No. 60/779,053, filed March 3, 2006, under 35 U.S.C. §119(e), the disclosures of both are incorporated herein by reference in their entireties.

BACKGROUND

15 1. TECHNICAL FIELD

[0002] This invention relates generally to asset monitoring systems. More specifically, the invention relates to a livestock management system, including an active RF tag and corresponding interrogator, configured to infer a monitored subject state from a sensed physical quantity of a monitored subject, relative to a monitored subject group.

20 2. DESCRIPTION OF RELATED ART

[0003] Livestock production can be a resource-intensive and, therefore, costly enterprise. The emergence of an asset loss point at any point in the supply chain can be deleterious to the well-being of individuals and the group, and may diminish a producer's efficiency, competitive advantage, and profitability. Livestock represent a class of high-value, high-risk assets that are managed and tracked over a geographically dispersed supply chain, extending from breeder to consumer. Livestock, such as cattle, typically are bred and raised in relatively open environments, where natural forces, predators, disease, injury, and theft represent loss points, which can impair robust production and may inflict significant losses. Livestock also represents a valuable food reserve, subject to global security risks, and to compliance mandates by government, industry groups, sellers, and consumers. Livestock tend to be a group of subject assets respectively manifesting social behavior, whether individually, as a social subgroup group, or as a social group. Recently, it has become desirable to trace the lineage, location, and condition of individual social group members, from birth to slaughter, with the objectives of identifying animals exposed to certain conditions and diseases, of determining the source of exposure, of improving the genetic traits, and thus profitability, of selected breeds, and of facilitating secure food production.

[0004] Typically, livestock stewards monitor the well-being of livestock herds and individual herd members by direct observation, in an open range, a corral, feedlot, or a production facility.

However, a typical herd may have hundreds of members dispersed over a relatively large geographic region, making accurate observations of individual herd members difficult, at best. Also, constituent members of a herd may become distressed by the advance of, and proximity to, social group stewards and other human handlers. Thus, it may be difficult to ascertain the presence, the identity, and the physical state of every herd member. In many circumstances, livestock separated from their social group, for example, by wandering, injury, disease, or theft, may not be noticed in time for recovery, treatment, or culling. For some infectious diseases or other conditions, such delays may result in extensive loss of life or substantial reductions in both the well-being of the social group and the profitability of the livestock producer. Biological and behavioral indicators can herald the emergence of an asset loss point, which may adversely affect one or more herd members, or an entire herd, creating consequences that may propagate through the supply chain.

[0005] Present systems and methods may not provide timely information about a high-value, high-risk livestock asset group and its constituent herd members, in a manner consistent with efficient, traceable livestock production.

15

SUMMARY

[0006] The present disclosure provides a subject management system, an intelligent active RF tag, an intelligent active transponder, an interrogator, and methods therefor. In one embodiment, an active tag for attaching to a monitored subject is provided, including a tag housing; a substrate having a conductive portion within the tag housing; a configurable transponder having transponder electrical circuitry coupled to the conductive portion; and an activation circuit coupled to the conductive portion. The tag housing encloses the substrate, the configurable transponder and the activation circuit. The transponder includes at least one transceiver configured to communicate a tag message using at least one selected communication technique. The activation circuit is configured to provide electrical power to a portion of the transponder electrical circuitry in self-activating response to the tag housing being attached to the monitored subject. The tag message is one of an outbound tag message transmitted by the transceiver or an inbound tag message received by the transceiver.

[0007] An active tag embodiment may include a configurable sensor sensingly coupled between the monitored subject and the transceiver. The sensor is configured to sense a selected sensed physical quantity pertaining to the monitored subject, and a selected sensed physical quantity representation is included in the tag signal. In embodiments, an antenna is coupled to the at least one transceiver and is configured to communicate the tag message on a selected frequency band, corresponding to at least one selected communication technique. Other embodiments include a managed power source coupled to the conductive portion and the activation circuit, and configured to selectively supply electrical power to the transponder electrical circuitry after activation by the activation circuit. Yet other embodiments include plural sensors sensingly coupled between the monitored subject and the transceiver. A first sensor includes a position sensor that produces a sensed position parameter

pertaining to the monitored subject. A second sensor includes a biological parameter pertaining to the monitored subject. The tag message includes the sensed position parameter, the sensed biological parameter, or both. In still other embodiments, the active tag includes two or more transponders coupled to the conductive portion of the substrate, and each of the transponders includes at least one transceiver
5 respectively configured to communicate a tag message using a respective selected communication technique. In other tag embodiments having a managed power source, the managed power source includes an energy harvesting module configured to convert ambient energy into recovered electrical energy. Selected active tag embodiments include a transponder having an operations mode manager coupled to at least one transceiver, to at least one of the sensors, and to the managed power source.
10 Such selected active tag embodiments are configured to select a predetermined operational state for the transponder, to select a predetermined transponder operation to be performed in the predetermined operational state, or both. Also, a predetermined transponder operation includes at least one predetermined communication operation, at least one predetermined sensing operation, or at least one predetermined power management operation, or a combination of at least two of a predetermined
15 communication operation, a predetermined sensing operation, or a predetermined power management operation. The predetermined operational mode is one of a predetermined transponder demand operational mode, a predetermined interrogator demand operational mode, or a predetermined periodic operational mode, or a predetermined combination operational mode. The operations mode manager configures the transponder to communicate an outbound tag message in response to the sensed position
20 parameter, the sensed biological parameter, or both, or selectively reconfigures the transponder from a first predetermined operational mode to a second predetermined operational mode responsive to an inbound tag message.

[0008] Also provided are embodiments of a transponder attachable to a monitored subject, which includes an RF module configured to exchange a message with an interrogator over two or more
25 selected communication ranges, using one or more selected communication techniques; a sensor module configured to provide at least one selected sensed physical quantity representation pertaining to the monitored subject; and a transponder control module in communication with the RF module and the sensor module. Transponder embodiments have cooperating elements including an operations mode manager, a communications mode manager, a processor, and a self-activating power management
30 module. The operations mode manager is configured to operate the transponder in accordance with a predetermined operational mode. The communications manager configured to select one of the two or more selected communication ranges, and to select one of the one or more selected communication techniques. The processor processes the sensed subject parameter, the message, or both, in accordance with a predetermined operational mode. The self-activating power management module is configured to
35 selectively provide electric power in accordance with a predetermined operational mode to one or more of the RF module, the sensor module, or the transponder control module. In other embodiments, the transponder includes an RF module configured to exchange the message in accordance with the selected

communication technique using a selected collision avoidance protocol. In additional embodiments, the selected communication technique can be a first selectable communication technique and a second selectable communication technique. The first selectable communication technique includes a WLAN-type communication technique having a selected communication range of at least about 1000 meters; the second selectable communication technique includes a WPAN-type communication technique having a selected communication range of up to about 30 meters. In still other transponder embodiments, the RF module is configured to exchange the message in accordance with one of the first selectable communication technique or the second selectable communication technique, and at least one of the first or second selectable communication techniques uses a selected collision avoidance protocol. Yet other tag embodiments further include an energy harvesting module configured to convert ambient energy to recovered electrical energy and electrically coupled to the self-activating power management module.

[0009] In addition, a subject management system is provided for managing a monitored subject in a monitored region. Embodiments of the system include an interrogator configured to communicate using at least one selected communication technique; and an intelligent active tag intimately affixed to the monitored subject. Embodiments of the intelligent active tag of the subject management system include a transceiver configured to selectively exchange an intelligent active tag message with the interrogator using the at least one selected communication technique. The intelligent active tag includes a motion sensor producing a first selected sensed physical quantity representation indicative of a motion of the monitored subject in the monitored region. The intelligent active tag includes the first selected sensed physical quantity representation in an outbound intelligent active tag message transmitted to the interrogator. In other embodiments, the intelligent active tag further includes a biosensor producing a second selected sensed physical quantity representation indicative of a biological function of the monitored subject. The intelligent active tag includes the second selected sensed physical quantity representation in an outbound intelligent active tag message transmitted to the interrogator.

[0010] Further, a tag reader system is provided for managing a monitored subject having an attached transponder. Embodiments of the tag reader system include an interrogator module and a host module. The interrogator includes an interrogator RF module, an interrogator processing module, an interrogator communication interface module. The host module includes a host interface, and a host computer interface. The interrogator RF module is configured to exchange a transponder message with the transponder using a first selected communication technique. The interrogator RF module also is configured to produce a transponder image from a preselected transponder signal characteristic of a received transponder message. The interrogator processing module is coupled to the interrogator RF module, and includes a controller configured to process the transponder image. The controller also is configured determine a monitored subject characteristic of the monitored subject. The interrogator communication interface module is coupled to the interrogator processing module, and is configured to communicate the monitored subject characteristic. The host interface is coupled to the interrogator communication interface module, and is configured to receive the monitored subject characteristic. The

host processor is coupled to the host interface, and is configured to process the monitored subject characteristic. The host computer interface is coupled to the host processor, and includes a host display that is configured to produce a perceptible characteristic representation of the monitored subject characteristic. In certain embodiments of the tag reader system, the preselected transponder signal characteristic is representative of a monitored subject spatial characteristic. In ones of the certain embodiments, the received transponder message includes a selected sensed physical quantity representation pertaining to the monitored subject, which the interrogator module stores and communicates to the host module. The host module provides a perceptible representation of the selected sensed physical quantity representation on the host display.

10 **[0011]** Moreover, a method is provided for operating an active tag, including an intelligent transponder, attached to a monitored subject. Embodiments of the method include selecting a predetermined operational mode for the transponder; supplying electrical power selectively to a portion of transponder electrical circuitry in accordance with the predetermined operational mode; selecting a predetermined transponder operation corresponding to the predetermined operational mode; and
15 performing the predetermined transponder operation in accordance with the predetermined operational mode. The intelligent transponder is a multimode transponder, and the tag is an intelligent active tag. The predetermined operational mode includes one of a predetermined periodic operational mode, a predetermined interrogator demand operational mode, a predetermined transponder demand operational mode, or a predetermined combination operational mode. The action of performing the predetermined
20 transponder operation includes the action of performing at least one predetermined communication operation, the action of performing at least one predetermined sensing operation, the action of performing at least one predetermined power management operation, or the action of performing a combination of at least two of performing a predetermined communication operation, performing a predetermined sensing operation, or performing a predetermined power management operation. In some
25 embodiments, selecting the predetermined transponder operation includes at least one predetermined communication operation, in which the active tag communicates with an interrogator. In these embodiments, the method further includes at least one of the action of selecting a selected communication technique, or the action of selecting a selected transponder communication protocol, with the respective actions of selecting being in accordance with the predetermined operational mode.
30 Also, the action of performing the predetermined transponder operation further includes exchanging an intelligent active tag message with the interrogator.

[0012] In other embodiments, the method includes at least one of the action of selecting a selected communication frequency band corresponding to the selected communication technique from among plural communication frequency bands; selecting a selected communication range corresponding
35 to the selected communication technique from among plural communication ranges; or selecting a network topology by which to communicate with the interrogator. In yet other embodiments, the action of selecting a predetermined transponder operation further includes the action of selecting a selected

sensed physical quantity for sensing. Also, performing the predetermined transponder operation further includes the action of sensing the selected sensed physical quantity. In additional embodiments, the action of exchanging an intelligent active tag message with the interrogator further includes one of receiving an inbound intelligent active tag message from the interrogator, or transmitting an outbound intelligent active tag message to the interrogator. In further embodiments of the method, supplying electrical power further includes the actions of activating the transponder and transmitting an outbound intelligent active tag REGISTRATION message to the interrogator. Activating is effected by altering a conductive property of an activation circuit to couple a power source to the transponder. The action of transmitting is performed in response to the action of activating the transponder.

10

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a graphical illustration of a subject management system, including an intelligent active tag, and in accordance with the teachings herein of the present invention;

[0014] FIG. 2A is a graphical illustration of an active tag embodied in an example first form factor, in accordance with the teachings herein of the present invention;

15 [0015] FIG. 2B is a graphical illustration of an active tag embodied in an example second form factor, in accordance with the teachings herein of the present invention;

[0016] FIG. 2C is a graphical illustration of an active tag embodied in an example third form factor, in accordance with the teachings herein of the present invention;

20 [0017] FIG. 3A is a graphical illustration of the active tag of FIG. 2A, attached to a monitored subject ear, in accordance with the teachings herein of the present invention;

[0018] FIG. 3B is a cross-section of a portion of FIG. 3A, illustrating an attachment of an active tag to a monitored subject;

[0019] FIG. 4 is an illustration of a plan view of an example active tag embodiment depicted in FIG. 2B, taken through Section A-A';

25 [0020] FIG. 5 is a logical block diagram of an example intelligent active transponder embodiment, in accordance with the teachings herein of the present invention;

[0021] FIG. 6A is a logical schematic drawing depicting an embodiment of an activation element depicted in FIG. 5;

30 [0022] FIG. 6B is a logical schematic drawing depicting another embodiment of an activation element depicted in FIG. 5;

[0023] FIG. 6C is a logical schematic drawing depicting yet another embodiment of an activation element depicted in FIG. 5;

[0024] FIG. 6D is a logical schematic drawing depicting still another embodiment of an activation element depicted in FIG. 5;

[0025] FIG. 7 is a logical block diagram illustrating one aspect of an example tag reader system, including an example interrogation and an example host, in accordance with the teachings herein of the present invention;

[0026] FIG. 8 is a logical block diagram depicting another aspect of the example tag reader system illustrated in FIG. 7;

[0027] FIG. 9 is a flow diagram illustrating an example of a TAG TALKS ONLY interrogator protocol method, in accordance with the teachings herein of the present invention;

[0028] FIG. 10 is a flow diagram illustrating an example of a TAG TALKS FIRST interrogator protocol method, in accordance with the teachings herein of the present invention;

[0029] FIG. 11 is a flow diagram illustrating an example of a TAG LISTENS FIRST interrogator protocol method, in accordance with the teachings herein of the present invention; and

[0030] FIG. 12 is a flow diagram illustrating an example of a method of operating a intelligent active tag, in accordance with the teachings herein of the present invention.

[0031] The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate embodiments of the present invention and, together with the description, further serve to explain the principles of the invention, and to enable a person skilled in the pertinent art to make and use the invention. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION OF EMBODIMENTS

[0032] Turning to FIG. 1, subject management system 1000 may include monitored subject 1010, who may be a constituent of monitored group, generally at 1020. Monitored subject 1010 is spatially positioned in a monitored region 1100. Although illustrated to be delineated by a physical boundary in the form of a barrier fence, monitored region 1100 does not need to be physically constrained, and may be a selected communication range. Group 1020 can include plural monitored subjects 1010-1013, spatially distributed within monitored region 1100. For the purposes of illustration, monitored group 1020 is depicted as a cattle herd, with monitored subjects 1010-1013 being depicted as constituent cattle of group 1020. However, if monitored subject 1010 is an animal, subject 1010 may be a member of any species of animal, including vertebrates and invertebrates. Monitored subjects 1010-1013 may exhibit a social behavior, and monitored group 1020 may be represent a social group. In general, ones of monitored subjects 1010-1013 may exhibit a social group behavior by forming determinable subgroups with others of monitored subjects 1010-1013, for example, by a dominance relationship, by an affiliative relationship, by individual behavioral characteristics, or by a combination thereof. Disposed within monitored region 1100 may be one or more attractors such as mineral supplement 1300, feed supplement 1310, and shaded water source 1320. In addition, region 1100 may contain one or more repulsors, represented by wooded area 1350, in which predator 1375 may await.

Positions of subject group members 1010-1013, alone, or as monitored subject group 1020, may be determined, at least in part, by a social group behavior, by proximity to an attractor 1300, 1310, or 1320, by the presence of a repulsor 1350, 1375, or by a respective physiological need of monitored subjects 1010-1013.

5 **[0033]** In general, selected ones of monitored subject 1010-1013 may bear a respective incorporated telemetry device, as represented by respective intelligent active tags (IAT) 1110-1113 (generally IAT 1110). Steward 1500 may be positioned near monitored region 1100, for example, to locate one or more of monitored subjects 1010-1013, individually, or as a monitored group 1020. Steward 1500 may be, without limitation, a representative of one or more of a private entity, a commercial entity, an administrative entity, a regulatory entity, a governmental entity, or a law enforcement entity, which entity may have an interest in monitoring one or more of monitored subjects 1010-1013, or monitored group 1020. Steward 1500 may have an interest in one or more of monitored subjects 1010-1013, and may visually observe one or more members of monitored group 1020. Handheld multimodal manager (HMM) 1525 can be a wireless device configured to communicate with IAT 1110. Steward 1500 may operate HMM 1525 to identify IAT 1110 and, by extension, to identify monitored subject 1010. Steward 1500 may communicate with respective IAT 1110 using HMM 1525, to retrieve and record information pertaining to at least a portion of monitored group 1020, including monitored subject 1010. Steward 1500 may use steward vehicle 1560 to move among plural monitored regions 1100, having therein respective monitored subjects 1010-1013 or monitored groups 1020. Mobile wireless computing platform (SUPERVISOR) 1550 may be disposed in steward vehicle 1560 to support steward 1500 activities. Monitored region 1100 may employ one or more monitored region transceivers (MRT) 1400-1402 (generally, MRT 1400), which may be disposed around monitored region 1100 to form a monitoring field. MRT 1400 may be configured to communicate with one or more of IAT 1110, HMM 1525, SUPERVISOR 1550, or WAN 1425. SUPERVISOR 1550 may be configured to communicate with HMM 1525, and with one or both of MRT 1400 or wide area radio network (WAN) 1425. WAN 1425 may be coupled to public internetwork 1430, to which may be coupled one or more of remote operation center 1435 or official agency 1440. Remote operations center 1435 may be representative of a private, a commercial, or an administrative entity in a monitored subject supply chain, which may hold an interest in one or more of monitored subject 1010, or monitored group 1020. Official agency 1440 may be representative of an administrative, a regulatory, a governmental, or a law enforcement agency, which also may hold an interest in one or more of monitored subject 1010, or monitored group 1020.

35 **[0034]** IAT 1110 may be configured to communicate using one or more selected communication techniques. Certain ones of IAT 1110 embodiments may be configured to communicate using a first selected communication technique, and certain others of IAT 1110 embodiments may be configured to communicate using a second selected communication technique, which may differ from the first selected communication technique. Selected IAT 1110 may be configured to communicate

using two or more selected communication techniques and to select between a first selected communication technique and a second selected communication technique. IAT 1110 communication technique selection may be an adaptive response by IAT 1110 to a transponder operational mode change, or in response to an inbound IAT message. IAT 1110 may communicate with one or more of HMM 1525, SUPERVISOR 1550, or MRT 1400 using a first selected communication technique, a second selected communication technique, or both. HMM 1525 may be configured to communicate using two or more selected communication techniques, and may communicate with certain embodiments of IAT 1110 using one or more selected communication techniques. HMM 1525 may be configured to communicate with one or more of SUPERVISOR 1550 or MRT 1400 using a third selected communication technique. One or more of HMM 1525, SUPERVISOR 1550, or MRT 1400, may be configured to communicate with WAN 1425 using a fourth selected communication technique. WAN 1425 may be coupled to public internetwork 1430, to which one or both of remote operation center 1435 and official agency 1440 may be coupled. HMM 1525 may be configured to allow steward 1500 to exchange a message with one or both of remote operation center 1435 or official agency 1440, over WAN 1425, directly or by way of SUPERVISOR 1550.

[0035] A selected communication technique may be characterized by a selected communication protocol, a corresponding selected communication frequency band, and a corresponding communication range. A selected communication protocol can be described by a selected wireless transmission protocol used in cooperation with a selected wireless medium interface, by which a wireless device may communicate over a selected wireless link. A selected communication frequency band can be a selected range of radio frequencies between about 100 kHz to about 250 GHz, which may include a portion of LF frequency range (about 30 kHz to about 300 kHz); MF frequency range (about 300 kHz to about 3 MHz); HF frequency range (about 3 MHz to about 30 MHz); VHF frequency range (about 30 MHz to about 300 MHz); UHF frequency range (about 300 MHz to about 3 GHz); SHF frequency range (about 3 GHz to about 30 GHz); or EHF frequency range (about 30 GHz to about 300 GHz). A selected communication range generally corresponds to the selected communication protocol, the selected communication frequency band, or both. Non-limiting examples of a selected communication range may include a proximity communication range, a short communication range, an intermediate communication range, a long communication range, or an extended communication range. A non-limiting example of a proximity communication range may be up to about 1 meter between communicating devices; a short communication range may be between about 1 meter to about 10 meters; an intermediate communication range may be between about 10 meters to about 100 meters; a long communication range may be between about 100 meters to about 1000 meters; and an extended communication range may be between about 1 kilometer to at least about 10 kilometers. Of course, as is well-known, communication ranges may be affected by many circumstances, including environmental conditions, so that the aforementioned ranges represent an approximation of corresponding communication range magnitudes. Selected communication techniques may be distinct, or may share a

portion of one or more of a selected wireless transmission protocol, a selected wireless medium interface, a selected communication frequency band, or a selected communication range.

[0036] A selected communication protocol may be a wireless personal area network (WPAN)-based communication protocol; a wireless local area network (WLAN)-based communication protocol; 5 a wireless metropolitan area network (WMAN)-based communication protocol; or a wireless wide area network communications (WAN)-based communication protocol, including a mobile telephony communication protocol. Non-limiting examples of a WPAN-based communication protocol include a BLUETOOTH®-type communication protocol or a ZigBee®-type communication protocol. One example of a BLUETOOTH®-type communication protocol may use a BLUETOOTH®-related 10 wireless transmission protocol in cooperation with an IEEE Standard 802.15.1-compliant radio air (wireless medium) interface. Another example BLUETOOTH®-type communication protocol may use a BLUETOOTH® WiBree™-related wireless transmission protocol, in cooperation with an IEEE Standard 802.15.3-compliant radio air interface (e.g., an MB-OFDM UWB-related technology or a DS-UWB-related technology). A BLUETOOTH®-related wireless transmission protocol is not constrained 15 to use the entirety of protocols described in the BLUETOOTH® specification. One example of a ZigBee®-type communication protocol may use a ZigBee®-related wireless transmission protocol in cooperation with an IEEE Standard 802.15.4-compliant radio air interface. Another example of a ZigBee®-type communication protocol may use a ZigBee®-related wireless transmission protocol in cooperation with an IEEE Standard 802.15.4a-compliant radio air interface. A ZigBee®-related 20 wireless transmission protocol is not constrained to use the entirety of protocols described in the ZigBee® specification. Another example of a WPAN-based communication protocol may use a portion of an IEEE Standard 802.15.4 LR-WPAN wireless transmission protocol in cooperation with an IEEE Standard 802.15.4-compliant radio air interface. Yet another example of a WPAN-based communication protocol may use a portion of an IEEE Standard 802.15.4a UWB-WPAN wireless 25 transmission protocol in cooperation with an IEEE Standard 802.15.4a-compliant radio air interface.

[0037] Non-limiting examples of a WLAN-based communication protocol may use a portion of a WiFi®-type wireless transmission protocol in cooperation with a radio air interface generally compliant with an IEEE 802.11 Standard, including, without limitation, at least one of an IEEE Std. 802.11a, IEEE Std. 802.11b, IEEE Std. 802.11g, or IEEE Std. 802.11n. However, another WLAN-type 30 wireless transmission protocol may be used. Non-limiting examples of WMAN-based communication protocol may use a portion of WMAN-type wireless transmission protocol in cooperation with a radio air interface generally compliant with an IEEE Standard 802.16-type a radio air interface. Non-limiting examples of a WMAN-type wireless transmission protocol may include a WiMAX®-related wireless transmission protocol, HIPERMAN-related wireless transmission protocol, or a WiBRO-related wireless 35 transmission protocol, although other WMAN-type wireless transmission protocol may be used. Non-limiting examples of a WAN-based communication protocol include a technique related to a 3GPP Universal Mobile Telecommunication System (UMTS) radio network communication protocol,

including at least one of a 2.5G communication protocol, a 3G communication protocol, or a 4G communication protocol. Of course, the foregoing are a non-limiting, non-exhaustive examples of communication protocols illustrating the teachings herein.

5 [0038] Incorporated telemetry device 1110-1113 (generally, intelligent active tag, or IAT, 1110) can be a telemetry device coupled to a respective monitored subject 1010, which may be disposed internally or externally to a monitored subject, which may be affixed or removable, and which may be coupled permanently or impermanently. Accordingly, certain non-limiting embodiments of active tag may be clipped, pinned, or bound, to, or implanted within, a monitored subject corpus. In certain other non-limiting implementations, an active tag, such as IAT 1110, may be secured to monitored subject 10 1010 as a collar, bracelet, ring, or apparel, or as an ear tag, tail tag, or piercing stud. In yet other non-limiting implementations, IAT 1110 may be restrained or moveable within monitored subject 1010, for example, as a digestive tract bolus device, or as a miniature transponder lodged or secured within the circulatory system, bone, or soft tissue. In ruminant monitored subjects such as cattle, a digestive tract bolus tag may be retained indefinitely within the animal. In a non-ruminant monitored subject, a 15 digestive tract bolus device may pass through the subject digestive tract and be eliminated. IAT 1110 may be provided with at least one sensor, by which subject dynamic information regarding monitored subject 1010 may be sensed and stored as subject data to a monitoring station, using a selected communication technique. A monitoring station may include HMM 1525, SUPERVISOR 1550, MRT 1400, remote operations center 1435, or official agency 1440.

20 [0039] IAT 1110 also may be configured to store subject dynamic information as subject data. Non-limiting examples of subject dynamic information includes a monitored subject vital sign, a sensed physiological parameter, a sensed motion of monitored subject 1010, a sensed behavior of monitored subject 1010, an ambient environmental condition proximate to monitored subject 1010, or a change in one or more of a sign, a parameter, a motion, or a condition. Another non-limiting example of subject 25 dynamic information may include a predetermined monitored subject state, which may be sensed by IAT 1110 or may be inferred from sensed subject dynamic information. IAT 1110 also may be configured to produce a predetermined subject state alert, in accordance with a predetermined subject state alert rule, which may correspond to one or more of subject data, or sensed or inferred subject dynamic information. A predetermined subject state alert may correspond to, without limitation, a 30 wellness state, a distress state, a breeding state, a preselected behavioral state, or a predation state. Other non-limiting examples of subject dynamic information may include intersubject distance (ISD) 1050 and maximum acceptable separation (MAS) 1075 between monitored subjects, depicted between monitored subjects 1010 and 1011, and between monitored subjects 1012 and 1013, respectively. ISD 1050 may be a factor used to infer a predetermined subject state of monitored subject 1010, 1011, as well as 35 inferring a predetermined group state, corresponding to monitored group 1020. MAS 1075 also may be a factor used to infer a predetermined subject state alert. For example, a social group animal that is positioned in excess of MAS 1075 may be in distress, as depicted by a inferred predation state

developing between monitored subject 1013 and predator 1375. A predetermined subject state alert indicative, for example, of inferred distress or predation, may be issued by IAT 1110 in response to an intersubject distance in excess of MAS 1075.

[0040] In general, monitored subject 1010 may be identified by a subject identifier (SID), which may include one or more of a name, an alias, or a identification number, which may be globally-unique or non-globally-unique. An SID may be associated with monitored subject 1010, as a globally-unique identifier (UID) employing, for example, 64 or more identifying bits, which may be assigned under the auspices of a UID assignment organization, although such is not required. An SID may be used to identify, monitor, or track monitored subject 1010, or monitored group 1020, over time, location, or both. One or more other identifiable attributes may be used in conjunction with an SID. For example, monitored subject 101 may be associated with a place of origin identified by an origin ID (OID). Monitored subject 1010 may be located on a premises identified by a premises ID (PID). Monitored subject 1010 may be a member of a monitored group identified by a monitored group ID (GID). Monitored subject 1010 may be assigned an electronic inventory number (EIN) as an element of an inventory. Certain embodiments of IAT 1110 may include an identification code generally in accordance with a standard including, without limitation an international standard, such as ISO 11784:1996 (and as amended in 2004), as promulgated by the International Standards Organization, Geneva Switzerland. A portion of data corresponding to monitored subject 1010 may be, for example, a tracking identifier (XID) bearing identifying indicia provided in accordance with predetermined subject monitoring protocol defined by one or more of a private, a commercial, an administrative, a regulatory, a governmental, or a law enforcement entity. A non-limiting example of a tracking identifier may be a 15-digit National Animal Identification System (NAIS) animal identifier, which may be provided on a tag affixed to beef cattle as monitored subject 1010, and to which a corresponding portion of data may include, without limitation, an event number, a premise number, and a production segment. Hereinafter, an SID will be representative of aforementioned identifiers pertaining to monitored subject 1010.

[0041] IAT 1110 may have corresponding tag identification (TID) data, which may be stored in IAT 1110. A TID may be a globally-unique identifier (UID), as described above, but is not required to be. When affixed to monitored subject 1010, TID may become associated with an SID of monitored subject 1010. A portion of other corresponding identifying data may be stored, along with a TID, for example, in IAT 1110, or in a monitored subject database external to IAT 1110. IAT 1110 also may be configured to store other subject data pertaining to monitored subject 1010 including, without limitation, subject birth data, subject lineage data, subject ownership data, subject physiological data, subject medication history data, subject breeding data, or geolocation data corresponding to monitored region 1100. Also, an exterior surface of IAT 1110 (not shown) may be marked with a visible identifier code, which may be one or more of a bar code, a numeric code, an alphanumeric code, or a color code. A visible code may correspond to, or may be supplemental to, tag identification (TID) data or other identifying data, for example, an SID, which may be stored as subject data in IAT 1010. A visible

identifier code also may pertain to a monitored subject characteristic or attribute, such a gender, breeding status, or group membership. When an association is established between IAT 1110 and monitored subject 1010, for example, in a monitored subject database, a TID can be representative of a corresponding SID, and vice versa. In one example, IAT 1010 may transit an outbound IAT message, containing a TID, to HMM 1525, which may be configured to access selected stored subject data corresponding to an SID assigned to monitored subject 1010, and which may display a representation of a portion of the selected stored subject data on a graphical user interface of HMM 1525.

[0042] IAT 1110-1113 can be representative of plural types or implementations of an intelligent active tag, in which one or more types of intelligent active tags may be selectively coupled to one or more monitored subjects 1010-1013. It is not required that IAT 1110 be similar for two or more members of monitored subject group 1020. In a non-limiting example, in which IAT 1110 and IAT 1111 may be different embodiments of an intelligent active tag as described herein, a first embodiment of an intelligent active tag, such as IAT 1110, may be coupled to first monitored subject 1010, and a second embodiment of an intelligent active tag, such as IAT 1111, may be coupled to second monitored subject 1011. Two or more intelligent active tags, which may be different types of intelligent active tags, as described herein, such as IAT 1110, 1111 may be coupled to a single monitored subject 1010. Moreover, monitored subject 1010 may bear two or more types of tags, with a first tag being an intelligent active tag IAT 1110, and a second tag being at least one of an existing active tag, a semi-passive (or battery-assisted) tag, a passive RF tag, or a passive visual tag. IAT 1110 may be preconfigured for an application corresponding to a predetermined entity type. Monitored group 1020 may be of a generally homogeneous plurality of entities, or of a generally heterogeneous plurality of entities. Monitored subjects 1010, 1011 may be entities of a similar type, for example, animals, livestock, or beef cattle, as well as, of a different type, for example, livestock or wildlife. Gender, breeding status, or origin also may be a factor in entity determination of monitored subject 1010. An active tag, such as IAT 1110, may be attached to a selected representative entity, such as monitored subject 1010, of monitored group 1020. In addition, in some embodiments of system 1000 monitored group 1020 may be a selected subgroup representative of a larger group of entities, some of which may not be coupled to an intelligent active tag such as IAT 1110. Data pertaining to monitored member 1010 or monitored group 1020 may be statistically representative of similar members, groups, or subgroups.

[0043] IAT 1110 may be configured to exchange an IAT message over IAT #1 wireless link 1210 using a preselected communication technique with a suitable RF transceiver disposed within communication range. As used herein, and unless expressed otherwise, an IAT message may be any signal, probe, data, data packet, beacon, or a portion thereof, in the form of a physical or a logical signal. Exchanging a message may include transmitting or receiving a ping, a query, a demand, a response, an acknowledgement, a status, or a data transfer, which may include transmitting and receiving. An outbound IAT message may be communicated by transmitting from IAT 1110; an inbound IAT message may be communicated for receiving by IAT 1110. An IAT message also may be exchanged by a

combination of transmitting and receiving. IAT 1110 may transmit an outbound IAT message including subject data, which may be stored subject data, subject dynamic information, or a predetermined subject state alert. IAT 1110 may receive an inbound IAT message, which may include subject data or a command, and which may be stored in IAT 1110. An operation of IAT 1110 may be altered in response to an inbound IAT message. In certain embodiments, IAT 1110 may exchange an IAT message over IAT wireless link 1210, using two or more preselected communication techniques.

[0044] IAT 1110 may be configured to exchange an IAT message with HMM 1525. An IAT message may selectively include an SID, a TID, subject data, subject dynamic information, a predetermined monitored subject state, or a predetermined subject state alert. An inbound IAT message requesting data from IAT 1110 may be one type of an interrogator demand IAT message. HMM 1525 may be configured to transmit an interrogator demand IAT message to IAT 1110, in which HMM 1525 may request selected data be provided by IAT 1110. For example, steward 1500 may operate HMM 1525 to transmit an interrogator demand IAT message to IAT 1110 which, in response, may transmit selected subject data, subject dynamic information, or subject state to HMM 1525. An outbound IAT message may be initiated by IAT 1110 as one type of transponder demand IAT message. IAT 1110 may initiate an IAT message in response to selected subject data, subject dynamic information, or a subject state, pertaining to monitored subject 1010, which is sensed or inferred by IAT 1110. A predetermined subject state alert pertaining to monitored subject 1010 may be another type of transponder demand IAT message, which may be sensed or inferred by IAT 1110, in accordance with a predetermined subject state alert rule. Typically, a transponder demand IAT message may include a TID or an SID.

[0045] Selected embodiments of IAT 1110 may be self-activating, that is, configured to activate upon attachment to monitored subject 1010. In addition, upon activation, IAT 1110 may be configured to broadcast a corresponding identifier including, without limitation, a TID or an SID. IAT 1110 may broadcast a corresponding identifier, periodically, or aperiodically, and may use a selected collision avoidance protocol while broadcasting to improve chances of communicating with HMM 1525 in a timely manner. Certain embodiments of self-activating IAT 1110 may send an activation signal to HMM 1525, upon being coupled to monitored subject 1010. In turn, HMM 1525 may assign and transmit an SID identifying monitored subject 1010 to IAT 1110, and may record the assigned SID in association with monitored subject 1010. An assigned SID may be a UID, uniquely identifying monitored subject 1010, and HMM 1525 may be configured to provision a UID to monitored subject 1010. Also, HMM 1525 also may transmit configuration information to IAT 1110, in accordance with a predetermined subject monitoring protocol. Such embodiments of IAT 1110 may permit auto-registration of monitored subject 1010 in a monitored subject database concurrently with attachment of IAT 1110 to monitored subject 1010.

[0046] HMM 1525 can be a handheld computing platform, including an intelligent RF interrogator, configured to exchange an IAT message with IAT 1110. Selected embodiments of HMM 1525 can be configured to locate monitored subject 1010, for example, at a geospatial position in

monitored region 1100, or at a location relative to other members of monitored group 1020. HMM 1525 may receive, and provide a perceptible display of, subject data, including subject dynamic information, received from IAT 1110, which may be viewed for response by steward 1500. HMM 1525 also may selectively store subject data pertaining to monitored subject 1010, for example, in a monitored subject database, and may receive data input by steward 1500. HMM 1525 may be configured with a graphical user interface on which the geophysical location of monitored subject 1010 may be displayed for observation by steward 1500. In addition, HMM 1525 also may be configured to manage, and may change, an IAT transponder operation, an IAT transponder operational state, or both. An embodiment of HMM 1525 may be configured to receive an identifier from IAT 1110, and to record along with the identifier, data corresponding to monitored subject 1010, which may be subject data transmitted by IAT 1110. Data corresponding to monitored subject 1010 may be processed from a monitored subject database maintained in HMM 1525, as a constituent of an embodiment of subject management system 1000. HMM 1525 may be configured to transmit a portion of data corresponding to monitored subject 1010 to a remote receiver, for example, one or more of SUPERVISOR 1550, MRT 1400, remote operations center 1435, or official agency 1440, which also may be a respective constituent of an embodiment of monitoring system 1000. HMM 1525 may process or store in a monitored subject database, an SID identifying monitored subject 1010 and configuration information pertaining to IAT 1110. HMM 1525 also may be configured to relay an SID identifying monitored subject 1010 and configuration information pertaining to IAT 1110 to one or more of SUPERVISOR 1550, remote operations center 1435, or official agency 1440. Also, in certain embodiments of subject management system 1000, HMM 1525 may receive data corresponding to monitored subject 1010 from one or more of SUPERVISOR 1550, MRT 1400, remote operations center 1435, or official agency 1440. HMM 1525 may push data selectively to IAT 1110.

[0047] In certain embodiments, HMM 1525 may be configured to receive a transponder demand IAT message from IAT 1110, which may provide steward 1500 with pertinent information concerning monitored subject 1010, in a timely manner. HMM 1525 also may be configured to process subject data received from IAT 1110, in accordance with a predetermined subject data management protocol. In one non-limiting example of a predetermined subject data management protocol, HMM 1525 may perform one or more of the following actions: establish communication with IAT 1110, receive an UID from monitored subject 1010, use the UID to provide a perceptible indication of a location of monitored subject 1010, pull selected subject data pertaining to monitored subject from IAT 1110, process selected pulled data in HMM 1525, push selected data to IAT 1110, or record a tally of data and communications exchanged with monitored subject 1010 in a monitored subject database. In response, IAT 1110 may store therein pushed selected data, and may reply to HMM 1525 with an acknowledgement. In response to an acknowledgement from IAT 1110, HMM 1525 may transmit a "SLEEP" interrogator demand IAT message, directing IAT 1110 to enter a predetermined reduced power mode. In response to the SLEEP interrogator demand IAT message from handheld platform

HMM 1525, IAT 1110 may change an operational mode to a SLEEP mode. The foregoing example is illustrative and not intended to limit an operation of, or a protocol used by, IAT 1110 or HMM 1525. IAT 1110 and HMM 1525 may be cooperatively configured to execute a predetermined subject data management protocol using an ultra-low power communication protocol. However, other
5 predetermined subject data management protocols may be provided. HMM 1525 may be configured with a sensor, which may allow steward 1500 to transmit sensed data for remote analysis, for example, sensed imaging data for remote viewing. In addition, in certain embodiments, HMM 1525 may be configured to exchange a message between IAT 1110 and one or both of remote operation center 1435 or official agency 1440, by way of SUPERVISOR 1550 or, alternatively, directly, while within
10 monitored region 1100. Certain embodiments of HMM 1525 can be configured to receive data from existing RF tags, including a passive RF tag, a semi-active RF tag, or an active tag other than IAT 1110.
[0048] HMM 1525 may be configured to communicate with SUPERVISOR 1550 using a third selected communication technique. SUPERVISOR 1550 may be, for example, a laptop computer having at least one wireless radio, which may be a configurable wireless radio. SUPERVISOR 1550
15 may be disposed, for example, in steward vehicle 1560, and may be optional in alternative embodiments of subject management system 1000. SUPERVISOR 1550 may be configured to exchange with HMM 1525 information regarding monitored subject 1010, including, without limitation one or more of TID, SID, subject data, subject dynamic information, a preselected subject state, or a preselected subject state alert. SUPERVISOR 1550 may receive and store data from HMM 1525, regarding monitored subject
20 1010, monitored group 1020, or monitored region 1100. SUPERVISOR 1550 may maintain a monitored subject database pertaining to monitored subjects 1010-1013, to monitored group 1020, or to plural monitored subjects in plural monitored groups. SUPERVISOR 1500 may process received data in accordance with a second predetermined subject data management protocol. In addition, SUPERVISOR 1550 may be configured to communicate over regional RF link 1410 to WAN 1425
25 using a fourth selected communication technique. Alternatively, HMM 1525 may be configured to communicate over regional RF link 1410 to WAN 1425 using a fourth selected communication technique.

[0049] In certain embodiments of system 1000, at least one monitored region transceiver (MRT) 1400-1402 (generally, 1400) may be disposed within, or in proximity to, monitored region 1100.
30 A certain selected embodiment of IAT 1110 may be configured to communicate with MRT 1400 over IAT wireless link 1210 using one of a first selected communication technique or a second selected communication technique. In certain embodiments of system 1000, MRT 1400 may be coupled to WAN 1425 over regional RF link 1410, and may be configured as an intermediary with WAN 1425 to exchange an IAT message with one or both of remote operation center 1435 and official agency 1440.
35 In an illustrative example, IAT 1110 may exchange an outbound IAT message over IAT wireless link 1210 to MRT 1400. MRT 1400 may relay the outbound IAT message over regional wireless link 1410 to WAN 1425, with the outbound IAT message being selectively relayed, in turn, over public

internetwork 1430, to remote operation center 1435, to official agency 1440, or to both. Similarly, an inbound IAT message may be relayed over public internetwork 1430 to WAN 1425, from remote operation center 1435, official agency 1440, or both. WAN 1425 may relay inbound IAT message over regional wireless link 1410 to MRT 1400. MRT 1400 may exchange the inbound IAT message directed to IAT 1110 over IAT wireless link 1210. One or more of IAT 1110-1113 may be configured to detect and to accept respective inbound IAT message.

[0050] System 1000 may be configured such that MRT 1400 may store a respective inbound IAT message, if IAT 1110 is not within communication range of MRT 1400. In alternative embodiments, one or more of MRT 1400 may be configured as a stand-alone monitored subject transport system, disposed at predetermined regional checkpoints, such as along a public highway or in a public venue, which monitored region 1100 may represent. MRT 1400 may be disposed in an ascertainable geophysical location. A physical proximity of monitored subject 1010 may be surmised, for example, when IAT 1110 is disposed within communication range of, and may be caused to exchange an IAT message with, MRT 1400. For example, such an alternative embodiment of MRT 1400 may sense proximity of IAT 1110 and may transmit an outbound IAT message querying the identity of IAT 1110 and, by extension, monitored subject 1020. Alternatively, IAT 1110 may transmit an outbound IAT message periodically, and, if so configured, MRT 1400 may relay the outbound IAT message to remote operations center 1435, official agency 1440, or both. As an illustrative example, during transport of monitored subject 1010, attached IAT 1110 may become disposed within a communication range of MRT 1400 and may be caused to exchange an outbound IAT message with MRT 1400 over IAT wireless link 1210. The outbound IAT message may provide a TID, an SID, subject data, subject dynamic information, or other information pertaining to monitored subject 1010. In this example, MRT 1400 also may store, or may selectively relay, the outbound IAT message to one or both of remote operational center 1435, official agency 1440, which may monitor transport of monitored subject 1010, or which may intervene in response to such knowledge. An embodiment of system 1000 may assist, for example, in reducing loss, or promoting wellness, of monitored subject 1010, during or after transport, although other supervisory, regulatory, or interventive applications may be reasonably foreseen and contemplated, within the scope of the teachings herein.

[0051] FIG. 2A-2C illustrates possible form factors of intelligent active tag 2000, although other physical configurations are encompassed by the teachings herein. Tag 2000, as illustrated in FIGS. 2A-2C, may be an embodiment of IAT 1110 in FIG. 1. One embodiment of tag 2000 can be in the form of an ear tag, which may be affixed to the ear of monitored subject, such as monitored subject 1010-1019 in FIG. 1. Tag 2000 also may be suitable for tag placement on another anatomical region of a subject member. Tag 2000 may be provided in other configurations, however, which may be suitable for tag placement on other anatomical regions of subject cattle, or for tag placement on another species of subject animal. As used herein, the term intimate affixment may describe a manner by which tag

2000 may be coupled to monitored subject 1010 corpus, and in which at least a portion of tag 2000 may contact a portion of monitored subject 1010.

[0052] FIG. 2A illustrates an embodiment of tag 2000, disposed in housing 2100, having an example first form factor in which power source compartment 2110, affixment fitting 2120, and transponder compartment 2130, can be aligned longitudinally along axis 2125. FIG. 2B depicts another embodiment of tag 2000, disposed in housing 2200, having an example second form factor, which can be configured such that power source compartment 2210 can be longitudinally aligned along first axis 2250, with affixment fitting 2220 and transponder compartment 2230 generally being aligned along second axis 2255 and, for the most part, perpendicularly to axis 2250, such that housing 2200 may have a more compact form factor than housing 2100. FIG. 2C illustrates still another embodiment of tag 2000, disposed in housing 2300, and having an example third form factor. In housing 2300, power source compartment 2310 can be longitudinally aligned along third axis 2350, and affixment fitting 2320 can be aligned along fourth axis 2355, which generally can be perpendicular to third axis 2350. Housing 2300 can be formed such that transponder compartment 2330 can be communicatively conjoined, and aligned along third axis 2350, with power source compartment 2310, such that housing 2300 may have a more compact form factor than either housing 2100 or housing 2200. Of course, other housing form factors may be possible.

[0053] Housing 2300 may bear an identifying indicia 2323, which may identify a monitored subject, such as monitored subject 1010, to which corresponding tag 2000 may be attached. Identifying indicia 2323 generally is disposed on external portion housing 2300 and may be positioned for observation, for example, by steward 1500. Identifying indicia 2323 can be configured with a detectable component for visual observation within the visible light spectrum. In addition, identifying indicium may include a detectable component for observation in one or more of an infrared light spectrum or an ultraviolet light spectrum. Identifying indicia 2323 may include one or more detectable components, with non-limiting examples of a detectable component including a bar code indicium, a numeric indicium, an alphanumeric indicium, an alpha indicium, an assigned color indicium, or an assigned symbol indicium. In selected implementations of system 1000, a monitored subject, such as monitored subject 1010, may bear a detectable corporal indicium as a detectable component of identifying indicia 2323, which may occur naturally or be devised. Non-limiting examples of a naturally-occurring corporal indicia, which may be unique to a monitored subject, include a facial shape or marking pattern, a hair or fur whorl pattern, a vascular pattern, or a vocalized pattern. Non-limiting examples of a devised corporal indicia include a tattoo, a brand, or a mark, which may be unique, distinctive, or otherwise helpful in determining an identity of a subject bearing the indicia.

[0054] With regard to power source compartments 2110, 2210, and 2310, form may follow function, in that respective compartments 2110, 2210, and 2310, may be shaped to conformally receive a power source for multi-modal tag 2000. Thus, although example power source compartments 2110, 2210, and 2310, are illustrated to have a generally cylindrical form, and may be shaped to receive a

generally cylindrical power source element therein, other forms may be provided for one or more of power source compartments 2110, 2210, and 2310, and shape is not to be seen as a limitation on either a form factor for tag 2000, or for the nature of a power source, which may be therewithin. Selected embodiments of tag 2000 may be self-activating, that is, be configured to initiate a power supply from tag power source to corresponding transponder components, upon tag 2000 being proximately affixed to the subject. In selected embodiments, activation element 2900 may be at least partially disposed across at least a portion of affixment fittings 2120, 2220, or 2320. Affixment of tag 2000 to a monitored subject, such as monitored subject 1010 in FIG. 1, may alter an electrical property of activation element 2900, and may cause tag transponder circuitry to be activated by coupling to a power source.

10 [0055] FIGS. 3A and 3B illustrate first example form factor housing 2100 of tag 2000, in FIG. 2A, which can be coupled to a predetermined subject region on monitored subject 1010, here cattle ear 3000. The description with respect to FIGS. 3A and 3B also may apply, mutatis mutandi, to the form factors of tag 2000, depicted in FIGS. 2B and 2C. In FIGS. 3A and 3B, tag 2000 is coupled to monitored subject 1010, by intimate affixment to a surface of cattle ear 3000. Intimate affixment, 15 exemplified by pinning, can be an intimate coupling, which may facilitate sensing a monitored subject parameter. FIG. 3A depicts tag 2000 being disposed in an interior surface 3100 of cattle ear 3000, for example, between cartilaginous ear ribs 3110 and 3120. This location can be a typical ear tag placement location on cattle, although tag 2000 may be positioned in intimate affixment relative to another predetermined subject region of a cattle. Tag placement can be in a predetermined anatomical region of 20 a subject, typically a region affording visibility of the tag while avoiding permanent physical injury to the subject. FIG. 3B illustrates a cross section of a placement of tag 2000, as may correspond to the ear tag placement in cattle ear 3000 of FIG. 3A. Cattle ear 3000 can be characterized by interior surface 3100, exterior surface 3200, and ear cartilage 3300 disposed therebetween. Tag 2000 is illustrated in an example form factor similar to that of FIG. 2A, although tag 2000 may be realized, without limitation, in 25 another respective form factor, as illustrated in FIGS. 2B and 2C. Also, a portion of affixment fittings 2120, 2220, or 2320 may be configured as a female element, and may be formed to receive male element 2500, which may be a tag securing stud. In housing 2100, for example, female element 2150 can be implemented by forming a locking socket 2160 and having affixment opening 2170 therethrough.

[0056] Typically, affixment opening 2170 is sized and shaped to receive male element 2500 30 therethrough; and a widest diameter of locking socket 2160 can be generally greater than a diameter of affixment opening 2170. A suitable male element 2500 may be in the form of a piercing stud, having shaft 2510 extending longitudinally from tag securing base 2520 on one end, and forming pointed tip 2530 on the other. In general, shaft 2510 is sized to pass through affixment opening 2170, with a diameter slightly less than a diameter of affixment opening 2170. Depending upon the configuration of 35 female element 2150, male element 2500 may include compressible locking shoulder 2540 on pointed tip 2530, which can be configured to compress to pass through affixment opening 2170 and, when within locking socket 2160, to expand such that male locking shoulder 2540 can be captured by female

socket 2160. Locking shoulder 2540 may be configured to be captured releasably, semi-permanently, or substantially permanently, by locking socket 2160. By piercing male element 2500 through affixment opening 2170 and activation element 2900, conductive properties of activation element 2900 may be altered, causing electrical activation of a power supply circuit within tag 2000. Embodiments of activation element 2900 can be further described within the contexts of FIGS. 6A-6D. A portion of tag 2000 can have a surface shape generally suitable for making contact with the surface to which tag 2000 may be proximately affixed. For example, housing 2200 may have rear surface region 3600, which is generally flat and suitable for affixment to a portion of inner surface 3100 of ear 3000. Region 3600 also may be contoured to complement a contour of the body to which tag 2000 may be attached.

[0057] Affixment of tag 2000 to cattle ear 3000 can be accomplished by urging piercing stud (male element) 2500 through exterior surface 3200, cartilage 3300, and inner surface 3100, such that stud 2500 is brought into proximity with tag 2000 and axially aligned with affixment opening 2170. Activation element 2900, here at least partially disposed across opening 2170, can be at least partially pierced by pointed tip 2530, which may cause an electrical property of activation element to be altered and electrical power to be supplied to a transponder (not shown) in tag 2000. Locking shoulder 2540 can be compressibly urged to pass through affixment opening 2170 and, can at least partially expand, seat, and be captured once within female socket 2160.

[0058] FIG. 4 illustrates an embodiment of active tag 2000 implemented, as implemented in second example form factor in FIG. 2B, and taken through plane A-A' of example housing 2020. It may be useful to describe certain aspects of FIG. 4, relative to FIGS. 2B, and FIGS. 3A and 3B. Such descriptions can be applicable to other example housing configurations, including, without limitation, those pertaining to FIG. 2A and FIG. 2C and 2D. Tag 2000 can include enclosure 4100, substrate 4200, transponder element (XPDR) 4300, and antenna module 4400. Example enclosure 4100 may be representative of example housing 2200 in FIG. 2B. Substrate 4200, XPDR 4300, and antenna module 4400 may be contained within transponder compartment 2230 in FIG. 2B. Affixment body section 4600 may provide a portion of fitment by which tag 2000 may be affixed to monitored subject 1010. Enclosure 4100 can be a unitary, overmolded configuration, in which internal elements, including substrate 4200, XPDR 4300, antenna module 4400, and power source 4500, may be hermetically sealed therewithin.

[0059] An overmolded configuration can provide isolation of the internal elements from exposure to harsh external environmental factors, such as rain, dust, or sunlight, including around affixment opening 2170. In certain embodiments of tag 2000, enclosure 4100 can be made of a rugged, weather-resistant, UV-resistant, biologically-inert substance, such as polyurethane. In another embodiment, a portion of enclosure 4100 may be formed over a transponder compartment using a material, which may be generally protective of a transponder, but which may permit penetration of a greater proportion of RF signals, when compared to another portion of enclosure 4100. In yet another embodiment, tag 2000 may be configured to be opened and re-sealed, for example, to configure or

replace an element therewithin. In such embodiments, enclosure 4100 may provide a perimeter sealing element for example, by restoring to enclosure 4100, a hermetic seal capable of excluding an undesirable environmental condition, such as humidity, rain, or dust. In selected self-activating embodiments of tag 2000, a portion of activation element 2900 can be disposed on a portion of affixment body section 4600, and can cover a portion of affixment opening 2170. Affixment body section 4600 can correspond to a portion of affixment fitting 2320, which can be penetrated by affixment opening 2170.

[0060] Activation element 2900 may be a conductive material, which may be electrically coupled to tag 2000. In certain embodiments, activation element 2900 may cover at least a portion of affixment opening 2170, with element 2900 and opening 2170 being disposed for breaching by male element 2500, as depicted in FIG. 3B. As described with respect to FIG. 3B, breaching by male element 2500 may alter a conductive property of activation element 2900, which may result in activation of tag 2000. In certain other embodiments, activation element 2900 may be a conductive material exposed to at least a portion of affixment opening 2710, which may be disposed for breaching by male element 2500. In selected ones of certain other embodiments, a portion of male element 2500 may be conductive such that, when male element 2500 breaches affixment opening 2710, a conductive portion of male element 2500 may be brought into electrical contact with a portion of activation element 2900, which may result in activation of tag 2000. In selected others of certain other embodiments, tag securing base 2520 of male element 2500 may include a power source therein, with a first portion of male element 2500 being electrically coupled to power source and a second portion in electrical connection therewith, being conductive such that, when male element 2500 breaches affixment opening 2710, the conductive second portion of male element 2500 can be brought into electrical contact with a portion of activation element 2900, and electrical power from power source 4500 may flow through the first and second portions of male element 2500 and into activation element 2500, which may result in activation of tag 2000. In general, substrate 4200 may be a circuit board on which XPDR 4300 is disposed. A portion of substrate 4200 can be a printed circuit board, which is suitable for use in environmental conditions to which tag 2000 can be expected to operate, and which is compatible, at minimum, with electrical operation of XPDR 4300 and antenna module 4400. Substrate 4200 generally provides electrical connection between XPDR 4300, antenna module 4400, and power source 4500. In implementations in which XPDR 4300 is formed from plural elements, such as XPDR 4300 and tag electronic element 4350, substrate 4200 may provide thereto electrical interconnection and physical support. XPDR 4300 may be electrically coupled to substrate 4200 by known surface mount packing techniques.

[0061] Antenna module 4400 may be implemented with a single antenna element 4410, which may be coupled to XPDR 4300 and configured to communicate over a predetermined RF frequency band, which may be a selectable predetermined RF frequency band. Alternatively, antenna module 4400 may be implemented with two or more antenna elements 4410, 4420, which may be coupled to XPDR 4300 and configured to communicate, respectively, over a first predetermined RF frequency band

and a second predetermined RF frequency band. In certain plural antenna element embodiments, at least one of a first predetermined RF frequency band and a second predetermined RF frequency band can be a selectable predetermined RF frequency band. Selected ones of active tag 2000 may include two or more transponders, XPDR #1 4300, XPDR #2 4800, each electrically coupled by substrate 4200 to antenna module 4400 and to power source 4500, by known surface mount techniques. In alternative embodiments of active tag 2000 having plural transponders, XPDR #1 4300 and XPDR #2 4800 may be coupled jointly to a single antenna element 4410, may be coupled respectively to antenna elements 4410 and 4420, or may be coupled respectively to plural antenna elements. Each transponder-antenna element pairing may be configured to communicate over a respective predetermined RF frequency band, of which at least one may be a selectable predetermined RF frequency band. In certain ones of tag 2000 embodiments, XPDR 4300 may incorporate one or both of antenna element 4400 or power source 4500. Typically, a length of antenna element 4410, 4420 of antenna module 4400 can correspond inversely to signal frequencies for which antenna module 4400 may be employed.

[0062] Antenna module 4400, and antenna element 4410 or 4420 therein, may be disposed substantially within a perimeter of substrate 4200, which may minimize a portion of antenna module 4400 extending beyond the a physical dimension of substrate 4200. In an alternative embodiment, a portion of antenna module 4400 may extend beyond a physical dimension of substrate 4200. At least a portion of antenna module 4400 can be effectively disposed as an embedded layer within substrate 4200. Embedded printed circuit board antennas are well-known in the arts and embedded antenna module 4400 may be configured to be responsive to one or more predetermined RF frequency band, or to a selected range of frequencies within an RF frequency band. In another alternative embodiment of tag 2000, antenna module 4400 may be configured to be responsive to two or more selected frequency bands which may span frequencies between, for example, about 250 MHz to about 10 GHz. In still another alternative embodiment of tag 2000, antenna module 4400 may be representative of two or more antenna elements, 4410, 4420, of which one or both may be coupled to XPDR 4300 as an embedded PCB antenna element, as a surface mount antenna element, or as a discrete antenna disposed in proximity to substrate 4200. In selected embodiments, passive RF element 4900 also may be attached to substrate 4200.

[0063] FIG. 5 illustrates an example embodiment of intelligent transponder (XPDR) 5000, which may be used as a constituent element of multi-modal intelligent active tag 2000. XPDR 5000 can be coupled to monitored subject 5800, for example, by intimate affixment, as described relative to FIG. 3. A suitable active tag may be an intelligent active tag, such as IAT 1110 in FIG.1 and tag 2000 in FIGS. 2 and 3. XPDR 5000 can be a non-limiting example embodiment of XPDR 4300, 4800 in FIG. 4. XPDR 5000 can be configured for contactless communication on a selected communication frequency band using a selected communication technique. XPDR 5000 can communicate with at least one remote device, represented by interrogator (INT #1) 5900. INT #1 5900 may be representative of HMM 1525, SUPERVISOR 1550, MRT 1400, or WAN 1425 in FIG. 1. Monitored subject 5800 can be disposed in

proximate environment 5850, which may surround at least a portion of monitored subject 5800. Environment 5850 may be an example of a portion of monitored region 1100 of FIG. 1. Subject management system 5050 may include XPDR 5000 and INT 5900. Certain embodiments of XPDR 5000 can communicate over two or more selected communication frequency bands using one or more selected communication techniques, and may switch between a first selected communication frequency band and a second selected communication frequency band, in response to a predefined frequency selection signal. XPDR 5000 may selectably communicate using half-duplex signaling, full-duplex signaling, or both. Selected embodiments of XPDR 5000 also may be configured to communicate using a selected communication technique with a predetermined subcarrier modulation technique, using at least one subcarrier.

[0064] Embodiments of XPDR 5000 also may be configured as a multi-range transponder, by which XPDR 5000 may communicate over two or more selected communication ranges using one or more selected communication techniques, including a proximity communication range, a short communication range, an intermediate communication range, a long communication range, or an extended communication range. XPDR 5000 may communicate by one or both of near-field coupling (less than about one radian wavelength of the predefined operating frequency), or far-field coupling (greater than about one radian wavelength of the predefined operating frequency). Near field coupling may be one or both of capacitive or magnetic coupling; far field coupling can be electromagnetic field coupling. In addition, selected embodiments of XPDR 5000 may employ one or more selected communication technique using a wireless point-to-point topology, a wireless point-to-multipoint topology, a wireless cluster topology, or a wireless multi-hop mesh topology. XPDR 5000 may be preconfigured to employ a preselected network topology, or may be configurable to select between two or more preselected network topologies. In one configurable embodiment of XPDR 5000, OPS 5120 may select adaptively between a first network topology and a second network topology, in response to a network topology selection signal. A network topology selection signal may be included in an inbound IAT message. For example, INT 5900 may transmit a predetermined interrogator demand IAT message to XPDR 5000. Alternatively, a network topology selection signal may correspond to a transponder operation in which XPDR 5000 may adaptively reconfigure its role in a network topology, for example, in response to a detected change in transponder network topology.

[0065] An embodiment of XPDR 5000 may be configured to communicate with a first interrogator, e.g., INT #1 5900, using a first selected communication technique, and to communicate with a second interrogator, e.g., INT #2 5901, using a second selected communication technique. In some embodiments, the first selected communication technique may be a WPAN-based communication technique, and the second selected communication technique may be a WLAN-based communication technique. The first selected communication technique may employ a first RF frequency band may at least partly overlap a second RF frequency band employed by the second selected communication technique, for example, as may occur with communication techniques which may share a popular ISM

frequency band between about 2.0 GHz to about 2.5 GHz. An embodiment of XPDR 5000 also may communicate using a selected communication technique, which may be compatible with existing RFID readers, and which may have an operating frequency of between about 100 kHz to about 150 kHz, of between about 12 MHz to about 14 MHz, or of between about 8MHz to about 2.5 GHz. Moreover, an
5 embodiment of XPDR 5000 can include passive RF element 5490, which may provide compatible passive RFID element communication with an existing passive RFID reader device, or with INT 5900, which may be in communication with an existing passive RFID device.

[0066] Embodiments of XPDR 5000 may be implemented using one or more wireless radio systems, integrated circuits, or functionally equivalent elements, to realize transponder functionality
10 suitable for a selected transponder application. Transponder functionality may include communication functionality and telemetry functionality, which may be configured for long-lived, low-power, selectable telemetry, which may be related to a monitored subject exposed to a rugged, if not harsh, environment, and which may selectably operate over plural communication ranges, one of which may exceed 100 meters, and may use plural selected communication techniques. A non-limiting example of a device that
15 may suitably implement a portion of XPDR 5000, may be a Chipcon CC2430, or alternatively, a Chipcon 2431, wireless radio system-on-a-chip integrated circuit, having microcontroller, radio, security, I/O, and power management elements, which are produced by Texas Instruments, Inc., Dallas, TX, USA. Such a device may be used with one or more antenna elements formed on a printed circuit board on which the integrated circuit may be mounted, or may be used with other antenna elements,
20 including a surface mounted antenna element or an external antenna element. A Chipcon 2430, or 2431, integrated circuit can be configured with an IEEE Standard 802.15.4-compliant radio air interface (e.g., ZigBee®-related LR-WPAN), or a 802.15.4a-compliant radio air interface (e.g., ZigBee®-related UWB-WPAN), and may be configured to interoperate with one or more other radio air interface systems, which may be provided on one or more other integrated circuits to constitute an embodiment of XPDR
25 5000. A transponder such as XPDR 5000 may be suitably configured to meet an application flexibility, lifespan, communication needs, and a power budget. Certain embodiments of XPDR 5000 can be configured with plural selected radio air interfaces to permit a subject management system, such as example system 1000, to provide both on-the-scene, and remote communications and monitoring, as well as to offer backward-compatibility with existing systems, as well as with existing elements and
30 techniques. A software-defined radio or a cognitive radio interface, if used with XPDR 5000, may offer common radio elements, which may permit operation using a wider range radio air interface systems, within a given hardware realization and power budget.

[0067] XPDR 5000 can perform a selected communication operation, using a selected transponder communication protocol, and may be configured to use more than one selected transponder
35 communication protocols. Non-limiting examples of a transponder communication protocol include a TRANSPONDER-TALK-FIRST transponder communication protocol, a TRANSPONDER-LISTEN-FIRST transponder communication protocol, or a TRANSPONDER-TALK-ONLY transponder

communication protocol. A selected communication operation may be a selected transmit operation, a selected receive operation, or a selected combination of a transmit operation and a receive operation. A non-limiting example of a selected transmit operation can be a transponder ping operation, in which XPDR 5000 initiates communication by transmitting an outbound IAT message to INT 5900, which
5 may identify XPDR 5000 to INT 5900. An outbound IAT message may be, but is not required to be, a TID or an SID corresponding to monitored subject 5800. Another non-limiting example of a selected transmit operation may include XPDR 5000 transmitting an outbound IAT message, including an acknowledgement signal (ACK), in response to an inbound IAT message received from INT 5900. Yet another non-limiting example of a selected transmit operation may be XPDR 5000 transmitting to INT
10 5900 an outbound IAT message including subject dynamic information pertaining to monitored subject 5800.

[0068] A non-limiting example of a selected receive operation can be an interrogator demand operation, in which INT 5900 transmits an inbound IAT message seeks a preselected response from XPDR 5000. Another non-limiting example of a selected receive operation can be an interrogator wake-
15 up demand operation, by which INT 5900 transmits an inbound IAT message, including a WAKE ON RADIO signal, which instructs XPDR 5000 to wake-up, that is, to supply electric power to at least a portion of transponder electric circuitry. In contrast, another selected receive operation may be an interrogator sleep demand operation, by which INT 5900 transmits an inbound IAT message, including a SLEEP signal, which instructs XPDR 5000 to sleep, that is, to remove electric power from at least a
20 portion of transponder electric circuitry. In yet another non-limiting example of a selected receive operation, INT 5900 may transmit to XPDR 5000 an inbound IAT message, including data, which may be stored on XPDR 5000, or a command, which may alter an operation of XPDR 5000. As one example of a selected combination of a transmit operation and a receive operation, XPDR 5000 may be configured to receive and respond to an interrogator ping, in which XPDR 5000 recognizes and receives
25 from INT 5900 an inbound IAT message identifying XPDR 5000, and transmits an outbound IAT message to XPDR 5000, including an ACK. A selected communication operation may be in accordance with a selected communication protocol, and an embodiment of XPDR 5000 can be configured to select between a first selected communication protocol and a second selected communication protocol, in response to a predefined protocol selection signal.

30 [0069] With reference to FIG. 1, monitored region 1100 may represent an interrogation field disposed with multiple monitored subjects 1010-1013 having respective transponders, such as IAT 1110-1113. In such an interrogation field, communication collision may occur where two or more transponders initiate a transmit operation at approximately the same time, where information can be lost. Communication contention may occur under a similar circumstance, but where information may not be
35 lost. Signaling arbitration may facilitate communication between interrogator INT 5900 and multiple transponders, including XPDR 5000, by reducing communication collision or contention. XPDR 5000 may be configured to provide signaling arbitration using a selected collision avoidance protocol, which

may reduce a communication collision between XPDR 5000 and INT #1 5900. As used herein, an “collision avoidance” protocol comprehends a protocol, which may reduce communication contention as well as communication collision. XPDR 5000 may configured to use more than one selected collision avoidance protocol, and to select between a first selected collision avoidance protocol and a second selected collision avoidance protocol, in response to an collision avoidance protocol selection signal, which may be provided by OPM 5120. In an example implementation of a selected collision avoidance protocol, XPDR 5000 may initiate communication by transmitting an outbound IAT message to INT 5900 on a preselected tag transmission interval, which may be periodic or aperiodic. A selected periodic collision avoidance protocol embodiment may be exemplified by XPDR 5000 periodically transmitting an outbound IAT message to INT 5900, over a selected periodic tag transmission interval of about 2 seconds.

[0070] A selected aperiodic collision avoidance protocol embodiment may be exemplified by XPDR 5000 transmitting an outbound IAT message to INT 5900, over a selected pseudo-random tag transmission interval, which may be provided with a minimum duration, a maximum duration, or both. An example pseudorandom interval may be between about 0.5 sec. to about 5.0 sec. In another non-limiting example of a selected aperiodic collision avoidance protocol embodiment, a pseudo-random time offset may modify selected pseudo-random tag transmission interval to provide a two-level pseudorandom interval. A predetermined offset range may be expressed as a bounded time range, for example, +/- 0.1 sec. A non-limiting example of a two-level pseudorandom interval may be described as being between about 0.5 sec. (± 0.1 sec.) to about 5.0 sec. (± 0.1 sec.).

In yet another non-limiting embodiment of a selected collision avoidance protocol, XPDR 5000 may be configured to communicate with a first degree of freedom, in which potentially overlapping transmission times of transponders may be offset respectively by a preselected tag transmission interval, t_{interval} , calculated in general accordance with the relationship:

$$t_{\text{interval}} = t_{\text{nom}} + p t_{\text{nom}}$$

where

t_{nom} is a preselected time interval; and

p is a time interval window, expressed in percent (e.g., 5%)

[0071] When p is selected to be about 5% and t_{nom} is selected to be about 2 seconds, then values for tag transmission interval, t_{interval} , may vary between about 1.900 seconds to about 2.100 seconds. XPDR 5000 may be configured to initiate an IAT message exchange at least once during a corresponding selected tag transmission interval. Other time intervals, and other time interval windows, may be employed to provide a suitable selected tag transmission interval having a first degree of freedom. A second degree of freedom may be provided by supplementing a tag transmission interval with a respective tag nonce. A temporal window bracketing t_{interval} may be divided into about 200

nonces, ranging from about 1.900 seconds to about 2.000 seconds, with each nonce being spaced apart by about 0.001 seconds. XPDR 5000 may initiate an IAT message upon activation by a power source, for example, at activation time t_{start} , which may be offset with a pseudo-randomized tag nonce value, such that

5 $t_{\text{xmit}} = t_{\text{start}} + \text{rand}(\text{nonce}),$

that is,

$$t_{\text{start}} + (1.900 \text{ seconds} \leq t_{\text{xmit}} \leq t_{\text{start}} + 2.100 \text{ seconds}).$$

[0072] Although, two or more tags may be activated at the substantially same time (i.e., same values of t_{start}), a different tag nonce may be selected to provide a pseudorandom offset of IAT message

10 initiation as measured from t_{start} . In an alternative embodiment, XPDR 5000 may determine a tag transmission interval adaptively, for example, by re-selecting a pseudorandom tag nonce value in response to an IAT message collision. Other collision avoidance protocols also are contemplated and may be used.

[0073] In certain embodiments, a selected tag transmission interval may be assigned to XPDR 15 5000, for example, during manufacture, by a vendor, or by INT 5900. Alternatively, XPDR 5000 may self-assign a selected tag transmission interval, for example, upon XPDR 5000 initialization, or in response to a change in a predetermined operational mode of XPDR 5000. INT 5900 may be configured to assign a selected tag transmission interval, without limitation, using a predetermined tag transmission interval selection technique, which may be preprogrammed into an operation of INT 5900, or using a 20 selectable tag transmission interval selection technique, which may be selected by an INT 5900 operator, or may be communicated remotely to INT 5900.

[0074] In general, XPDR 5000 can reduce overall transponder power consumption by performing a predetermined power management operation, which may be a predetermined context-aware power management operation. For example, XPDR 5000 can be configured to perform a 25 predetermined power management operation in support of a predetermined communication operation, a predetermined sensing operation, or both. Certain embodiments of XPDR 5000 may incorporate predetermined power management operations therein. For example, in an embodiment of XPDR 5000 using an aforementioned CC2430 wireless radio system-on-a-chip integrated circuit, and functionally similar devices, at least one predetermined power management operation may be implemented thereon, 30 which may reduce overall transponder power consumption. Other power consumption apparatus and techniques, known in the art, may be used to supplement, or to substitute for, a power management operation which may be incorporated into an integrated circuit implementation of XPDR 5000. However, other power consumption apparatus and techniques may be used in other implementations of XPDR 5000. Also, XPDR 5000 may perform a predetermined power management operation in 35 response to a predetermined communication operation, a predetermined sensing operation, or both. A

predetermined power management operation may include supplying electric power to at least one portion of XPDR 5000 transponder electrical circuitry, removing electric power from at least one portion of XPDR 5000 transponder electrical circuitry, or supplying electric power to a first portion of XPDR 5000 transponder electrical circuitry and removing electric power from a second portion of XPDR 5000 transponder electrical circuitry.

[0075] XPDR 5000 may be configured to function in one or more predetermined operational mode such that tag 2000 may function as a single-mode active or as a multi-mode intelligent active tag. An operational mode can correspond to one or more transponder operations performed by XPDR 5000, and vice versa. As used herein, a predetermined transponder operation can be at least one predetermined communication operation, at least one predetermined sensing operation, or at least one predetermined power management operation, or a combination of at least two of a predetermined communication operation, a predetermined sensing operation, or a predetermined power management operation. In the context of plural operations, a predetermined transponder operation may be a combination of at least two of a predetermined communication operation, a predetermined sensing operation, or a predetermined power management operation that is executed in a predefined transponder operation sequence. A predetermined operational mode may be, without limitation, a predetermined periodic operational mode, a predetermined interrogator demand operational mode, a predetermined transponder demand operational mode, or a predetermined combination operational mode. A predetermined combination operational mode may include two or more predetermined transponder operations respectively corresponding to two or more of a predetermined periodic operational mode, a predetermined interrogator demand operational mode, or a predetermined transponder demand operational mode.

[0076] In a predetermined periodic operational mode, XPDR 5000 may repeat a predetermined transponder operation, or a predetermined sequence of predetermined transponder operations, with a respective transponder operation periodicity. Periodicity generally describes an interval between, or alternatively, a frequency of, a transponder operation occurrence. A transponder operation periodicity may be selectable and a selectable transponder operation periodicity may be set in response to a selectable transponder operation periodicity signal. In a predetermined interrogator demand mode, XPDR 5000 can perform a predetermined transponder operation, or a predetermined sequence of predetermined transponder operations, in response to an interrogator demand signal, for example, received from INT 5900. In a predetermined transponder demand mode, XPDR 5000 can perform a predetermined transponder operation, or a predetermined sequence of predetermined transponder operations, in response to a transponder demand signal produced within XPDR 5000. A transponder demand signal may correspond to a predefined characteristic alert, to a transponder parameter alert, or to a transponder programmatic signal. Typically, a transponder parameter alert is indicative of a predefined transponder state, for example, a voltage, a current, a temperature, or a logic state. A transponder programmatic signal can be produced by programmed instructions, which may be executed within XPDR 5000.

[0077] An operational mode of XPDR 5000 may be switched in response to a preselected mode management signal. Without limitation, a preselected mode management signal may include, may produce, or may cause to be produced, an interrogator demand signal, a transponder demand signal, a predefined frequency selection signal, a preselected protocol selection signal, or a selectable operation periodicity signal. In selected embodiments, XPDR 5000 may be switched between a first predetermined operational mode and a second predetermined operational mode, responsive to a first preselected mode management signal. For example, in such embodiments, XPDR 5000 may operate in a predetermined interrogator demand operational mode as a first predetermined operational mode and, in response to a first preselected mode management signal, XPDR 5000 may operate in one of a predetermined periodic operational mode or a predetermined transponder demand operational mode, as a second predetermined operational mode. Similarly, responsive to a second preselected mode management signal, certain embodiments of XPDR 5000 may be switched between a second predetermined operational mode, and one of a first predetermined operational mode or a third predetermined operational mode. Non-limiting examples of a preselected mode management signal may be a timer signal, an interrogator demand signal, or a transponder demand signal, including a predetermined sensed subject parameter.

[0078] XPDR 5000 can include transponder controller module (TCM) 5100, power management module (PMM) 5200, sensor module (SDM) 5300, and RF module (RFM) 5400. As used herein, the term "transponder electrical circuitry," or its equivalent, pertains to all, or to an electrically segregable circuit portion, of XPDR 5000 electrical circuitry, including one or more of TCM 5100, PMM 5200, SDM 5300, or RFM 5400. TCM 5100 may include microcontroller (uC) 5110 and memory (MEM) 5160. MEM 5160 may be representative of a memory element, in general, so that MEM 5160 may include volatile memory, including RAM, non-volatile memory, including EEPROM or NVRAM, or both. In general, uC 5110 can operate in accordance with executable instructions corresponding to stored operating system code (OS) 5112, to stored application program code agents 5114, or to both. OS 5112 is not required to be a formal operating system or a virtual machine, but may be suitable and sufficient operating instructions incorporated in firmware coupled to uC 5110 or, alternatively, integrated within uC 5110. However, certain selected ones of TCM 5100 embodiments may realize OS 5112, at least in part, in a bytecode language, which may be interpreted or dynamically compiled. Similarly, agents 5114 can be suitable and sufficient application program instructions, which may execute one or more functions corresponding to causing XPDR 5000 to perform, without limitation, a predetermined transponder operation. TCM 5100 generally may operate in a manner similar to a Smart Card, for example, using a microcontroller, memory, security coprocessor and a communication interface, which may be an RF interface. Although selected implementations of XPDR 5000 may implement a selected feature described in one or more parts of multi-part standard ISO/IEC 7816, performing contactless, proximity-type (e.g., less than about 1 meter) LF communication, XPDR 5000 embodiments are not constrained to conform to ISO/IEC 7816, or to proximity-type communications.

[0079] In some selected embodiments, cryptographic engine 5190 may perform selected cryptographic functions, including communication encryption and decryption, a cryptographic key function, entity authentication and certificate management. In other selected embodiments, operating system code 5112 and agents 5114 may cause uC 5110 to perform selected cryptographic functions. An example of a cryptographic key function may include generation of a public-key infrastructure (PKI) key pair corresponding to XPDR 5000. TCM 5100 also may include secure non-volatile memory (SECMEM) 5170, for example, to secure store sensitive information, such as a PKI key pair. Typically, access to data stored in SECMEM 5170 may be limited to access by TCM 5100, so that malicious access or errant code operations may be thwarted. SECMEM 5170 may store subject data securely. TCM 5100 may include one or more functional elements such as operations mode manager (OPM) 5120, power manager 5130, sensor manager 5140, and communication manager 5150. In some embodiments, OPM 5120, power manager 5130, sensor manager 5140, and communication manager 5150 can be representative of one or more functions of TCM 5100, which may be implemented physically, logically, or in a functional combination thereof. One or more of the functions described with respect to OPM 5120, power manager 5130, sensor manager 5140, or communication manager 5150 may be implemented, at least in part, by uC 5110 under the direction of OS 5112 and agents 5114. Typically, OPM 5120 cooperates with uC 5110 to control operation of XPDR 5000, in conjunction with operating system code 5112 and agents 5114. For convenience, OPM 5120 may be said to "control" an operation of one or more of power manager 5130, sensor manager 5140, and communication manager 5150, or of XPDR 5000, TCM 5100, PMM 5200, SDM 5300, or RFM 5400, alone or within the context of such cooperative interaction with uC 5110. In general, OPM 5120 may select, and may cause XPDR 5000 to operate in, a predetermined operational mode. Also, OPM 5120 may select, and may cause XPDR 5000 to perform, a predetermined transponder operation corresponding to the predetermined operational mode.

[0080] OPM 5120 can monitor one or more of power manager 5130, sensor manager 5140, or communication manager 5150, and may receive therefrom, a transponder power status signal, a transponder status signal, or a transponder communication status signal, respectively. OPM 5120 may characterize one or more of the transponder power status signal, the transponder sensor status signal, or the transponder communication status signal, as a transponder parameter alert. A transponder parameter alert may be indicative of a transponder condition including, without limitation, a power source state, a sensor functional state, or a transceiver operational state. A transponder parameter alert indicative of a deleterious transponder condition may be, for example, a low battery or power malfunction state, a sensor malfunction state, or a transceiver fault state. However, a transponder parameter alert is not required to indicate a deleterious transponder condition. OPM 5120 may cause a transponder parameter alert to be communicated selectively to INT #1 5900, for example, as an outbound IAT message. Also, OPM 5120 may receive a predefined characteristic alert from sensor manager 5140. A predefined characteristic alert may be indicative of a notable condition corresponding to monitored subject 5800

including, without limitation, a physiological state, a wellness state, a safety state, or an environmental condition. OPM may cause a predefined characteristic alert to be communicated selectively to INT #1 5900, for example, as an outbound IAT message. In addition, OPM 5120 may receive at least one of a transponder programmatic signal from uC 5110, or a wake-up signal from communication manager 5150.

[0081] To control PMM 5200, OPM 5120 may transmit a power management signal to power manager 5130. To control SDM 5300, OPM 5120 may transmit a sensor management signal to sensor manager 5140. Similarly, to control RFM 5400, OPM 5120 may transmit a communication management signal to communication manager 5150. In addition, OPM 5120 may include one or more timing controllers, and may provide a timing signal, a synchronization signal, or both, to one or more of power manager 5130, sensor manager 5140, or communication manager 5150. Alternatively, one or more of power manager 5130, sensor manager 5140, or communication manager 5150, may incorporate therein a respective timing controller, which may operate independently of, or in cooperation with, OPM 5120, to provide a timing signal, a synchronization signal, or both, to respective PMM 5200, SDM 5300, or RFM 5400. OPM 5120 may be configured to characterize as a transponder demand signal, one or more of a transponder parameter alert, a predefined characteristic alert, or a predetermined programmatic signal. In response, OPM 5120 may produce a preselected mode management signal, and may change an operational mode of XPDR 5000. A preselected mode management signal may include one or more of a power management signal, a sensor management signal, or a communication management signal. In addition, OPM 5120 may transmit a preselected mode management signal to uC 5110, and may cause uC 5110 to execute program code effecting a change of a predetermined operational mode.

[0082] OPM 5120 may control a predetermined operational mode of XPDR 5000, by selectively controlling one or more of power manager 5130, sensor manager 5140, or communication manager 5150, in accordance with the predetermined operational mode. In one general example, OPM 5120 may selectively control power manager 5130 which, in turn, may direct PMM 5200 to selectively supply or remove electrical power to transponder electrical circuitry corresponding to a predetermined transponder operation, in accordance with the predetermined operational mode. As another general example, OPM 5120 may selectively control sensor manager 5140 which, in turn, may direct SDM 5300 to selectively sense one or more predetermined sensed subject parameter, corresponding to a predetermined transponder operation, in accordance with the predetermined operational mode. In yet another general example, OPM 5120 may selectively control communication manager 5150 which, in turn, may direct RFM 5400 to selectively operate a transceiver, corresponding to a predetermined transponder operation, in accordance with the predetermined operational mode. OPM 5120 may selectively control power manager 5130 and one or both of sensor manager 5140 or control communication manager 5150, using a predetermined transponder operation sequence, in accordance with the predetermined operational mode. In some embodiments, electric power may be supplied

substantially constantly to predetermined sentinel circuits of transponder electrical circuitry, in accordance with the predetermined operational mode. An example sentinel circuit may include a portion of sensor manager and a preselected one of sensors 5310, 5320, or 5330, which may receive electric power when SDM 5300 is quiescent, so that a selected sensed physical quantity meeting or exceeding a preselected parameter value may activate XPDR 5000 and cause a corresponding alert to be transmitted to INT 5900.

[0083] In a predetermined periodic operation mode, OPM 5120 may cause XPDR 5000 to operate periodically during at least one predetermined periodic operating period. One non-limiting example of an operational sequence corresponding to a predetermined periodic operation may include OPM 5120 causing PMM 5130 to supply power to RFM 5400 and causing communication manager 5150 to transmit a predetermined periodic signal from RFM 5400, for example, to emit a "ping" for detection by an external receiver. Another non-limiting example of a predetermined periodic operation may include OPM 5120 effecting a sequence including one or more of causing PMM 5200 to supply power to SDM 5300, causing SDM 5300 to sense a selected subject parameter, causing PMM 5200 to terminate power to SDM 5300 after sensing and to supply RFM 5400, causing communication manager 5150 to transmit the sensed selected subject parameter through RFM 5400, or causing PMM 5200 to terminate power to RFM 5400 after the sensed selected subject parameter is transmitted. Periodic transponder operation may reduce power consumption over time as compared to uninterrupted transponder operation, which may prolong an operational lifetime of power source 5600. Of course, OPM 5120 may be configured to operate in other predetermined periodic operation modes.

[0084] In a predetermined interrogator demand operational mode, OPM 5120 may cause XPDR 5000 to operate in response to a demand received by RFM 5400, for example, from INT 5900. Communication manager 5150, alone or in coordination with alert monitor 5450, may implement a well-known "WAKE ON RADIO" function, which may be representative of a predetermined interrogator demand operational mode. One non-limiting example of an operational sequence corresponding to predetermined demand operational mode can include OPM 5120 receiving a wake-up call from alert monitor 5450, and in turn, causing PMM 5130 to supply power to RFM 5400, causing uC 5110 to receive a demand for a predetermined demand subject datum through RFM 5400, causing PMM 5130 to supply power to SDM 5300, causing SDM 5300 to sense the predetermined demand subject datum, causing communication manager 5150 to transmit the predetermined demand subject datum through RFM 5400, and causing PMM 5130 to terminate power to SDM 5300 and RFM 5400 after the sensed demand subject datum is transmitted. OPM 5120 may be configured to operate in other predetermined demand operation modes.

[0085] In a predetermined transponder demand operational mode, OPM 5120 may cause XPDR 5000 to operate in response to a predetermined transponder demand signal produced by at least one of TCM 5100, PMM 5200, SDM 5300, or RFM 5400, and received by OPM 5120. One non-limiting and illustrative example of a predetermined transponder demand operational mode can be a transponder

registration mode corresponding to activation of XPDR 5000, as may occur upon an initial coupling of XPDR 5000 to power source 5600. In a transponder registration mode, operation of activation circuit 5210 may supply electric power to power manager 5130, which, in turn, notifies OPM 5120 of activation. In response, OPM 5120 may cause PMM 5200 to supply electric power to RFM 5400, and causes communication manager 5150 to transmit an IAT message including a TID to INT #1 5900, for example, by causing uC 5150 to retrieve the TID from SECMEM 5170 and to form an outbound IAT message bearing the TID, and by directing XCVR #1 5410 to transmit the TID from SECMEM 170 to INT #1 5900. Communication manager 5150 also may direct XCVR #1 5410 to await an inbound IAT message, which may include an SID, from INT #1 5900. In an embodiment in which INT #1 5900 supplies an SID corresponding to monitored subject 5800, XCVR #1 5410 may receive an inbound message including the SID from INT #1 5900. uC 5110 may extract and store the SID in SECMEM 5170.

[0086] One non-limiting example of an operational sequence corresponding to a predetermined transponder demand operational mode, may include OPM 5120 performing one or more of the actions: causing XPDR 5000 to operate in response to a selected sensed subject parameter, causing communication manager 5150 to transmit through RFM 5400, an outbound IAT message, including the selected sensed subject parameter, or causing PMM 5130 to terminate power to SDM 5300 and RFM 5400 after the selected sensed subject parameter is transmitted. Non-limiting examples of a selected sensed subject parameter may include a sensed monitored subject body temperature above a preselected threshold value, a predetermined sensed acoustic sound produced by a monitored subject, or a predetermined sensed operational parameter (e.g., power source voltage) corresponding to XPDR 5000.

[0087] XPDR 5000 can be configured for bidirectional data flow through RFM 5400, including data push from, or data pull by, an external device, such as INT 5900. Typically, pushed data can be received from INT 5900 by RFM 5400, and may be stored, for subsequent use by XPDR 5000, in MEM 5160, SECMEM 5170, or both. Pushed data may include, without limitation, a transponder operational configuration, a transponder sensor configuration, a transponder power configuration, a predetermined power management policy, spatial position-related information, a selected sensed physical quantity threshold, a portion of operating system instruction code, a portion of system agent program code, monitored subject-related data, monitoring system-related data, premises data, or an identification code. Monitored subject-related data may include, without limitation, a birth location, lineage data, breeding data, ownership history data, medication history data, a tracking code, or an identifier, which may be a unique subject identifier. In certain embodiments including secure non-volatile memory, selected sensitive data may be securely stored in SECMEM 5170. A non-limiting example of selected sensitive data can be a portion of monitored subject-related data. Pulled data may be data transmitted by RFM 5400 as an outbound IAT message from XPDR 5000 to INT 5900. At least a portion of pulled data may be buffered in MEM 5160, SECMEM 5170, or both. Pulled data may include, without limitation, a selected sensed physical quantity representation generated by SDM 5300; sensed positioning data

generated by SDM 5300; a configuration or status of one or more of XPDR 5000, TCM 5100, PMM 5200, SDM 5300, or RFM 5400, stored tag-side data, subject data, dynamic information, stored monitored subject-related data, stored monitoring system-related data, or an identification code. Monitored subject-related data may include, without limitation, a birth location, lineage data, medication history data, or an identifier, which may be a unique identifier of monitored subject 5800.

[0088] In a non-limiting example of one embodiment of a predetermined combination operational mode, XPDR 5000 may perform a predetermined sensing operation and a predetermined communication operation (e.g., sense and report a body temperature of monitored subject 5800) both periodically and on demand by INT 5900. In another non-limiting example, XPDR 5000 may operate in a predetermined transponder demand mode during which a predefined characteristic alert produces a transponder demand signal which, in turn, evokes a predetermined communication operation and switches XPDR 5000 to a predetermined periodic operational mode. As one non-limiting and illustrative example of a predetermined transponder operation sequence, OPM 5120 may perform one or more of the actions: direct power manager 5130 to cause PMM 5200 to supply electrical power to SDM 5300; direct sensor manager 5140 to cause SDM 5300 to selectively sense one or more selected sensed physical quantities; direct sensor manager 5140 to transfer the one or more selected sensed physical quantities to MEM 5160; direct power manager 5130 to cause PMM to supply electric power to RFM 5400 and to remove electric power from SDM 5300 after sensing; cause uC 5150 to form an outbound IAT message from the one or more selected sensed physical quantity representation retrieved from MEM 5160; direct communication manager 5150 to cause RFM 5400 to transmit the outbound IAT message to INT 5900 using XCVR #1 5410; or direct power manager 5130 to cause PMM 5200 to remove electric power from RFM 5400 and from selected portions of TCM 5100. In an example of predetermined periodic operational mode, OPM 5120 may periodically perform the aforementioned example predetermined transponder operation sequence. In an example of a predetermined interrogator demand operational mode, OPM 5120 may perform one or more actions of the aforementioned example predetermined transponder operation sequence, in response to a interrogator demand from INT 5900. Also, in an example of a predetermined transponder demand operational mode, OPM 5120 may perform the aforementioned example predetermined transponder operation sequence in response to a selected sensed physical quantity detected by SDM 5300. Of course, in view of the teachings herein, a skilled artisan would realize that the foregoing predetermined transponder operational modes and transponder operation sequences are illustrative and non-limiting examples, and that other predetermined transponder operation sequences and predetermined transponder operational modes are within the scope of the present disclosure.

[0089] Certain ones of embodiments of XPDR 5000, as well as IAT 1110-1113 in FIG. 1, may be configured to select from among a plurality of XPDR communication distribution modes, to designate an outbound IAT message recipient from among a plurality of outbound IAT message recipients, or both. Certain others of embodiments of XPDR 5000, as well as IAT 1110-1113 in FIG. 1,

may be configured to implement a predetermined XPDR communication distribution mode, having a predetermined designated outbound IAT message recipient, or both. An example of selecting an XPDR communication distribution mode may include selecting one of a unicast distribution mode, a multicast distribution mode, a broadcast distribution mode, or an anycast distribution mode. Designating an IAT message recipient may be influenced by the selected XPDR communication mode. Selected embodiments of interrogator, such as INT #1 5900 or INT #2 5901, can be configured to cooperate with an embodiment of XPDR 5000, which may be configured to communicate using one or more communication distribution modes. Certain ones of the selected embodiments of INT #1 5900 may be configured to transmit an inbound IAT interrogator demand message to XPDR 5000 including a communication mode distribution selection signal. A corresponding embodiment of XPDR 5000 may receive and may reconfigure in accordance with a communication mode distribution selection signal, for example, in cooperation with implementation of the communication mode distribution selection signal by OPS 5120.

[0090] In a unicast distribution mode, XPDR 5000 may direct an IAT message to a predetermined interrogator, e.g., INT 5900, having a predetermined interrogator address. Designating a predetermined interrogator to receive an outbound IAT message may include incorporating a predetermined interrogator address of a designated recipient interrogator into an outbound IAT message. In a multicast distribution mode, XPDR 5000 may direct an outbound IAT message to a predetermined interrogator group address, representing a predetermined interrogator group, of which one interrogator, e.g., INT 5900, may be disposed to receive and recognize an outbound IAT message transmitted by XPDR 5000. Designating a predetermined interrogator group to receive an outbound IAT message may include incorporating the designated recipient predetermined interrogator group address into an outbound IAT message. An available interrogator within predetermined interrogator group may operate to recognize and receive the outgoing IAT message from XPDR 5000. In an alternative embodiment of multicast-type designating, plural predetermined interrogator addresses, which may represent a predetermined interrogator group, may be incorporated into an outbound IAT message. In a broadcast distribution mode, XPDR 5000 may direct an IAT message to any suitable interrogator, e.g., INT 5900, disposed to recognize and receive an outbound IAT message from XPDR 5000. Designating an IAT message recipient may include identifying an outbound IAT message as a broadcast IAT message directed to an available interrogator, e.g., INT 5000. In an anycast distribution mode, XPDR 5000 may direct an IAT message to a predetermined interrogator group, which may be disposed in a predetermined group topology. Typically, at least one interrogator of the predetermined interrogator group can be selected to recognize and receive an outbound IAT message from XPDR 5000. Designating an IAT message recipient in an anycast distribution mode may include providing, in the IAT message, a predetermined range of interrogator group addresses within the predetermined interrogator group topology, from which is selected a recipient interrogator, such as INT 5900. In certain anycast embodiments, a predetermined interrogator group topology may include an interrogator router, which

may select a recipient interrogator for the outbound IAT message from XPDR 5000, which may not participate in selecting a recipient interrogator. Alternatively, XPDR 5000 may cooperate with an interrogator router to select a recipient interrogator. A non-limiting example of an interrogator router may be MRT 1400 or SUPERVISOR 1550 in FIG. 1. However, one or more of XPDR 5000, as well as
5 of IAT 1110-1113 in FIG. 1, may represent a cooperating routing element of an IEEE STD. 802.15.4-related pervasive network, which may be an ad hoc, multi-hop network.

[0091] PMM 5200 may include activation circuit 5210, voltage regulator (V/R) 5220, and power manager 5130. Power manager 5130 may be controlled, at least in part, by OPM 5120. Power manager 5130 also may be integrated into other elements of TCM 5100. In general, PMM 5200 may
10 selectively control electrical power received from power source 5600 and distributed to TCM 5100, SDM 5300, and RFM 5400. Responsive to power manager 5130, PMM 5200 may supply or remove electric power from power source 5600 to one or more modules, or to one or more functional element of a module, to respectively energize or de-energize at least a portion of transponder electrical circuitry, in accordance with a predetermined operational mode. Power manager 5130 may operate PMM 5200 in
15 accordance with a predetermined power conservation policy, which may correspond to a predetermined operational mode. Embodiments of PMM 5200 may employ voltage regulator (V/R) 5220 to maintain a substantially constant voltage output from PMM 5200 to at least one of TCM 5100, SDM 5300, or RFM 5400. Stabilization of power source 5600 output by V/R 5220 may assist in consistent operation of XPDR 5000 and may help to reduce energy loss to power source 5600. V/R 5220 also may provide
20 voltage regulation and low voltage drop-out protection in embodiments in which energy harvesting module 5150 may be employed. A suitable example of a voltage regulator, which may be used as V/R 5220 may be a TI TPS 73130DBVT, which is a low dropout voltage linear voltage regulator with reverse current protection, produced by Texas Instruments, Inc. Dallas, TX, USA. Other suitable voltage regulators may be used. Power manager 5130 can be used to control voltage applied, or current
25 flowing, from power source 5600 and through XPDR 5000. In one embodiment, power manager 5130 may include a switch-mode power converter which may assist in efficient transfer of electric energy from power source 5600 to XPDR 5000 electrical circuitry. Alternatively, power manager 5130 may include a simple power switch.

[0092] Activation circuit 5210 can be used to couple power source 5600 to electrical circuitry
30 of XPDR 5000, when tag 2000 is intimately affixed to monitored subject 5800, for example, as described with respect to activation element 2900 in FIGS. 2A-2C, FIG. 3, and FIG. 4. In certain embodiments, activation circuit 5210 may include activation element 2900, having a conductive property. XPDR 5000 may be activated when a conductive property of activation element 2900 is altered, for example, using a "BREAK"-type circuit, using a "MAKE"-type circuit, or using an "AUTO-
35 ACTIVATE" circuit. One non-limiting example of a "BREAK"-type activation circuit is described with respect to FIG. 6A. Another non-limiting example of a "BREAK"-type activation circuit is described with respect to FIG. 6B. One non-limiting example of a "MAKE"-type activation circuit is described

with respect to FIG. 6C. One non-limiting example of an "AUTO-ACTIVATE" circuit is described with respect to FIG. 6D.

[0093] In selected embodiments of XPDR 5000, electrical activation of XPDR 5000 may cause OPM 5120 to place XPDR 5000 in a predetermined transponder demand operational mode and to initiate a predetermined transponder REGISTRATION operation sequence. A predetermined transponder REGISTRATION sequence may include transmitting an outbound IAT registration message including a TID corresponding to XPDR 5000. In a non-limiting and illustrative example of a transponder REGISTRATION operation sequence, OPM 5120 may direct power manager 5130 to cause PMM 5200 to supply electrical power to uC 5110, communication manager 5150, SECMEM 5160, and at least a portion of RFM 5400. In addition, OPM 5120 may place XPDR 5000 into a predetermined periodic operational mode, which may correspond to a predetermined transponder REGISTRATION sequence, in which RFM 5400 periodically transmits an outbound IAT registration message by way of XCVR #1 5410 using one of a first selected communication technique or a second selected communication technique. In an embodiment of XPDR 5000, a corresponding TID may be stored securely in, and retrieved from, SECMEM 5170. In addition, communication manager 5150 may cause the outbound IAT registration message to be transmitted in accordance with a preselected transponder communication protocol, for example, a TRANSPONDER TALKS FIRST communication protocol. Transmission from XPDR 5000 may be configured as a continuing periodic broadcast, with a period of about 2 seconds, until an interrogator, such as INT 5900, receives, and acknowledges receipt of, XPDR 5000 TID. Upon receipt of an ACK from INT 5900, OPM 5120 may direct communication manager 5150 to change operation to a TRANSPONDER LISTENS FIRST communication protocol, and to place XPDR 5000 in a predetermined interrogator demand operational mode. In such a transponder state, XPDR 5000 may await additional data to be pushed from INT 5900. Non-limiting examples of additional data may include, without limitation, transponder configuration information, an SID to be associated with XPDR 5000 TID, or both. An SID may be a UID. Transponder configuration information may be stored in MEM 5160, and may be used by XPDR managers, including OPM 5120, power manager 5130, sensor manager 5140, or communication manager 5150, to operate XPDR 5000 selectively. In a non-limiting example, transponder configuration information may include a rule for sensing a preselected subject parameter by SDM 5300, a rule for sensor manager 5140 to define a predetermined subject state alert, a destination communication address for communication manager 5150 to direct XCVR #1 5410 to transmit such an outbound IAT message having a predetermined subject state alert, or one or more commands which may direct OPM 5120 to alter a transponder operation, or a transponder operational mode, in response to an occurrence of the predetermined subject state alert.

[0094] XPDR 5000 also can employ SDM 5300 to perform a predetermined sensing operation, which can include one or both of sensing a physical quantity in proximity with XPDR 5000, or transforming the sensed physical quantity representation to a sensed data signal, which may be

communicated to INT 5900. SDM 5300 may include one or more sensors SENSOR #1 5310, SENSOR #2 5320, or SENSOR #N 5330. A sensor can be a transducer configured to sense a measurable physical property of a physical system, and to produce a measurand representative of an attribute of the measurable physical property. A measurable physical property may be a mechanical, an electrical, a chemical, an optical, or a biological property. An attribute may be static, substantially static, partially dynamic, or substantially dynamic in nature. The physical system may be monitored subject 5800, an environment in which monitored subject 5800 exists, or an environmental context of monitored subject 5800. The measurand may represent a qualitative attribute, a quantitative attribute, or both. A quantitative attribute can be representative of a magnitude of a physical property being measured. A qualitative attribute may indicate a presence or absence, relative or absolute, of a physical property, including the occurrence of a quantitative attribute magnitude, relative to a predetermined attribute threshold. As used herein, the term preselected subject parameter can be representative of a measurand of a preselected measurable physical property of monitored subject 5800, of an environment in which monitored subject 5800 exists, such as proximate environment 5850, or an environmental context of monitored subject 5800, for example, a premises, a range, a pen, a housing unit, or a transporter. A selected sensed physical quantity can be a selected sensed subject parameter corresponding to monitored subject 5800, or a selected sensed ambient physical quantity, detectable in an environment proximate to monitored subject 5800. A predetermined sensing operation also may include one or more of monitoring a predefined sensed data signal, identifying a predetermined sensed data characteristic in one or more sensed data signals, or producing a predefined characteristic alert corresponding to one or more sensed data characteristic. A predefined characteristic alert may be produced in response to sensed data, or in response to an inference from sensed data. Non-limiting examples of a physical property of an environment in which monitored subject 5800 exists may be an ambient weather condition surrounding subject 5800; an environmental context of monitored subject 5800 may be a geospatial location of subject 5800. Non-limiting examples of a quantitative attribute corresponding to monitored subject 5800 may be an acceleration value, a corpus temperature value, or a cardiac pulse rate, as well as an inertial movement of subject 5800. The term corpus refers herein to at least a portion of the body of monitored subject 5800. A non-limiting example of an absolute qualitative attribute may be a presence of a preselected ambient sound; and a non-limiting example of a relative qualitative attribute may be a corpus temperature of monitored subject 5800, which exceeds a predetermined corpus temperature threshold.

[0095] Sensor manager 5140 may selectively control a sensor SENSOR #1 5310, SENSOR #2 5320, or SENSOR #N 5330 to sense a preselected subject parameter. SDM 5300 can include one or more sensors integrated with XPDR 5000, as represented by SENSOR #1 5310 or SENSOR #2 5320. In selected embodiments, SDM 5300 may include one or more sensors apart from XPDR 5000, such as SENSOR #N 5330. SENSOR #N may be representative of a sensor implanted in, or separately attached to, monitored subject 5800, but at least partially detached from XPDR 5000. XPDR 5000 may be

configured to receive sensed data from SENSOR #N, for example, by a wired or a wireless link. SDM 5300 may employ sensor manager 5140 to control operation of an integrated sensor, such as SENSOR #1 5310 or SENSOR #2 5320. Sensor 5140 also may control operation of detached SENSOR #N 5330. Sensor 5140 can be configured to selectively cause one or more of SENSOR #1 5310, SENSOR #2 5320, or SENSOR #N 5330 to sense preselected subject parameter to provide sensed data to uC 5110. In addition, SMM 5340 may monitor and characterize sensed data of one or more of SENSOR #1 5310, SENSOR #2 5320, or SENSOR #N 5330 and, in response to a predetermined sensed characteristic, sensor manager 5140 may provide one or both of OPM 5120 or uC 5110 with a sensed parameter alert, in accordance with a predetermined transponder demand operational state. Sensor manager 5140 can cooperate with one or both of uC 5110 or OPM 5120 to selectively cause a predetermined subject parameter to be sensed, reported, or both by a sensor coupled to SDM 5300. Sensor manager 5140 also may cooperate with one or both of uC 5110 or OPM 5120 to selectively produce and act upon an inference from one or more of sensed data, subject data, or dynamic information. Sensor manager 5140 may be a constituent of SDM 5300 and may be controlled, at least in part, by TCM 5100.

[0096] A non-limiting example of a suitable implementation of a sensor, such as SENSOR #1 5310, may be a MEMS accelerometer, configured to sense an acceleration of monitored subject 5800. An accelerometer sensor may sense an acceleration representative of a predefined motion of monitored subject 5800, including, without limitation, a locomotive motion, a posturing motion, a posture, or a behavior. SENSOR #1 may be an accelerometer array, capable of sensing acceleration of subject 5800 relative to two or more directions. In selected embodiments, SENSOR #1 5310 may be configured as a sensor accelerometer array having constituent accelerometers configured to sense motions occurring on disparate scales, for example, two or more of a large-scale motion, a medium-scale motion, or a small-scale motion. It may be possible to characterize motions, which may occur on more than one scale, or in a predetermined order, into at least one predetermined subject state, which also may be an inferred subject state. Also, an accelerometer array, such as SENSOR #1 5310, may include one or more accelerometers configured to sense motions, occurring on disparate scales, for example, two or more of a large-scale motion, a medium-scale motion, or a small-scale motion. A non-limiting example of a large-scale motion monitored subject 5800 may be locomotion or a posturing motion, such running or shaking a head. A non-limiting example of a medium-scale motion may be a posture, a change of posture, or a bodily function motion, including reclining, trembling, tilting, chewing, or scratching. A medium-scale motion also may correspond to an inferred individual or a social behavior or an emotive state. A non-limiting example of a small-scale motion may be a motion corresponding to a pulse, a blood pressure, a respiration, or other physiologically-based motion of monitored subject 5800. A small-scale motion also may be indicative of an individual or social behavior, or an emotive state, e.g., rapid pulse or respirations. It may be possible to characterize motions, which may occur on more than one scale, or in a predetermined order, into one or more presumed predetermined subject state. In addition, one or both of a medium-scale motion or a small-scale motion also may correspond to

mechanical motions, including an acoustic signal produced by, or in the presence of, monitored subject 5800. For example, a loud bellow emitted by monitored subject 5800 may produce sufficient mechanical motion to be sensed by an accelerometer of corresponding scale, which may be an element of SENSOR #1 5310. As another example, a loud ambient sound, such as a nearby clap of thunder, may produce sufficient mechanical motion to be sensed by an accelerometer of corresponding scale, which may be an element of SENSOR #1 5310. SENSOR #1 sensed data may be corroborated, for example, by another sensor, by observation, or by known ambient conditions.

[0097] Sensor #1 5310 may be configured to provide inertial motion and positioning (IMP) data corresponding to monitored subject 5800, which may be used to identify one or more of monitored subject 5800 motion or geolocation. In certain selected embodiments XPDR 5000, SENSOR #1 5310 may be an angular motion sensor configured to provide inertial motion and positioning (IMP) data corresponding to monitored subject 5800. Ones of certain selected embodiments of SENSOR #1 5310 may combine an accelerometer-based sensor with an angular motion sensor, to provide inertial motion and positioning (IMP) data corresponding to monitored subject 5800. INT 5900 may determine geospatial information from IMP data received from XPDR 5000, which may be used to identify, track, or predict a behavior or a geospatial position of monitored subject 5800.

[0098] Another non-limiting example of a suitable implementation of a sensor, such as SENSOR #1 5310, SENSOR #2 5320, or another sensor, including SENSOR #N 5330, may be an acoustic sensor, configured to sense an acoustic sound corresponding to monitored subject 5800. An acoustic sensor may be configured to sense a vocalized sound, a corpus sound, or an ambient sound. A vocalized sound can be indicative of a predetermined emotive, social, or survival behavior of monitored subject 5800. For example, a vocalized sound may be associated with a breeding behavior, a social dominance behavior, a feeding behavior, a parenting behavior, or a defensive behavior. A vocalized sound, sensed by SENSOR #1 5310, may correspond to behavior characteristic of a defensive response to a threat from a nearby predator. Another non-limiting example of a sensor, such as SENSOR #1 5310, SENSOR #2 5320, or another sensor, including SENSOR #N 5330, may be a thermal sensor configured to sense a temperature relative to monitored subject 5800, including a subject body temperature, or an ambient temperature. In general, XPDR 5000 may be proximately affixed to monitored subject 5800, having sufficient contact with the body of subject 5800 to yield a sensed body temperature. SENSOR #1 5310 may provide a sensed thermal parametric signal over a predetermined range of body temperatures, or may produce a sensed thermal parametric signal when a predetermined temperature threshold is met or surpassed, as may indicate hyper- or hypo-thermia of monitored subject 5800. Also, a thermal sensor, such as SENSOR #2 5320, may be used alone, or in conjunction with thermal sensor, SENSOR #1 5310, to sense an environmental temperature, a temperature difference, relative to monitored subject 5800, or a temperature gradient, relative to a predefined thermal zone proximate to monitored subject 5800. It may be possible to configure SENSOR #1 and SENSOR #2 to produce a sensed thermal gradient parametric signal, as well.

[0099] Other non-limiting examples of sensors, which may be used with XPDR 5000 as a sensor may include an impedancemetric sensor for sensing water vapor or humidity, which may indicate a hydration state of monitored subject 5800; an electrokinetic sensor, which may sense bodily fluid transport or flow; an electrophoretic sensor for detecting a level of a substance within a fluid sample of monitored subject 5800, or a biopotential sensor for identifying electrophysiological events including one or more of EEG (electroencephalogram), ECG (electrocardiogram), and EMG (electromyogram) waves.

[00100] A suitable sensor configuration selected for an embodiment of XPDR 5000 may recognize a balance of XPDR 5000 features including, without limitation, intended transponder environment, transponder application, or expected transponder lifespan; monitored subject lifespan; power availability, power renewability, or energy harvesting availability; sensor type, location, or sturdiness; data generation, data storage, or data offloading; telemetry burden; or cost. In view of the teachings herein, it may become apparent that, in general, sensors used with various embodiments of XPDR 5000 may be selected pragmatically from a full-range of suitable mechanical, electrical, optical, chemical, or biological sensors, which may be implemented using, implanted, minimally-invasive, microsensor or MEMS technologies.

[00101] Sensor manager 5140 can receive at least one selected subject parameter and can produce a subject inferent indicative of a predetermined inferred state of monitored subject 5800. A selected subject parameter may be one or more of subject data, dynamic information, or a subject state. A non-limiting example of a predetermined inferred state may include thermal distress, a hydration state, environmental distress, birthing, breeding, illness, predation, or a social behavior. In one non-limiting example, SENSOR #1 5310 may sense a corpus temperature in monitored subject 5800 indicative of hyperthermia, SENSOR #2 5320 may sense a corpus heart rate indicative of tachycardia, and SENSOR #N may be an acoustic sensor, which detects a corpus sound indicative of rapid, labored breathing. Sensor manager 5140 may be configured to characterize respective inputs received from one or more of SENSOR #1 5310, SENSOR #2 5320, or SENSOR #N 5330, as characteristic of a dehydration state and, in response thereto, also may be configured to produce a subject inferent corresponding to a sensed parameter alert indicating dehydration, in accordance with a predetermined transponder demand operational state. Continuing with the non-limiting example, OPM 5120 may receive the sensed parameter alert indicating dehydration and, in response, evoke a predetermined transponder communication operation, causing RFM 5400 to transmit a selected subject state alert to INT #1 5900. INT #1 5900 may be a handheld platform, such as HMM 1525 in FIG. 1, operated by steward 1500. INT #1 5900 may produce a perceptible representation of a selected subject state alert, to which the steward 1500 may respond. In another non-limiting example, sensor manager 5140 may characterize one or more received input from SENSOR #1 5310, SENSOR #2 5320, or SENSOR #N 5330, which may be indicative of an inferred state, such as transport state indicative of monitored subject 1020 being transported or prepared for transport, with a corresponding subject inferent causing a predetermined

subject state alert to be transmitted to INT 5900. Miniaturized sensors, including the example MEMS sensors described above, are well-known in the remote sensor arts.

[00102] RFM 5400 may incorporate an RF transceiver, as represented by XCVR #1 5410, by which RFM 5400 may selectively transmit or receive communicated data, including an IAT message, with at least one remote interrogator (INT) 5900. XCVR #1 5410 may be configured to communicate using one or more selected communication techniques. For example, XCVR #1 5410 may be configured to communicate using a first selected communication technique, or a first and a second selected communication technique. In certain embodiments, XCVR #2 5411 may represent one or more additional transceivers, which may be configured to communicate using one or more selected communication techniques, and which may cause RFM 5400 to selectively communicate an IAT message to plural interrogators, such as INT#1 5900 and INT #2 5901. In one example embodiment, XCVR #1 5410 may communicate using a first selected WPAN communication technique and a second selected WPAN communication technique. In another example embodiment, XCVR #1 5410 may communicate using a first selected WPAN communication technique and a first selected WLAN communication technique. In yet another example embodiment, second transceiver XCVR #2 5411 may communicate using a first selected WMAN communication technique and a first selected WAN communication technique. In still another example embodiment, XCVR #1 5410 may communicate using a first selected WPAN communication technique and a first selected WLAN communication technique, and second transceiver XCVR #2 5411 may communicate using a first selected WMAN communication technique. In view of the present teachings, one of ordinary skill in the art would realize that other foreseeable combinations of transceivers, and selected communication techniques, can be contemplated.

[00103] In selected embodiments of RFM 5400, two or more selected communication techniques, for example, the first selected communication technique and the second selected communication technique, may share one or both of a physical (PHY) layer and a media access control (MAC) layer, and XCVR #1 5410 may be configurable to communicate using two or more such selected communication techniques. Also, in selected embodiments, XCVR #1 5410 may be representative of a single configurable RF transceiver, which may be selectably configured to communicate using a first selected communication technique or a second selected communication technique. In some embodiments, a configurable transceiver may be configurable to implement a third, or additional, selected communication technique. Although not so required, a first selected communication technique may be different from one or more of a second, third, or fourth selected communication technique; a first selected communication frequency band may be different from, or may overlap, one or more of a second, third, or fourth selected communication frequency band; or a first selected communication range may be different from one or more of a second, third, or fourth selected communication range.

[00104] In a non-limiting example, XCVR #1 5410 may be a radio configured in accordance with an IEEE STD. 802.15.1 interface, and employing a portion of a BLUETOOTH®-type

communication protocol, to communicate over a first preselected communication range of up to about 100 meters, between XPDR 5000 and INT 5900. A BLUETOOTH®-type communication protocol can be in accordance with the Bluetooth® Core Specification (26 July 2007), as promulgated by the Bluetooth® SIG, Bellvue, WA, USA. In another non-limiting example, XCVR #1 5410, which may be an LR-WPAN device or radio operating, in accordance with IEEE Std. 802.15.4-2006, within a selected one of selected communication frequency bands of between about 850 MHz to about 950 MHz, or between about 2.4 GHz to about 2.5 GHz, and having an intermediate communication range of up to at least about 100 meters, between XPDR 5000 and INT 5900. However, selected embodiments of an IEEE Std. 802.15.4-type device or radio may be configured to communicate over a long communications range of at least 1000 meters. An embodiment of one or both of XCVR 5410, 5411 may include a radio configured in accordance with an IEEE Std. 802.15.4 interface, which may employ a portion of an IEEE Std. 802.15.4 communication protocol, including a portion of an IEEE Std. 802.15.4 communication stack. Also, an embodiment of one or both of XCVR 5410, 5411 may include a radio configured in accordance with an IEEE Std. 802.15.4 interface, which may employ a ZigBee®-type communication protocol, including a portion of a ZigBee®-type communication stack. A ZigBee®-type communication protocol can be in accordance with the ZigBee® Specification (Dec. 2006), as promulgated by the ZigBee® Alliance, Inc., San Ramon, CA, USA. An embodiment of one or both of XCVR #1 5410 or XCVR #2 5411 may use a selected communication technique, which may include a portion of an IEEE Std. 802.15.4-2006 protocol stack and a portion of a ZigBee® protocol stack.

[00105] In an alternative embodiment of XPDR 5000, XCVR #1 5410 may be configured as an UWB-WPAN device or radio operating, in accordance with IEEE Std. 802.15.4a-2007, using a first selected communication technique within a first selected communication frequency band of between about 2.4 GHz to about 2.5 GHz, which may communicate with INT 5900 up to a distance of up to about 100 meters. XCVR #1 5410 also may be configured as an LR-WPAN device or radio operating, in accordance with IEEE Std. 802.15.4-2006, using a second selected communication technique, which may be a ZigBee®-type communication technique, within a first selected communication frequency band of between about 2.4 GHz to about 2.5 GHz, which may communicate with INT 5900 up to a distance of up to at least about 1000 meters. In yet another alternative embodiment of XPDR 5000 including a second transceiver, XCVR #2 5411 may be a radio operating in accordance with IEEE Std. 802.15.1-2005, using a third selected communication technique, which may be a Bluetooth®-type communication technique, within a first selected communication frequency band of between about 2.4 GHz to about 2.5 GHz, which may communicate with INT 5900 up to a distance of up to about 10 meters. In another alternative example embodiment, XCVR #2 5411 may be configured as a WLAN radio operating, in accordance with one of an IEEE Std. 802.11-2007, using a WiFi®-type communication technique, within selected communication frequency bands of between about 2.4 GHz to

about 2.5 GHz, or between about 5.0 GHz to about 6.0 GHz, which may communicate with INT 5900 up to a distance of at least about 1000 meters.

5 [00106] TCM 5100 may operate to cause RFM 5400 to communicate using upper OSI layer protocols exemplified, without limitation by a well-known TCP/IP protocol, or a well-known Session Initiation Protocol (SIP). By comparison, a selected communication technique such as a WPAN, a WLAN, a WMAN, or a WAN communication technique may be a lower OSI layer protocol. A selected communication technique may be logically constituted of a hierarchy, or "stack," of one or more lower OSI layer protocols, alone or in cooperation with, one or more upper OSI layer protocols. For example, TCM 5100 may execute a program to cause RFM 5400 to communicate with INT 5900 using a selected
10 communication technique, which may encompass a stack using both a lower OSI layer protocol (e.g., a LR-WPAN communication technique) and an upper OSI layer protocol. (e.g., a combination of a TCP/IP protocol and an SIP protocol). . Selected communication techniques may use lower OSI layer protocols to exchange an outbound IAT message between XPDR 5000 and INT 5900. Upper OSI layer protocols may assist in pushing an outbound IAT message, including data pertaining to monitored
15 subject 5800, to a remote receiver, which may be coupled to INT 5900 by way of a public internet, as illustrated with respect to FIG. 1.

[00107] Embodiments of XPDR 5000 may be capable of communicating using multiple selected communication techniques, which may be respective selectable communication techniques. Selected embodiments of TCM 5100 may direct communications manager 5150 to select between a first
20 selectable communication technique and a second selectable communication technique, alone or in cooperation with OPM 5120. For example, communication manager 5150 may be configured to select between a first selectable communication technique and a second selectable communication technique, responsive to a communication technique selection signal received from OPM 5120. OPM 5120 may be configured to perform context-aware communication technique selection, producing a communication
25 technique selection signal in response to a detected transponder context, for example, corresponding to a sensed subject parameter, a subject parameter alert, or a portion of an IAT message. Communication technique selection, including context-aware communication technique selection, may correspond to a predetermined operational mode. In one non-limiting example, a selected sensed physical quantity representation may be exchanged in an outbound IAT message using a first selectable communication
30 technique in a first predetermined operational mode, and a subject parameter alert may be exchanged in an outbound IAT message using a second selectable communication technique in a second predetermined operational mode. Alternatively, communication manager 5150 may be configured to perform context-aware communication technique selection without receiving a communication technique selection signal from OPM 5120.

35 [00108] Also, XPDR 5000 may include passive RF element 5490, and may be configured such that uC 5150 may access data stored in passive RF element 5490, may modify stored data, or both. Alternatively, passive RF element 5490 may be configured as a semi-passive, or battery-assisted passive

RFID element. For example, an embodiment of XPDR 5000 may provide electrical power to a semi-passive embodiment of RF element 5490; for example, to increase backscatter coupling communication range. In another non-limiting embodiment of XPDR 5000, a second transceiver XCVR #2 5411 may be used to implement proximity-range communication, where XCVR #2 5411 may communicate over
5 selected communication range of up to about 0.5 meter. Proximity communication may employ capacitive or inductive coupling, as is well-known in the art of contactless RFID devices, including Smart Card devices.

[00109] RFM 5400 may be coupled to a single antenna element 5500, which may be shared by plural transceivers 5410, 5411, or may be coupled to plural antenna elements 5500, 5501. Plural
10 antenna elements 5500, 5501 may correspond to respective plural transceivers 5410, 5411, although such is not required. In a single-antenna/multiple-transceiver embodiment, antenna element 5500 may be configured to communicate on plural communication frequency bands. As described with respect to antenna module 4400 in FIG. 4, antenna 5500, 5501 may be embedded in a printed circuit board, or may be mounted on a substrate, which may be a printed circuit board. In one embodiment, one or more
15 antenna elements 5500, 5501 may be mounted in a housing of XPDR 5000. Communication manager 5150 can selectively cooperate with one or both of uC 5110 or OPM 5120 to cause RFM 5400 to perform predetermined communication functions, including communicating using one or more of a predetermined bidirectional communication protocol, a predetermined unidirectional communication protocol, or a selected collision avoidance protocol. Communication manager 5150 may be a
20 constituent of RFM 5400, and also may be controlled, at least in part, by TCM 5100.

[00110] Power source 5600 may be a component of XPDR 5000, or may be a component of tag 2000 coupled to XPDR 5000, and may be contained within power source compartment, such as power source compartment 2110, 2210, or 2310. Where housing 2100, 2200, or 2300 is a molded uni-body construction, power source 5600 might not be changed during the service life of tag 2000, which may be
25 disposed or replaced after use. One suitable embodiment of a single-use power source 5600 may be a high-energy density cell, such as a lithium/thionyl chloride primary battery, having a long service life under low continuous current or moderate pulse current requirements, a low self-discharge rate, resiliency under harsh environmental conditions, and relatively low weight and volume. A non-limiting example of a suitable lithium/thionyl chloride primary battery can be a LST-17330 battery, produced by
30 Saft of Bagnolet, France, although other types of energy cells, using different energy cell chemistry, or other types of self-contained power sources, may be used. In certain embodiments, tag 2000 and XPDR 5000 may be configured to employ a suitable rechargeable energy cell as power source 5600, which may supply comparable power during XPDR 5000 operation.

[00111] In certain selected ones of tag 2000 embodiments, PMM 2100 may include energy
35 harvesting module 5150, configured to recover and convert ambient energy into recovered electrical energy. In general, energy harvesting module 5150 can operate under control of power manager 5140. Types of ambient energy that may be converted by known energy harvesting techniques include, without

limitation, a mechanical vibration, thermal energy, an electromagnetic field, or solar power. A non-limiting example embodiment of energy harvesting module 5150 may include, at least in part, a MEMS-based piezoelectric energy generator configured to convert ambient mechanical vibrations, including subject-produced and environmental sounds, into recovered electric energy. Similarly, another non-limiting example embodiment of energy harvesting module 5150 may include, at least in part, an ambient thermal energy converter, such as a thermistor or thermocouple, which may generate recovered electric energy from an ambient thermal energy source or thermal gradient, respectively. Thermal energy may be provided, for example, by the body of the monitored subject or by a difference in temperature between the subject and the environment. Still another non-limiting example embodiment of energy harvesting module 5150 may include, at least in part, an electromagnetic energy converter, which may be configured to convert an incident RF wave into recovered electric energy. Such an embodiment of energy harvesting module 5150 may advantageously yield recovered electric energy from an incident RF signal, which may not be intended to elicit a response from tag 2000, as may occur if tag 2000 detects an incoming beacon signal addressed to a different, but nearby, active tag. In addition, an embodiment of electromagnetic energy harvesting module 5150 may convert RF signals from neighboring tags into recovered electric energy. Yet another non-limiting example embodiment of energy harvesting module 5150 may include, at least in part, a miniature solar cell or array, configured to generate recovered electric energy from ambient light, which may be incident on tag 2000. Moreover, another embodiment of energy harvesting module 5150 may be configured to convert at least two types of ambient energy into recovered electrical energy. Recovered electrical energy may be supplied to a storage capacitor, which may be a constituent of energy harvesting module 5150, and which may supplement energy drawn from power source 5600. Also, in embodiments where power source 5600 is rechargeable, an embodiment of energy harvesting module 5150 may provide a trickle charging current to at least partially replenish stored energy in power source 5600. Power manager 5130 may operate V/R 5220 to control a voltage applied to power source 5600 by energy harvesting module 5150 to provide a suitable recharging voltage profile.

[00112] FIGS. 6A-6D illustrate non-limiting example embodiments of an activation circuit, which may be suitable for use as activation circuit 5210 in FIG. 5. One of the circuits in FIG. 6A-6D may be used by an embodiment of PMM 5200 to electrically couple power source 5600 to V/R 5220. In turn, V/R 5220 may provide electrical power to at least a portion of transponder electrical circuitry 6810 of XPDR 5000. One or both of capacitor 6812 and resistor 6814 may be employed to improve one or more of source impedance, noise, or power source rejection ratio (PSRR), and may be optional. In the examples of FIGS. 6A-6E, V/R 5220 may be turned "ON," that is, rendered generally operable, by placing on enable input EN, a signal having a substantially "HIGH" or (1) logical value. Conversely, V/R 5220 may be turned "OFF," that is, rendered generally inoperable, placing on enable input EN, a signal having a substantially "LOW" or (0) logical value. Embodiments of activation circuit 5210, and example activation circuits 6000, 6100, 6200, or 6300 may permit a transponder to remain powered

down until it is applied to a corresponding monitored subject. In addition, energizing of activation circuits 5210, 6000, 6100, 6200, or 6300 may initiate a registration process of a corresponding transponder, monitored subject, or both.

[00113] FIG. 6A illustrates an embodiment of a "BREAK"-type activation circuit 6000, which may employ an activation element, such as activation element 2900 in FIG. 2C and 3B, in the form of conductive strap 6010. FIG. 6A may be an embodiment of activation circuit 5210 in FIG. 5. Prior to activation of XPDR 5000, conductive strap 6010 generally may be intact, so that the EN input is provided a substantially "LOW" or (0) logical value so that V/R 5220 may be rendered generally inoperable, and generally preventing electrical power from activating XPDR 5000. When electrical continuity of conductive strap 6010 is disrupted, it may be possible to raise a signal on enable input EN to a substantially "HIGH" or (1) logical value, causing V/R 5220 to become operable and to permit electrical power to flow to XPDR 5000. FIG. 6B illustrates another embodiment of a "BREAK"-type activation circuit 6100, which may employ an activation element in the form of plural conductive straps 6110, 6111. Activation circuit 6100 also may be an embodiment of activation circuit 5900 in FIG. 5. Activation circuit 6100 may include a logical gate, such as OR gate 6150, which is configured to resist erroneous activation, for example, by floating voltages. Prior to activation of XPDR 5000, conductive strap 6110 may generally be intact, so that the EN input and first logic input 6120 are provided with a substantially "LOW" or (0) logical value, which respectively renders V/R 5220 generally inoperable, and tends to force gate 6150 output to a logical LOW value. In addition, intact conductive strap 6111 provides second logic gate input 6121 with a substantially "LOW" or (0) logical input value, which, in conjunction with a similar value on first logic input 6120, tends to hold a substantially "LOW" or (0) logical input value on the EN input, rendering V/R 5220 generally inoperable. When electrical continuity is disrupted for one or both of conductive strap 6110, 6111, it may be possible to raise a signal on enable input EN to a substantially "HIGH" or (1) logical value, which in turn may cause V/R 5220 to become operable and to permit electrical power to flow to XPDR 5000. Capacitor 6812 may be provided to reduce an effect of non-DC frequency components on second logic gate input 6121, which may be useful to reduce spurious triggering of gate 6150. FIG. 6C generally illustrates one embodiment of a "MAKE"-type activation circuit 6200, which may employ an activation element in the form of plural conductive portions 6210, 6211. One or both of contacts 6220, 6221 may represent a conductive portion of activation element 2900, electrically connected to V/R 5220. One or both of conductive portions 6210, 6211 may be disposed on male element 2500 and may be electrically connected to power source 5600. Prior to activation of XPDR 5000, at least one of conductive strap 6210, 6211 may not be in contact with one of contacts 6220 or 6221, such that the EN input of V/R 5220 is provided with a substantially "LOW" or (0) logical value, generally rendering V/R 5220 generally inoperable, and generally preventing electrical power from activating XPDR 5000. Activation of XPDR 5000 may be effected by bringing plural conductive portions 6210, 6211 into electrical contact with plural contacts 6220, 6221, so that an electrical connection is made with V/R 5220, and the V/R EN input is provided

with a substantially "HIGH" or (1) logical value, allowing V/R 5220 to transmit electrical power to XPDR 5000 circuitry. FIG. 6D generally illustrates one type of "AUTO-ACTIVATE"-type activation circuit 6300, which may include coupled energy receiver 6325 and antifuse element 6350, electrically connected to coupled energy receiver 6325. Energy receiver 6325 may be a power coil, of a type well-known in the arts. Prior to activation of XPDR 5000, antifuse element 6350 may appear as a large input impedance to V/R 5220, for example, on the order of mega-ohms or tens of mega-ohms, which may substantially impair the application of electrical power by power source 5600 to XPDR 5000. Activation of XPDR 5000 may be effected by coupling a suitable amount of electromagnetic energy to coupled energy receiver 6325, which may be capable of generating activation current 6360 to pass through antifuse element 6350. Activation current 6360 may alter a conductive property of antifuse element 6350, as to appear as a relatively small input impedance to V/R 5220, for example on the order of a few tens of ohms. The altered conductive property of antifuse 6350 may permit electrical power to energize and flow through V/R 5220, substantially unimpaired. A suitable amount of electromagnetic energy may be coupled to coupled energy receiver, for example, by an LF radio transmitter employed during intimate affixment of tag 2000 to a corresponding monitored subject.

[00114] In FIGS. 7 and 8, an example embodiment of subject management system 7000 may employ tag reader system (TRS) 7010, which includes interrogator module (INT) 7100, and handheld host platform (HOST) 8000, coupled to interoperate with INT 7100. FIG. 7 illustrates respective aspects of example embodiments of TRS 7010, INT 7100, and HOST 8000 of system 7000. FIG. 8 illustrates other respective aspects of example embodiments of TRS 7010, INT 7100, and HOST 8000 of system 7000. In some embodiments, INT 7100 may be a device separate from, but coupled to communicate with, HOST 8000. HOST 8000 may mechanically couple to and support INT 7100. Alternatively, HOST 8000 may integrate therein at least a portion of INT 7100, so that descriptions pertaining to INT 7100 or to HOST 8000 may apply, by extension, to an integrated embodiment of TRS 7010. In general, INT 7100 can be configured to interact with a transponder, such as XPDR #1 7020 or XPDR #N 7021, using one or more selected communication techniques. Typically, XPDR #1 7020 and XPDR #N 7021 (generally, XPDR 7020) can be respectively coupled to monitored subject #1 7025 and monitored subject #N 7026, (generally, monitored subject 7025) for example, by an intimate affixment technique, such as a known ear-pinning technique. Monitored subjects 7025 and 7026 may be constituent members of monitored group 7030. INT 7100 can be configured for contactless communication on a selected communication frequency band, from between about 100 kHz to about 250 GHz. Like XPDR 5000 in FIG. 5, XPDR 7020 may be included in an embodiment of an intelligent active tag, such as IAT 1110 in FIG. 1, and may be additionally described with respect to tag 2000 in FIGS. 2A-2C and FIG. 4. INT 7100 may include a device that may complement at least a portion of functionality implemented with respect to XPDR 5000, for example, a Chipcon CC2430, or alternatively, a Chipcon 2431, wireless radio system-on-a-chip integrated circuit, having microcontroller, radio, security, I/O, and power management

elements, as described above. Other devices may be used in substitution for the aforementioned wireless radio system, or to provide additional functions and features, as may be described below.

[00115] Embodiments of INT 7100 may be a multimodal interrogator configured to communicate over one or more selected communication ranges, on one or more selected communication frequency bands, using one or more selected communication techniques. In selected example embodiments, INT 7100 may be configured to communicate over two or more selected communication ranges, including two or more of a proximity communication range, a short communication range, an intermediate communication range, a long communication range, or an extended communication range. Of course, as is well-known, communication ranges may be affected by many circumstances, including environmental conditions, so that the aforementioned ranges represent an approximation of corresponding communication range magnitudes. INT 7100 may communicate by one or more of near-field coupling (less than about one radian wavelength of the predefined operating frequency), backscatter coupling, or far-field coupling (greater than about one radian wavelength of the predefined operating frequency). Near field coupling may be one or both of capacitive or magnetic (inductive) coupling, which may be used to communicate over a proximity communication range or a short communication range. Far-field coupling may include backscatter coupling and electromagnetic field coupling. Backscatter coupling may be passive backscatter coupling or semi-passive backscatter coupling. In backscatter coupling, a portion of an incident interrogator signal may be reflected from a transponder back to an interrogator. With passive backscatter coupling, a transponder passively reflects back a portion of an incident interrogator signal, so that a communication range may be limited to a proximity communication range or a short communication range. However, semi-passive backscatter coupling techniques often use a transponder power supply to raise power of a signal backscattered to an interrogator, increasing communication range to an intermediate communication range, or possibly, greater. Far field coupling can be electromagnetic field coupling using a radiated signal, which may be used to communicate over a short communication range, an intermediate communication range, a long communication range, or an extended communication range. Typically, a passive transponder employs near-field coupling or passive backscatter coupling; a semi-passive transponder also may employ semi-passive backscatter coupling; and an active transponder may employ electromagnetic field, or radiated signal coupling. Embodiments of INT 7100 can be configured to communicate with an active transponder using electromagnetic field, or radiated signal, coupling. INT 7100 may communicate with an existing active transponder, as well as an intelligent active transponder, such as IAT 7020. Selected embodiments of INT 7100 may be configured additionally to communicate with a transponder using one or more of backscatter coupling or near-field coupling, and may communicate with an existing passive tag, an existing active transponder, as well as an intelligent active transponder, such as IAT 7020. Certain embodiments of INT 7100 can communicate on two or more predetermined RF frequency bands, with communication a predetermined communication frequency band being selectable, in response to a predefined interrogator frequency selection signal. INT 7100 may selectively communicate

using half-duplex signaling, full-duplex signaling, or both. Selected embodiments of INT 7100 also may be configured to communicate data with a predetermined subcarrier modulation technique, using at least one subcarrier.

[00116] Selected embodiments of INT 7100 may communicate using a selected communication technique including, without limitation, at least one of a selected wireless personal area network (WPAN)-based communication technique, a selected wireless local area network (WLAN)-based communication technique, a selected wireless metropolitan area network (WMAN)-based technique, or a selected wireless wide area network communications (WAN)-based technique, including a mobile telephony technique. Non-limiting examples of a WPAN-based technique include a technology related to an IEEE Standard 802.15.1-compliant radio air interface (e.g., BLUETOOTH®-related technology, including WiBree™-related ultra-lower power technology), related to an IEEE Standard 802.15.3-compliant radio air interface (e.g., an MB-OFDM UWB-related technology or a DS-UWB-related technology), related to an IEEE Standard 802.15.4-compliant radio air interface (e.g., ZigBee®-related LR-WPAN), or related to a 802.15.4a-compliant radio air interface (e.g., ZigBee®-related UWB-WPAN). Non-limiting examples of a WLAN-based technique include a technology related to an IEEE 802.11-compliant radio air interface (e.g., IEEE 802.11a-, 802.11b-, 802.11g-, or 802.11n-related technology, including a WiFi®-related technology). Non-limiting examples of WMAN-based techniques include a technology related to an IEEE Standard 802.16-based technique (e.g., a WiMAX®-related technology, HIPERMAN-related technology, or a WiBRO-related technology). Non-limiting examples of a WAN-based technique include a technology related to a 3GPP Universal Mobile Telecommunication System (UMTS) radio network technology, which may include one of a 2.5G technology, a 3G technology, or a 4G technology. Of course, the foregoing are non-limiting, non-exhaustive examples of technologies illustrating the teachings herein.

[00117] In addition, INT 7100 may employ one or more selected communication technique using a wireless point-to-point topology, a wireless point-to-multipoint topology, a wireless cluster topology, or a wireless multi-hop mesh topology. An embodiment of INT 7100 may adaptively select between a first wireless topology and a second wireless topology, in response to a predefined communication topology signal. An embodiment of INT 7100 may be configured to communicate on a first selected communication frequency band with a first transponder, e.g., XPDR #1 7020, over a first communication range using a first selected communication technique, and to communicate on a second selected communication frequency band with a second transponder, e.g., XPDR #2 7021, over a second selected communication range using a second selected communication technique. Although first and second transponders are illustrated to be intelligent active transponders, XPDR #1 7020, XPDR #2 7021, respectively, INT 7100 may communicate with one or more of another active tag, a semi-passive tag, or a passive tag. In some embodiments, the first selected communication frequency band may be different from the second selected communication frequency band. However, in other embodiments, the first selected communication frequency band may at least overlap a portion of the second selected

communication frequency band, for example, as may occur in a popular ISM frequency band between about 2.0 GHz to about 2.5 GHz. An embodiment of INT 7100 can communicate with existing RFID readers, such as passive tag reader 7400, which may have an operating frequency of between about 100 kHz to about 150 kHz, of between about 12 MHz to about 14 MHz, or of between about 8MHz to about 2.5 GHz. INT 7100 may be configured to communicate passive tag data with passive tag reader 7400, using a wireless local link, such as link 7185. Alternatively, an embodiment of INT 7100 may be configured to communicate directly with a an existing passive or semi-passive (battery-assisted) RF element, using passive tag RF link 7405.

[00118] In general, interrogator module (INT) 7100 includes interrogator RF interface module (IRM) 7105, interrogator processing module (IPM) 7200, and communication interface module (CIM) 7400. In certain embodiments, INT 7100 also may include interrogator sensor module (ISM) 7300. Typically, IPM 7200 includes controller (uC) 7210 and memory (MEM) 7220. IPM 7200 may execute operational instructions corresponding to operating system code (OS) 7250. In conjunction with OS 7250, uC 7210 also may execute program instructions, corresponding to software agents 7260. At least a portion of OS 7250, software agents 7260, or both, may be communicated from, and stored by a command from, HOST 8000, so that code and data in INT 7100 may be kept updated. Software agents 7260 may represent operational code, application program code, or a functional combination thereof. Software agents 7260 may be configured to cause INT 7100 to receive a message from a multi-modal transponder, such as XPDR #1 7020, to transmit a message to a multi-modal transponder, such as XPDR #1 7020, or both.

[00119] IPM 7200 also may include cryptographic engine 7230, which may facilitate processing module performing selected cryptographic functions for INT 7100. Non-limiting examples of preselected cryptographic functions may include one or more of generating or managing cryptographic keys, hashing, generating pseudorandom numbers, performing authentication, providing a digital signature, implementing a preselected cryptographic algorithm, establishing a secure communication channel, or encrypting and decrypting data communicated with INT 7100. One or more preselected cryptographic functions may be in support of secure communication using a preselected wireless communication technique. Cryptographic engine 7230 may be implemented in one or more of hardware, firmware, or software. In addition, IPM 7200 may include secure memory (SECMEM) 7240, which may be secure non-volatile memory, in which sensitive data may be stored. SECMEM 7240 may be configured to restrict access to stored data other than by one or both of cryptographic engine 7230 or uC 7210.

[00120] Under control of OS 7250 and software agents 7260, IPM 7200 may perform predetermined interrogator operations, including, without limitation, operating IRM 7105, operating CIM 7400, or operating ISM 7300. Non-limiting examples of IPM 7200 operating IRM 7105 include, without limitation, transmitting to transponder 7020; receiving from transponder 7020; determining a location of transponder 7020 in response to one of the transmitting or receiving; pushing data to

transponder 7020; pulling data from transponder 7020; communicating with transponder 7020 on a selectable transponder frequency band over a selectable transponder transmission range; communicating a interrogator demand to transponder 7020; or causing transponder 7020 to change a transponder operational mode. Other non-limiting examples of IPM 7200 operating IRM 7105 may include
5 operating external directional antenna 7190, by which one or more of transmitting to, receiving from, or determining a location of, transponder 7020 may be performed. In some embodiments, operating IRM 7105 can include one or both of receiving data from, or transmitting data to, external passive tag reader 7600. Non-limiting examples of IPM 7200 operating CIM 7400 include, without limitation, transmitting to HOST 8000; pushing data to HOST 8000; receiving from HOST 8000; pulling data from to host
10 platform 8500; providing a perceptible representation of a characteristic of transponder 7020 to HOST 8000; or communicating with to HOST 8000 using at least one of CIM wireless link 7420 or CIM wireline link 7440. Non-limiting examples of operating ISM 7300 may include sensing a preselected interrogator parameter, sensing a preselected environmental parameter, or both; storing a sensed interrogator parameter; or causing a sensed interrogator parameter to be communicated. Of course, IPM
15 7200 can cooperatively operate two or more of IRM 7105, ISM 7300, or CIM 7400, such that the aforementioned ones of module 7105, 7300, or 7400 may interact to perform one or more integrated interrogator operations. One non-limiting example of an integrated operation may be INT 7100 selectively collecting data from selected transponder 7020 in response to a corresponding list received from HOST 8000, which data subsequently may be forwarded to HOST 8000.

20 [00121] ISM 7300 can be configured with one or more sensors 7310, 7320. Sensors 7310, 7320 may be used to collect data, typically corresponding to a preselected aspect of subject management system 7000. In one non-limiting example, sensor 7310 may be a geospatial position (e.g., GPS) sensor, configured to identify a geospatial position of interrogator module 7100, which may be referenced to a local position, or to a globally-referenced position, which may be characterized by at least one of
25 latitude, longitude, or altitude. In addition, certain transponder embodiments, which may include XPDR #1 7020, XPDR #2 7021, or both, may transmit sensed inertial positioning data pertaining to the respective transponder spatial position. Accordingly, selected embodiments of interrogator module 7100 may include GPS sensor 7170, which may be configured to determine a spatial position of a suitably-equipped transponder, for example, XPDR #1 7020. The determined spatial position of the
30 communicating transponder may be relative to a sensed geospatial position of interrogator module 7100, relative to a local frame of reference, or to a global frame of reference, which may include latitude, longitude, or altitude. In another non-limiting example, sensor 7320 can be an imaging sensor, which may be configured to capture imaging data representative of a still image, a video image, or both. Imaging data may correspond to monitored subject 7025, 7026, to monitored group 7030, or to
35 surrounding environs. Imaging data may be captured and stored in MEM 7220, and later retrieved and processed, for example, for archival recording. In addition, imaging data may be captured and forwarded externally to TRS 7010, for example, to a remote operations center. INT 7100 may cause

such imaging data to be stored and forwarded upon demand of an external requestor, or may cause at least some imaging data to be forwarded externally in near real time, for example, to implement remote monitoring, supervision, or consultation regarding, monitored subject 7025, 7026, to monitored group 7030. Also, in certain embodiments of ISM 7300, imaging data captured by imaging sensor 7320 may be processed by an image processing and recognition program, which may operate on one or both of INT 7100, or HOST 8000. For example, imaging sensor can capture an image, which may include a characteristic feature of monitored subject 7025. IPM 7200 or HOST 8000 may analyze such a captured image, may extract such a characteristic feature, and may respond in recognition of such characteristic feature. A non-limiting example of a characteristic feature of monitored subject 7025 may be a characteristic bar code detectably imprinted on an exterior surface of XPDR 7020, a detectable characteristic anatomical or marking feature of monitored subject 7025, or a detectable characteristic indicia on XPDR 7020, monitored subject 7025, or both. Imaging sensor 7320 is not limited to capturing images detectable in the visible light spectrum, but also may be configured to sense an image detectable in one or both of the infrared or ultraviolet light spectra.

[00122] CIM 7400 may be provided to facilitate communication between INT 7100 and HOST 8000. Communication may be bidirectional – data may be pushed from HOST 8000 to INT 7100 and may be pulled from INT 7100 to HOST 8000. CIM 7400 may facilitate bidirectional communication between transponder 7020 and HOST 8000, which may be intermediated by INT 7100. CIM 7400 may include CIM wireless interface (CWI) 7410, CIM wireline interface (CWL) 7430, or both. CWI 7410 may be configured to facilitate wireless communication over CIM wireless link 7420 between INT 7100 and a corresponding RF wireless communication interface in HOST 8000, such as HOST local wireless interface (HRLI) 8800 (see FIG. 8). CWI 7410 may be configured to communicate using, for example, a Wireless Personal Area Network-type (WPAN) interface, or a Wireless Universal Serial Bus-type (WUSB) interface. Non-limiting examples of a suitable WPAN interface may include one based on a radio air interface, generally in accordance with one of an IEEE Standard 802.15.1-related radio air interface, an IEEE Standard 802.15.3-related radio air interface, or an IEEE Standard 802.15.4-related radio air interface, or an IEEE Standard-802.15.5-related radio air interface. A WUSB Interface may be in general compliance with the Wireless Universal Serial Bus Specification, Revision 1.0 (May 2005; revised, Feb. 2007), as promulgated by the USB Implementers Forum, Beaverton, OR, USA. CWI 7410 also may be configured to communicate over CIM wireless link 7420 with compatible passive RFID tag reader 7600. For example, CWI 7410 and passive tag reader 7600 each may include a wireless transceiver, generally complying with an IEEE Standard 802.15.1-related radio air interface and configured to employ a BLUETOOTH®-type protocol. INT 7100 may be capable of communicating over CIM wireless link 7420 with passive tag reader 7600, which may be, without limitation, a mobile RFID reader, such as a handheld wand RFID reader, or a stationary RFID reader, such as a panel RFID reader. In some embodiments, CWI 7410 may include two or more coexisting wireless interfaces, for example, a BLUETOOTH®-type WPAN wireless link, a WiFi®-type WLAN wireless link, a WUSB

wireless link, or an infrared wireless link, and may be configured to communicate on CIM wireless link 7420 at least partly concurrently over the two or more wireless interfaces. Certain WPAN embodiments of CWI 7410 may emulate a well-known RS-232-type link, using, for example, an RS-232 pass-through protocol.

5 **[00123]** CWL 7430 may be configured to facilitate wireline communication over CIM wireline link 7440 between INT 7100 and a corresponding wireline communication interface in HOST 8000, such as HOST local wireline interface (HWL) 8850 (see FIG. 8). CWL 7430 can be a well-known wireline interface, such as, without limitation, a USB serial link or an IEEE 1394 serial link. A USB serial link may be in general compliance with USB Specification Rev. 2.0 (revised May 2002 and
10 supplemented Dec. 2006). An IEEE 1394 serial link may be in general compliance with IEEE Standard 1394c-2006. Another example of CWL 7430 may be a well-known RS-232-type interface. In some embodiments, CWL 7430 may include two or more wireline interfaces, and INT 7100 may be configured to select a wireline interface for use as CWL 7430. Other wireline interfaces may be employed in substitution for, or in addition to the foregoing, including a suitable parallel interface. In
15 certain embodiments including both wireless interface 7410 and wireline interface 7430, CIM 7400 may be configured to communicate at least partly concurrently over wireless interface 7410 and wireline interface 7430. For example, CIM 7400 may be configured to communicate with reader 7600 using CWI 7410, while communicating with HOST 8000 using CWL 7430.

[00124] IRM 7105 may incorporate an RF transceiver, XCVR #1 7110, coupled to interrogator
20 antenna module (IAM) 7150, and may exchange data with, and be at least partially controlled by, IPM 7200. XCVR #1 7110 may transfer an incoming message to IPM 7200, and may transmit an outgoing message received from IPM 7200. INT 7100 can employ IRM 7105 to selectively transmit or receive communicated data, with at least one transponder, e.g., transponder #1 7020, or transponder # N 7021. IPM 7200 can cause IRM 7105 to perform predetermined communication functions, including
25 communicating using one or more of a selected bidirectional communication protocol, a selected unidirectional communication protocol, or a selected collision avoidance protocol. As used herein, an interrogator communication mode may be represented by communications using a selected communication technique, on a selected communication frequency band, over a selected communication range. In addition, selected embodiments of IRM 7105 may employ two or more transceivers, as
30 represented by XCVR #2 7111. One or both of XCVR #1 7110 or XCVR #2 7111 may be programmable and at least partially configurable. In ones of such selected embodiments, first transceiver 7110 may communicate using a first communication protocol on a first communication frequency band over a first communication frequency range, and second transceiver 7111 may communicate using a second communication protocol on a second communication frequency band over
35 a second communication frequency range, in which one or more of respective first and second communication protocols, first and second communication frequency bands, or first and second communication frequency ranges, may be similar or different.

[0100] INT 7100 can be configured to communicate over a selected communication range using one or more selected communication techniques, and may be configured to communicate over two or more selected communication ranges, using two or more selected communication techniques. In a non-limiting example of a intermediate communication range, a transceiver, such as XCVR #1 7110, may be a radio having physical (PHY) and media access (MAC) layers configured in accordance with an IEEE STD. 802.15.4, and employing ZigBee®-type communications up to a distance of up to about 100 meters. One non-limiting example of a long to extended communication range may include using a selected low-rate IEEE Standard 802.15.4a-related, ZigBee®-like, UWB WPAN selected communication technique, on a selected communication frequency band of between about 2.4 GHz to about 2.5 GHz, over a selected communication range of between about 100 meters to about 3000 meters. Another non-limiting example of a selected communication technique having a short to intermediate communication range may be a selected IEEE 802.15.1-related, Bluetooth®-type WPAN communication technique, on a selected communication frequency band of between about 2.4 GHz to about 2.5 GHz, over a selected communication range of between about 3 meters to about 10 meters. In certain ones of TRS 7010 embodiments, INT 7100 can include XCVR #1 7110 configured as an LR-WPAN device or radio operating, in accordance with IEEE Std. 802.15.4-2006, within a selected communication frequency band of between about 850 MHz to about 950 MHz, or between about 2.4 GHz to about 2.5 GHz, and having a long communication range of up to about 1000 meters. XCVR #1 7110 may use a first selected communication technique, which may employ a portion of an IEEE Std. 802.15.4-2006 protocol stack, a portion of a ZigBee® protocol stack, or both. In an alternative embodiment, XCVR #1 7110 may be configured as an UWB-WPAN device or radio operating, in accordance with IEEE Std. 802.15.4a-2007, within a selected communication frequency band of between about 2.5 GHz to about 11 GHz, which may communicate with XPDR #1 7020 over a communication range of up to about 100 meters. In another alternative embodiment, XCVR #1 7110 may use another selected communication technique, which may employ a portion of an IEEE Std. 802.15.4-2006 protocol stack, a portion of a ZigBee® protocol stack, or both.

[0101] In certain embodiments of INT 7100, XCVR #1 7110 may operate within a first selected communication frequency band using a first selected communication technique. Similarly, XCVR #2 7120 may operate within a second selected communication frequency band using a second selected communication technique. Although not so required, the first selected communication frequency band may be similar to, may be different from, or may overlap, the second selected communication frequency band; and the first selected communication technique may be different from the second selected communication technique. However, the first selected communication technique and the second selected communication technique may share one or both of a physical (PHY) layer and a media access control (MAC) layer. Also, in selected embodiments, XCVR #1 7110 may be representative of a single configurable RF transceiver, which may be used to communicate using the first selected communication technique and the second selected communication technique. A configurable transceiver, for example,

XCVR #1 7110, may be configurable to a third, or more, selected communication technique. More than two transceivers XCVR #1 7110, XCVR #2 7111 also may be used. Each of the more than two transceivers XCVR #1 7110, XCVR #2 7111 may communicate using respective ones of two or more selected communication techniques, on respective ones of two or more communication frequency bands, over respective ones of two or more communication ranges, with one or more of such techniques, bands, or ranges being generally different from another one or more of such techniques, bands or ranges.

[0102] IAM 7150 provides an antenna, that is, a physical air interface, by which RF signals may be transmitted or received, or a message may be exchanged, by XCVR #1 7110 or XCVR #2 7111. As used herein, an "antenna" may be constituted of a single antenna element, or of plural antenna elements, and may be configured to employ an antenna diversity technique including, without limitation, a spatial diversity technique, a frequency diversity technique, or a phase diversity technique. IAM 7150 may include at least one antenna, which may be shared by plural transceivers 7020, 7021, for example, using an antenna time-sharing technique. IAM 7150 may include one or both of omnidirectional interrogator antenna 7160, or directional interrogator antenna 7170. A single antenna element may be configured to communicate over one or more preselected communication frequency bands. Plural antenna elements may allow INT 7100 to simultaneously communicate over two frequency bands, as well as to permit INT 7100 to communicate over multiple ranges of communication frequency bands.

[0103] Moreover, in selected embodiments of IRM 7105, a directional interrogator antenna may include plural antenna elements, for example, directional interrogator antenna element #1 7170 and directional interrogator antenna element #2 7171. Typically, first directional interrogator antenna element 7170 produces a first beam pattern 7175, and second directional interrogator antenna element 7171 produces a second beam pattern 7176. Directional antenna elements 7170 and 7171 may be cooperatively configured to perform beamforming. Beamforming may be used to control directional sensitivity of a transmitted signal, of a received signal, or of both. Such controlled beamforming also may be used to determine, for example an azimuthal position of one or more of transponder #1 7020, transponder #N, 7021, relative to a position of INT 7100. In an embodiment of IRM 7105, directional antenna elements 7170 and 7171 may be cooperatively configured such that first beam pattern 7175 at least partially overlaps second beam pattern 7176, to produce a combined directional antenna beam pattern 7180, which, typically exhibits greater sensitivity and enhanced directivity, relative to individual beam patterns 7175 and 7176. In one alternative embodiment, antenna elements 7170 and 7171 may be cooperatively configured to perform adaptive beamforming. In one aspect of INT 7100, IAM 7150 may be configured to couple to, and receive signals by way of, external antenna 7190, which may be a directional antenna, such as a Yagi-type antenna. In selected embodiments of IRM 7105, external antenna 7190 may be configured to perform directional motion, as may facilitate determining one of both of an azimuthal bearing and a range (distance) of transponder 7020, 7021, relative to INT 7100, in a manner similar to well-known radio direction and ranging (RADAR) techniques. Moreover, in an embodiment of IRM 7105, one or more of IAM 7150 internal antennas 7160, 7170, may be configured

to cooperate with external antenna 7190, for example to perform a preselected antenna diversity technique, including beamforming, which may include adaptive beamforming.

[0104] Although not a requirement, one or more of omnidirectional interrogator antenna 7160, directional interrogator antenna 7170 or, when implemented, directional interrogator element 7171, may be formed on a constituent printed circuit board of INT 7100, in a manner similar to antenna module 4400 in FIG. 4. In one alternative, one or more of antennas 7160, 7170, or 7171 may be formed on a constituent printed circuit board of INT 7100 while another of antenna 7160, 7170, or 7171 may be surface mounted or formed on a housing of INT 7100. In yet another alternative, each of antennas 7160, 7170, or 7171 may be surface mounted or formed on a housing of INT 7100. In certain selected embodiments of INT 7100, more than two transceivers, XCVR #1 7110, XCVR #2 7111, and two or more IAM 7150 may be included in INT 7100.

[0105] In general, software agents 7160 may be configured to cause INT 7100 to cooperatively exchange an IAT message with a multi-modal transponder, such as XPDR #1 7020. In addition, software agents 7160 may be provided to cause INT 7100 to communicate with respective ones of plural transponders, such as XPDR #1 7020, XPDR #2 7021, which may communicate using respective ones of plural selected communication techniques on respective ones of plural communication frequency bands over respective ones of plural communication ranges. In addition, selected software agents 7160 in INT 7100 may cooperate with selected software agents 5114 in XPDR 5000, to implement an embodiment of a selected transponder collision avoidance protocol. Other selected software agents 7160 may be configured to selectively pull data from transponder XPDR 5000, to push data to transponder XPDR 5000, or to transmit an interrogator demand from INT 7100 to a transponder, such as XPDR 5000, having a preselected operational mode including an interrogator demand operational mode. Yet other selected software agents 7160 may be configured to perform at least one of cooperatively receive a predetermined subject alert from a transponder, such as XPDR 5000, to determine an alert response of TRS 7010 corresponding to a received predetermined subject alert, or perform a predetermined TRS response in response to a predetermined subject alert. An example of a predetermined TRS response may be to provide on a display of HOST 8000, a perceptible representation of a corresponding predetermined subject alert. Another example of a predetermined TRS response may be to transmit a representation of a corresponding predetermined subject alert to one or both of remote operations center 1435 or official agency 1440. Still other selected software agents 7160 may be configured to facilitate communication over public internetwork 1430, for example, the Internet, by using an upper OSI layer protocol. Non-limiting examples of suitable upper OSI layer protocols include a TCP/IP-like protocol, or a session initiation protocol (SIP). For example, INT 7100 may couple to WAN 1425 using a selected WAN communication technique, and may employ a SIP messaging to relay data, such as a predetermined subject alert, over internetwork 1430 to one or both of remote operations center 1435 or official agency 1440.

[0106] IRM 7105 may be configured to determine a characteristic of XPDR 7020 from characteristic signal data associated with a respective transponder message received by XCVR 7110. In general, when a message is received from XPDR #1 7020, XCVR #1 7110 may provide characteristic signal data 7117, as a representation of a received message, to location engine (LE) 7115. LE 7115 may analyze characteristic signal data 7117 and, in response, may produce transponder image 7119. Transponder image 7119 may be used in interrogator-transponder distance mensuration, or in determining another monitored subject characteristic. Other information may be used in conjunction with characteristic signal data 7117 to produce transponder image 7119. For example, GPS sensor 7310 in ISM 7300 may provide positioning data, in the form of relative X, Y coordinate data, or non-relative positioning data, which may be used to generate a position for XPDR 7020 by LE 7115, or by LE 7115 in cooperation with IPM 7200. Also, in embodiments in which XPDR 7020 is configured to provide INT 7100 with inertial motion and positioning (IMP) data corresponding to monitored subject 7025, such inertial movement data may be used, alone, or in conjunction with positioning data to produce transponder image 7119. Transponder image 7119 may be scalar data, such as a magnitude, or be vectored data, including a magnitude and a heading. In certain embodiments, IRM 7105 may include plural transceivers, as represented by transceivers 7110 and 7111, which may provide respective characteristic signal data to LE 7115 from which respective transponder images may be produced. Beneficially, IPM 7200 may cause a perceptible representation of transponder image 7119 to be presented on HOST display 8215 as a position of XPDR #1 7020, relative to XCVR #1 7110. Because XPDR #1 7020 can be attached to monitored subject 7025, host user display 8215 may display a relative position of monitored subject 7025. If a position of INT 7100 can be identified as a globally referenced position, for example, as a geospatial position having latitude and longitude, then it may be possible to identify a globally-referenced position for XPDR 7020 and monitored subject 7025.

[0107] In general, transponder image 7119 corresponds to a preselected transponder signal characteristic of signal data 7117, and may be received and processed by IPM 7200 to estimate a distance between INT 7100 and a transponder, such as XPDR #1 7020. A preselected transponder signal characteristic may include, without limitation, a preselected signal phase characteristic, a preselected signal quality characteristic, or a preselected signal time characteristic. A preselected transponder signal characteristic also may be a combination of two or more of a preselected signal phase characteristic, a preselected signal polarity characteristic, a preselected signal time characteristic, or a preselected signal quality characteristic.

[0108] A non-limiting example of a preselected signal phase or angle characteristic can be an Angle of Arrival, AoA, characteristic, which generally describes the direction of transponder signal propagation received from transponder 7020 at INT 7100. An AoA characteristic may be determined by measuring an angle between a line between XPDR #1 7020 and INT 7100, and a reference line extending from INT 7100 in a predefined reference direction. An AoA signal characteristic may be facilitated in embodiments in which antenna module 7120 is configured to implement signal reception

using a predetermined signal diversity technique, such as spatial diversity. In a non-limiting example of a preselected signal polarity characteristic, antenna module 7120 may be disposed with plural antenna elements having different polarizations. A distance between XPDR #1 7020 and INT 7100 may be determined by measuring a transponder signal polarity difference between such antenna elements of antenna module 7120.

[0109] A non-limiting example of a preselected signal time characteristic can be a Time of Arrival (ToA) characteristic, a Time Difference of Arrival (TDoA) characteristic, or a Time of Return Flight (TRF) characteristic. A preselected signal time characteristic may be useful to measure distance, for example, when transceivers may communicate using an ultrawideband (UWB) signal. A ToA characteristic generally describes the propagation delay, or the amount of time required for a transponder signal to travel from XPDR #1 7020 to INT 7100. Typically, a ToA characteristic may be measured relative to a reference time, or synchronized signal, source, which may be, for example, SUPERVISOR 1550, MRT 1400, WAN 1425, remote operations center 1435, or another interrogator. Similarly, a TDoA characteristic generally describes the time difference between the time at which a transponder signal is received at a first receiver and at a second receiver, with the distance between transponder 7020 being calculated as a proportional function of time. Selected embodiments of INT 7100 may function as first or second receiver, and be configured to cooperate with another receiver, such as SUPERVISOR 1550 or MRT 1400. A TRF characteristic may be measured by INT 7100, for example, by measuring the amount of time elapsed between transmitting a message to, and receiving a reply from, XPDR #1 7020. Such round-trip message measurements may accommodate for a latency corresponding to the time taken by XPDR #1 7020 to process the transmitted message from, and to formulate a reply to, INT 7100.

[0110] A non-limiting example of a preselected signal quality characteristic can be a received signal strength indication (RSSI) characteristic, or a link quality indicator (LQI) characteristic. An RSSI characteristic generally describes the strength of the transmitted transponder signal at the receiver. An LQI characteristic generally describes the strength and/or quality of a received transponder signal, and may be determined using an RSSI characteristic and a signal-to-noise ratio estimate. Typically, the received transponder signal strength and quality decreases as the distance between XPDR #1 and INT 7100 increases. Frequently, RSSI measurements may be made without antenna diversity or polarization techniques, or synchronized or reference sources. Many wireless radio interface standards provide for RSSI measurement including, without limitation, IEEE Std. 802.15.1, IEEE Std. 802.15.3, IEEE Std. 802.15.4, IEEE Std. 802.15.4a, IEEE Std. 802.15.5, IEEE Std. 802.11, and IEEE Std. 802.16, so that providing an RSSI value as received signal data 7117 may be implemented readily. In selected embodiments of INT 7100, LE 7115 may generate transponder image 7119 in response to received signal data 7117 as an RSSI characteristic. A preselected transponder signal characteristic corresponding to received signal data 7117 also may be a combination of two or more of a preselected signal phase characteristic, a preselected signal polarity characteristic, a preselected signal time

characteristic, or a preselected signal quality characteristic. In an embodiment of INT 7100, LE 7115 may generate transponder image 7119 using an RSSI characteristic, and one of a AoA characteristic, a signal polarity characteristic, a ToA characteristic, a TDoA characteristic, or a TTF characteristic. LE 7115 may receive additional positioning information, for example, reference X and Y position data of INT 7100 relative to a proximate region, a globally-referenced position data of INT 7100, or both, and may be provided by one or both of HOST 8000, or from GPS sensor 7170 in ISM 7165. Such additional positioning information may refine interrogator-transponder distance mensuration by INT 7100.

[0111] Transponder image 7119 can be received and processed by IPM 7200 to determine a monitored subject characteristic of monitored subject 7025. An example of a monitored subject characteristic may be a monitored subject spatial characteristic, such as a monitored subject position, which may be a relative position or a non-relative position. A relative position may be relative to a location within a monitored region, such as monitored region 1100 in FIG. 1, or may be relative to a position of TRS 7010. A monitored subject spatial characteristic may be represented by a bearing, i.e., an azimuthal position, relative to TRS 7010 or a range, e.g., a distance from TRS 7010. A non-limiting example of a non-relative position can be a globally-referenced geospatial location. IPM 7200 may selectively store plural preselected monitored subject characteristics corresponding to a respective transponder 7020 and associated monitored subject 7025, may analyze such plural characteristics, and may produce a respective monitored subject trajectory 7027, which may be a monitored subject spatial trajectory, a monitored subject temporal trajectory, or a monitored subject spatiotemporal trajectory. Such a monitored subject trajectory 7027 may provide information regarding a movement or a state of monitored subject 7025, alone or in the context of another monitored subject, such as monitored subject 7026, or of a monitored subject group, such as group 7030. A non-limiting example of a monitored subject spatial trajectory includes a heading, a postural change, a spatial displacement, a route, or a spatial distribution of one monitored subject relative to another monitored subject. A non-limiting example of a monitored subject temporal trajectory includes a time-based characteristic such as a motion, an acceleration, a rate of travel, or relocation of a corresponding monitored subject over a definable epoch, include a lifespan. In a non-limiting example embodiment in which a transponder, such as XPDR #1 7020, may be attached to an asset, such as monitored subject 7025, TRS 7010 may be an embodiment of a mobile asset manager, which may be configured to perform one or more of asset identification, asset recordation, asset monitoring, or asset tracking.

[0112] In a context in which monitored subject 7025 may be a social animal, and monitored subject group 7030 may be a social animal group, each may demonstrate respective behaviors, which may be identified or inferred. Selected embodiments of TRS 7010 also may be used to identify, infer, monitor, or predict a behavior of one or members of group 7030, including monitored subject 7025. Indeed, a preselected monitored subject trajectory 7027 may correspond to a predetermined monitored subject behavior. Non-limiting examples of predetermined monitored subject behavior may include a breeding state, an ownership state, a wellness state, a perceived predation state, or a state indicative of

monitored subject misappropriation. IPM 7200 may be disposed with sufficient memory MEM 7220, so that TRS 7010 may manage multiple monitored subject trajectories for one transponder 7020 and one monitored subject 7025, a respective monitored subject trajectory for multiple transponders 7020, 7021 and monitored subjects 7025, 7026, or multiple transponder trajectories for respective multiple transponders 7020, 7021 and corresponding multiple monitored subjects 7025, 7026. MEM 7220 may be configured to provide a data structure, which may be organized logically as a database. IPM 7200 may be used to collect, analyze, or disseminate, one or more monitored subject trajectories, which may be stored in MEM 7220 or may be derived contemporaneously from transponder image 7119. IPM 7200 also may be programmed to generate an event alert, in response to a predetermined monitored subject trajectory rule, which may correspond to a predetermined monitored subject behavior. One or more monitored subject trajectories may be generated by TRS 7010 and transferred to an external repository, such as one or more of mobile computing platform 8500, remote operations center 1435, or authority 1440, which may respond to monitored subject trajectory information. In addition, TRS 7010 may receive at least a portion of a monitored subject trajectory from one or more of HOST 8000, remote operations center 1435, or authority 1440. Certain selected ones of TRS 7010 may be configured as a stand-alone unit, which may be positioned at a regional chokepoint, at highway monitoring point, in a portion of a grazing region, on a portion of a ranch, or in a mobile vehicle, and which may produce an event alert in response to a predetermined monitored subject behavior.

[0113] FIG. 8 illustrates another example embodiment of subject management system 7000, employing TRS 7010, which may be configured to include INT 7100 and HOST 8000. Subject management system 7000 may be an example of subject management system 1000 in FIG. 1, and subject management system 5050 in FIG. 5. TRS 7010 may exemplify an embodiment of HMM 1525 in FIG. 1. TRS 7010 may exchange an IAT message with transponder 7020 affixed to monitored subject 7025. Monitored subject 7025 may be a member of monitored subject group 7030. INT 7100 may communicate with HOST 8000 using CIM wireless link 7420, CIM wireline link 7440, or both. In certain embodiments, INT 7100 may be integrated into HOST 8000. An integrated embodiment of TRS 7010 may be suitably configured to a selected tag reader application. For example, embodiments of TRS 7010 integrating INT 7100 and HOST 8000 may implement HMM 1525. Other embodiments of an integrated TRS 7010 may implement an embodiment of SUPERVISOR 1550. Yet other embodiments of an integrated TRS 7010 may implement an embodiment of MRT 1400 in a monitored region transceiver configuration. Still other embodiments of an integrated TRS 7010 may implement an embodiment of MRT 1400 in a stand-alone monitored subject transport configuration.

[0114] In general, HOST 8000 can be a handheld computing platform, suitably configured for an environment in which TRS 7010 may be expected to operate. For example, in a harsh outdoors environment, a suitable example of such a handheld computing platform may be an ARCHER® Field PC, produced by Juniper Systems, Logan, UT, USA. An ARCHER® Field PC is a rugged, handheld computing platform, which typically is resilient to adverse drop, vibration, immersion, humidity, and

operating temperature conditions. Also, an ARCHER® Field PC may use Microsoft® Windows® Mobile Operating System, which may be configured to perform services including, without limitation, a remote terminal service, synchronization with a remote host, or multi-protocol, multi-range wireless communications services. Also, an ARCHER® Field PC may be customized, and one or more elements and functionality of INT 7100 may be integrated therein. Of course, TRS 7010, INT 7100, and HOST 8000 are not limited to an aforementioned example implementation of a platform or an operating system.

[0115] Selected embodiments of HOST 8000 may be configured with host computer interface (HCI) 8110, which may include host HCI display 8120 and host HCI manual entry port 8130. HCI display 8120 may be a multi-line LCD screen, and HCI port 8130 may be a manual keypad with one or more programmable keys. HCI 8110 also may have host HCI audiovisual (A/V) port 8140, which may be configured to capture imaging data, audio data, or both. Also, HCI A/V port 8140 may be configured to provide an audio signal output, which may be perceptible to a user, such as steward 1500 in FIG. 1. One or both of captured imaging data or captured audio data may be stored, processed, or communicated remotely by HOST 8000. Such image capturing functionality may allow a user, for example, to capture a still or video image of monitored subject 7025, which may correspond to subject data received from transponder 7020 by INT 7100. Similarly, audio capturing functionality may allow a user to record spoken observations or information regarding monitored subject 7025, monitored group 7030, or environs thereof. HOST 8000 may include host processor 8200, which may operate under instructions provided by operating system 8210. In addition, one or more software agents 8220 may cooperate with host OS 8210 to cause host processor to manipulate data which may be stored, for example in memory 8230, may be input via HCI 8110, received from a transponder, such as transponder 7020, or may be received from a remote sender, such as remote operations center 1435 or official agency 1440. Also, in certain embodiments, selected software agents 8220 may cooperate with INT 7100 to push data to, or pull data from, transponder 7020, or both. Moreover, certain software agents 8220 may be configured to cooperate with INT 7100 to provide an interrogator demand to transponder 7020, which interrogator demand may cause transponder 7020 to change an operational mode from a first predetermined transponder operational mode to a second operational mode, to effect a transponder operation, or to selectively communicate data with transponder 7020.

[0116] HOST 8000 may include host local wireless interface (HRFI) 8800, host wireline interface (HWL) 8850, or both. HRFI 8800 may be configured to facilitate wireless communication over a wireless link, such as communication with INT 7100 over CIM wireless link 7420. HRFI 8800 may be configured to communicate using, for example, a Wireless Personal Area Network-type (WPAN) interface, or a wireless Universal Serial Bus-type (WUSB) interface. Non-limiting examples of a suitable WPAN interface may include one based on a radio air interface, generally in accordance with one of an IEEE Standard 802.15.1-related radio air interface, an IEEE Standard 802.15.3-related radio air interface, or an IEEE Standard 802.15.4-related radio air interface, or an IEEE Standard-

802.15.5-related radio air interface. HRFI 8800 also may be configured to communicate with compatible passive RFID tag reader 7600, which may be, without limitation, a mobile RFID reader, such as a handheld wand RFID reader, or a stationary RFID reader, such as a panel RFID reader. For example, HRFI 8800 and passive tag reader 7600 each may include a wireless transceiver, generally
5 complying with an IEEE Standard 802.15.1-related radio air interface and configured to employ a BLUETOOTH®-type protocol. In some embodiments, HRFI 8800 may include two or more coexisting wireless interfaces, for example, a BLUETOOTH®-type WPAN wireless link, a WiFi®-type WLAN wireless link, a WUSB wireless link, or an infrared wireless link, and may be configured to communicate at least partly concurrently over the two or more wireless interfaces.

10 [0117] HWL 8850 may be configured to facilitate wireline communication over a wireline link, such as CIM wireline link 7440, between HOST 8000 and a corresponding wireline communication interface in INT 7100, such as HOST local wireline interface (CWL) 7430. HWL 8850 can be a well-known wireline interface, such as, without limitation, a USB serial link or an IEEE 1394 serial link. In some embodiments, HWL 8850 may include two or more wireline interfaces, and HOST 8000 may be
15 configured to select a wireline interface for use as HWL 8850. Other wireline interfaces may be employed in substitution for, or in addition to the foregoing, including a suitable parallel interface. In certain embodiments including both HRFI 8800 and HWL 8850, HOST 8000 may be configured to communicate at least partly concurrently over wireless interface 8800 and wireline interface 8850.

[0118] HOST 8000 may be configured to communicate remotely using host remote RF
20 interface 8300. Embodiments of HRFI host remote RF interface may communicate using a selected communication technique including, without limitation, at least one of a wireless local area network (WLAN)-based technique, a wireless metropolitan area network (WMAN)-based technique, or a wireless wide area network communications (WAN)-based technique, including a mobile telephony technique. Selected embodiments of HOST 8000 may include two or more radio air interface
25 technologies in host remote RF interface 8300, with non-limiting examples of a WLAN-based technique include a technology related to an IEEE 802.11-compliant radio air interface (e.g., IEEE 802.11a-, 802.11b-, 802.11g-, or 802.11n-related technology, including a WiFi®-related technology). Non-limiting examples of WMAN-based techniques include a technology related to an IEEE Standard 802.16-based technique (e.g., a WiMAX®-related technology, HIPERMAN-related technology, or a
30 WiBRO-related technology). Non-limiting examples of a WAN-based technique include a technology related to a 3GPP Universal Mobile Telecommunication System (UMTS) radio network technology, which may include one of a 2.5G technology, a 3G technology, or a 4G technology. Of course, the foregoing are non-limiting, non-exhaustive examples of technologies illustrating the teachings herein.

[0119] As a non-limiting example, HOST 8000 may use host remote RF interface 8300 to
35 communicate with MRT 1400 using monitored region wireless link 1410, or with SUPERVISOR 1550 using manager-supervisor wireless link 1570, using a WLAN-related technique. Also, in certain selected embodiments of HOST 8000, HOST RF interface 8300 may be configured to communicate

with WAN 1425, using one or more of a WLAN-related, WMAN-related, or WAN-related technology, which may couple HOST 8000 to public internetwork 1430. Alternatively, HOST 8000 may be coupled to public internetwork 1430 through a remote services link provided by SUPERVISOR 1550, which communicate with WAN 1425, using one or more of a WLAN-related, WMAN-related, or WAN-related technology.

[0120] HOST 8000 may provide perceptible representations of monitored data on host HCI display 8120 including, without limitation, data regarding monitored subject 7025, at least a part of which may be received from transponder 7020. Non-limiting examples of representations of monitored data include monitored subject label 8500, monitored subject distance indicator 8510, monitored subject bearing annunciator 8520, or monitored subject parameter 8540. A portion of data regarding monitored subject 7025, may be retrieved from data storage in INT 7100, HOST 8000, or both. Data may be presented on HCI display 8120 in a simplified, at-a-glance format, which may be readily assimilated by a busy user in an uncontrolled environment. Monitored subject label 8500 may be an identifier associated with monitored subject 7025, such as, without limitation, an UID, an EID, a subject member name or alias, or an identifier symbol. Monitored subject label 8500 also may provide a code or symbol 8505 representative of a preselected member characteristic. For example, in certain implementations, an "M" may be prepended to the identifier 8515 associated with a male monitored subject 7025 on monitored subject label 8500 display and, similarly, an "F" may be prepended to an identifier associated with a female monitored subject 7025. Monitored subject label 8500 may include more than one code or symbol, for example, to indicate breeding status, lineage, origin, or special status. Monitored subject distance indicator 8510 may provide a numeric representation of a distance between TRS 7010 and transponder 7020, but also may provide a graphical representation of a position of monitored subject 7025, relative to one or more other members of monitored subject group 7030.

[0121] In addition, transponder 7020 may be configured to transmit a monitored subject alert to TRS 7010, in response to a predetermined monitored subject alert state detected by transponder 7020. A monitored subject alert state may represent a monitored subject parameter that, in accordance with predetermined member state rules, may be designated as an alert state. Such predetermined member state rules may be operative in one or more of transponder 7020, TRS 7010, or HOST 8000. HCI display 8120 may provide monitored subject parameter display 8540 so that a user of HOST 8500 may receive a perceivable representation of the corresponding monitored subject parameter. In selected embodiments, monitored subject alert annunciator 8530 may provide a perceptible symbol associated with the detection of an alert state. Also, host A/V port 8140 may produce an audible alarm corresponding to a monitored subject parameter alert. An alert state may indicate, but is not required to be, a monitored subject parameter representative of monitored member distress. In a non-limiting example of a functionality of HCI display 8120, in which transponder 7020 is held in intimate affixment to monitored subject 7025, TRS 7010 may communicate with transponder 7020 and may determine that monitored subject 7025 can be identified as male (ref. 8505) group member 172534 (ref. 8515), which is

located approximately 120 meters (ref. 8510) NNE (ref. 8520) of TRS 7010. Also, transponder 7020 may transmit a monitored subject parameter, for example, a corporal temperature of 102°F (ref. 8540), which may correspond to a monitored subject parameter alert, and which may be indicated by a symbol displayed on monitored subject alert annunciator 8530. HOST 8000 may store data corresponding to the information displayed on HCI display 8120, for example, in a database record. Also, in response to a monitored subject alert regarding monitored subject 7025, HOST 8000 may couple with public internetwork 1430 and communicate data corresponding to monitored subject 7025 to remote operations center 1435. Remote operations center 1435 may respond to data corresponding to monitored subject 7025, for example, by sending a supervisory command to HOST 8000 to instruct transponder 7020 to periodically sense and communicate a corporal temperature of monitored subject 7025. HOST 8000 may relay the supervisory command to INT 7100, which forms and exchanges an IAT message, including the interrogator demand, with transponder 7020. In turn, transponder 7020 may change a predetermined transponder operational mode from a predetermined transponder demand operational mode to a predetermined periodic operational mode, in which a corporal temperature of monitored subject 7025 is sensed by transponder 7025 and communicated periodically to one or more of INT 7100 or HOST 8000.

[0122] FIGS. 9, 10, and 11 illustrate non-limiting example embodiments of preselected transponder communication protocols, which are described within the context of the example embodiments of FIG. 7 and FIG. 8. However, one or more of Methods 9000, 10000, or 11000 may be used in conjunction with other suitable subject management systems. One or more of FIGS. 9, 10, or 11 may be used in accordance with a selected communication distribution protocol, as described with respect to XPDR 5000 of FIG. 5. A transponder, such as XPDR 7020 or 7021, may communicate with an interrogator in a tag reader system, such as INT 7100 in TRS 7010, using one or more preselected transponder communication protocols.

[0123] In FIG. 9, method 9000 illustrates a non-limiting embodiment of a TRANSPONDER TALKS ONLY (TTO) communication protocol, which may be used with subject management system 1000 in FIG. 1, subject management system 5050 in FIG. 5, and subject management system 7000 in FIGS. 7 and 8. In Method 9000, a transponder, such as XPDR 7020, may communicate by transmitting an outbound IAT message to an interrogator, such as INT 7100 in TRS 7010. Example embodiment of method 9000 can describe a communication protocol, in which HOST 8000, as illustrated in FIGS. 7 and 8, is configured to instruct INT 7100 to listen for an outbound IAT message from one or more selected transponders 7020, 7021. A TTO protocol may implement periodic communication or aperiodic communication. XPDR 7020 may initiate transmitting using a TTO protocol, for example, while operating in a predetermined transponder periodic operational mode or a predetermined transponder demand operational mode. In an example embodiment of a TTO communication protocol, XPDR 7020 may be configured to periodically transmit a predetermined outbound IAT message after

activation, having a selected tag transmission interval of about 2 seconds. A non-limiting example of a predetermined outbound IAT message is a REGISTRATION message.

[0124] A TTO communication protocol may facilitate selective collection of subject data in an environment in which large numbers of transponders 7020, 7021 may be transmitting, but from which
5 subject data may be sought from a subset of the transmitting transponders. Example method 9000 may begin by generating (S9010) a target transponder command set. A target transponder command set may be generated HOST 8000 or by INT 7100 subsequent to awakening, in cooperation with HOST 8000. A target transponder command set may identify selected transponders, and may define monitored subject data to be collected from the selected transponders. A logical representation of a target transponder
10 command set may include a target transponder list. INT 7100 may proceed by awakening (S9020) in response to a command from HOST 8000 using a predetermined command channel. Examples of a predetermined command channel may include one or both of CIM wireless link 7420 or CIM wireline link 7440, in FIGS. 7 and 8. INT 7100 may respond by acknowledging (S9030) being awakened. HOST 8000 may continue by downloading (S9040) a transponder monitoring command set to INT 7100
15 over the predetermined command channel. INT 7100 may respond to receiving transponder monitoring command set by listening (S9050) for a transponder, which may be identified on a target transponder list, by recognizing (S9060) a transmitting transponder 7020 enumerated on an identified transponder list corresponding to the transponder monitoring command set, and by receiving (S9070) an inbound IAT message from transponder 7020 that is so identified. Transmitting transponder 7020 may
20 communicate an IAT message to INT 7100, for example, using a selected communication distribution mode, and may transmit an outbound IAT message periodically over a selected periodic tag transmission interval. In Method 9000, INT 7100 may operate by storing (S9080) one or more IAT messages corresponding to respective ones of XPDR 7020, 7021, or a representation thereof, for example, in one or more buffers in memory MEM 7160 of INT 7100. A transponder monitoring command set may
25 define a transponder monitoring interval, over which interval interrogator INT 7100 continue listening (S9090) for an outbound message from a transponder XPDR 7020 and after which listening may be discontinued. Method 9000 then may continue by INT 7100 uploading (S9100) to HOST 8000, one or more outbound IAT messages, or a representation thereof, which may be received from respective ones of 7020, 7021, and may be accumulated over transponder monitoring interval in MEM 7160. Uploading
30 (S9100) also may be in response to INT 7100 communicating with all transponders enumerated on a target transponder list, or by downloading a request by HOST 8000, which may be sent to INT 7100 before all enumerated transponders 7020, 7021 have communicated with INT 7100. HOST 8000 may store, process, or remotely communicate selected IAT messages, or representations thereof, received from enumerated transponders 7020, 7021. In selected embodiments, INT 7100 may conclude method
35 9000 by changing an interrogator operational mode (S9110) to a low power interrogator operational mode.

[0125] In FIG. 10, method 10000 illustrates a non-limiting embodiment of a TRANSPONDER TALKS FIRST (TTF) communication protocol, which may be used with subject management system 1000 in FIG. 1, subject management system 5050 in FIG. 5, and subject management system 7000 in FIGS. 7 and 8. Certain embodiments of a TTF protocol may be similar to a TTF communication protocol.

5 Example embodiment of method 10000 can describe a communication protocol, in which HOST 8000, as illustrated in FIGS. 7 and 8, is configured to instruct INT 7100 to listen for an inbound IAT message from one or more selected transponders 7020, 7021. A TTF communication protocol may facilitate selective collection of subject data in an environment in which large numbers of transponders 7020, 7021 may be transmitting, but from which subject data may be sought from a subset of the transmitting

10 transponders. Example method 10000 may begin by generating (S10010) a target transponder command set. A target transponder command set may be generated HOST 8000 or by INT 7100, in cooperation with HOST 8000. A target transponder command set may identify selected transponders, and may define monitored subject data to be collected from the selected transponders. A logical representation of a target transponder command set may include a target transponder list. INT 7100 may proceed by

15 awakening (S10020) in response to a command from HOST 8000 using a predetermined command channel. Examples of a predetermined command channel may include one or both of CIM wireless link 7420 or CIM wireline link 7440, in FIGS. 7 and 8. INT 7100 may respond by acknowledging (S10030) being awakened. HOST 8000 may continue by downloading (S10040) a transponder monitoring command set to INT 7100 over the predetermined command channel. INT 7100 may respond to

20 receiving transponder monitoring command set by listening (S10050) for a transmitting transponder 7020, by receiving (S10060) a outbound IAT message from transponder 7020, and by verifying (S10070) that the outbound IAT message is received from a transponder 7020 identified from a target transponder list. In Method 10000, INT 7100 may operate by storing (S10080) one or more IAT messages corresponding to respective ones of XPDR 7020, 7021, or a representation thereof, for

25 example, in one or more buffers in memory MEM 7160 of INT 7100. INT 7100 may respond to XPDR 7020 by transmitting (S10090) a predetermined inbound IAT message, such as an inbound IAT ACKNOWLEDGEMENT message. XPDR 7020 may be configured to communicate with an associated interrogator, such as INT 7100 and to ignore a response from an unassociated interrogator. In addition, INT 7100 may include one or more commands, such as an interrogator demand, in a predetermined

30 inbound IAT message. Non-limiting examples of an interrogator demand include a predetermined operational mode change demand, a selected sensed physical quantity demand, a power mode change demand, a WAKE-ON-RADIO demand, or a POWER DOWN demand. By transmitting (S10100) the predetermined inbound IAT message to XPDR 7020, INT 7100 may cause XPDR 7020 to change a state, for example, a predetermined operational mode. Furthermore, INT 7100 may include selected

35 data in the predetermined inbound IAT message, including selected subject data pertaining to monitored subject 5800. A non-limiting example of selected subject data includes an SID assigned by HOST 8000 to correspond to XPDR 7020 TID. Method 10000 may proceed by INT 7100 listening (S10110) for a

transmitting transponder 7020 over a preselected search interval, and, after expiration of the preselected search interval, by uploading (S10120) from MEM 7160 to HOST 8000, one or more outbound IAT messages, or a representation thereof. Alternatively, uploading (S10120) may be in response to INT 7100 communicating with selected transponders enumerated on a target transponder list, or by an uploading request from HOST 8000, which may be sent to INT 7100 before all enumerated transponders 7020, 7021 have communicated with INT 7100. HOST 8000 may store, process, or remotely communicate selected IAT messages, or representations thereof, received from enumerated transponders 7020, 7021. In selected embodiments, INT 7100 may conclude method 10000 by switching (S10130) to a low power interrogator operational mode.

10 **[0126]** In FIG. 11, method 11000 illustrates a non-limiting embodiment of a TRANSPONDER LISTENS FIRST communication (TLF) protocol, which may be used with subject management system 1000 in FIG. 1, subject management system 5050 in FIG. 5, and subject management system 7000 in FIGS. 7 and 8. Example embodiment of method 11000 can describe a communication protocol, in which HOST 8000, as illustrated in FIGS. 7 and 8, is configured to instruct INT 7100 to communicate with one or more selected transponders 7020, 7021, which may be selected by HOST 8000. A TLF communication protocol also may facilitate selective collection of subject data in an environment in which large numbers of transponders 7020, 7021 may be available to transmit, but from which subject data may be sought from a subset of the transmitting transponders.

20 **[0127]** In general, transponders 7020 may operate by “listening” for an inbound IAT message from INT 7100. Some transponders, including certain ones embodiments of transponder 7020, may be configured to respond during transponder operations to LISTEN for an incoming interrogator demand, for example, seeking an identifier associated with transponder 7020, or sensed subject data corresponding to monitored subject 7025. Such embodiments of transponder 7020 may LISTEN by awaiting and recognizing an incoming interrogator demand, and receive an incoming IAT message, from INT 7100. Other transponders, including certain other embodiments of transponder 7020, may be configured to operate in a low-energy, standby-like state. In one non-limiting example of a low-energy, standby-like state, electrical power may be removed from at least a portion of inactive transponder electrical circuitry, which may reduce transponder energy consumption, and may allow a transponder power source to be generally more compact and longer-lived. One well-known standby-like state technique may be a “WAKE ON RADIO” mode, in which a transponder returns from a standby-like state in response to a received radio signal, for example, by restoring electrical power to appropriate portions of transponder electrical circuitry. The “WAKE ON RADIO” signal may be provided by INT 7100, but is not required to be. Once awakened, an energized transponder may recognize and receive an interrogator demand from INT 7100.

30 **[0128]** Example method 11000 may begin by HOST 8000 generating (S11010) a target transponder command set. A target transponder command set may identify selected target transponders to be contacted, may define monitored subject data to be collected from the target transponders, and may

define a search interval during which target transponders, such as transponder 7020, may be queried with an interrogator demand, for example, an interrogator ATTENTION demand, from INT 7100. Alternatively, INT 7100 may be configured to implement generating (S11010) of one or more target transponder command set. A logical representation of a target transponder command set may include a target transponder list, in which identifiers of selected target transponders to be contacted may be maintained. INT 7100 may proceed in method 11000 by awakening (S11020) in response to an ALERT signal received from HOST 8000 using a predetermined command channel. Examples of a predetermined command channel may include one or both of CIM wireless link 7420 or CIM wireline link 7440, in FIGS. 7 and 8. INT 7100 may reply by acknowledging (S11030) being awakened. INT 7100 may continue method 11000 by receiving (S11040) a target transponder command set downloaded by HOST 8000 over the predetermined command channel. INT 7100 may respond to receiving the target transponder command set from HOST 8000 by transmitting (S11050) an interrogator ATTENTION demand on a predetermined communication frequency band using a predetermined communication protocol over a predetermined communication range. A non-limiting example of an interrogator ATTENTION demand may be a WAKE ON RADIO signal. Typically, an interrogator ATTENTION demand can be broadcast by INT 7100 on a predetermined transponder frequency band using a predetermined transponder protocol to one or more available transponders 7020, 7021, which may be disposed within a predetermined transponder range. In one alternative, an interrogator ATTENTION demand can be selectively transmitted by INT 7100 to a first transponder 7020, which may be disposed within a first transponder range of INT 7100, on a first transponder frequency band using a first transponder protocol, and to a second transponder 7021, which may be disposed within a second transponder range of INT 7100, on a second transponder frequency band using a second transponder protocol, to a selected transponder, or a selected group of transponders, which may be disposed within a communication range of INT 7100.

[0129] Subsequent to transmitting (S11050) an interrogator ATTENTION demand, INT 7100 may proceed to detecting (S11060) a transponder ATTENTION response, which may be, without limitation, an IAT message including a transponder identifier corresponding to responding transponder 7020. Responding transponder 7020 may communicate an IAT message to INT 7100, for example, using one or more techniques described with respect to Method 9000, in FIG. 9. INT 7100 may be configured to perform transmitting (S11050) an interrogator ATTENTION demand repeatedly, for example, until transponders in a target transponder list have been reckoned, or until a predefined search interval elapses. In addition, INT 7100 may be configured to process a received transponder signal characteristic, for example, by determining (S11070) a transponder signal strength produced by transponder 7020. Also, method 11000 may include INT 7100 verifying (S11080) that a transponder identifier corresponding to responding transponder 7020 is a selected transponder identified on a target transponder list. In embodiments in which INT 7100 iteratively processes a respective transponder ATTENTION response from plural responding transponders 7020, 7021, method 11000 may include

storing (S11090) in an interrogation buffer information corresponding to respective transponders 7020, 7021 including without limitation, a verified transponder identifier, a transponder signal strength, or both. Other information may be received from a responding transponder, and stored. In certain embodiments of method 11000, INT 7100 may ignore a response from a transponder that is not identified on a target transponder list. Alternatively, method 11000 may include noting (S11100) a response from a transponder that is not identified on a target transponder list, which may be useful to identify, for example, an errant monitored subject, which may not be part of monitored group 7030, but which may have strayed into range of INT 7100. Method 11000 also may include INT 7100 continuously listening (S11110) for a preselected search interval.

10 [0130] In an example in which all transponders 7020 on a target transponder list have responded to INT 7100, method 11000 may include INT 7100 uploading (S11120) to HOST 8000 a stored interrogation buffer having responding transponder information. In an example in which a preselected search interval elapses before all transponders 7020 on a target transponder list have responded to INT 7100, method 11000 may include uploading (S11120) to HOST 8000 a stored
15 interrogation buffer having identifying transponders that did not respond within the preselected search interval. A stored interrogation buffer corresponding to uploading action S11110 also may include responding transponder information, for example, a verified transponder identifier, a transponder signal strength, or both. In selected embodiments, INT 7100 may conclude method 11000 by switching (S11130) to a low power interrogator operational mode.

20 [0131] FIG. 12 illustrates an example embodiment of method 12000 for operating an active tag, which may be described with respect to an intelligent transponder. For the purposes of illustration, method 12000 may be described with reference to FIG. 5, including XPDR 5000. XPDR 5000 may be a constituent of an intelligent active tag, such as IAT 1110 in FIG. 1, and tag 2000 in FIG. 2C and FIG. 3B. Also XPDR 5000 may be attached to monitored subject 5800. In general, embodiments of method
25 12000 may employ one or more of the action: selecting (S12100) a predetermined operational mode for the transponder; supplying (S12200) electrical power selectively to a portion of transponder electrical circuitry in accordance with a predetermined operational mode; selecting (S12300) a predetermined transponder operation corresponding to the predetermined operational mode; and performing (S12400) the predetermined transponder operation in accordance with the predetermined operational mode.

30 [0132] In support of example embodiments of method 12000, the predetermined operational mode may include one of a predetermined periodic operational mode, a predetermined interrogator demand operational mode, a predetermined transponder demand operational mode, or a predetermined combination operational mode, although other operational modes may be implemented in addition thereto, or in substitution thereof. In selected embodiments of method 12000, supplying (S12200)
35 electrical power further may include activating (S12210) the transponder by altering a conductive property of an activation circuit to couple a power source to the transponder. The action of performing (S12400) a predetermined transponder operation may include performing (S12405) at least one

predetermined communication operation, performing (S12410) at least one predetermined sensing operation, performing (S12415) at least one predetermined power management operation, or a combination of at least two of performing a predetermined communication operation, performing a predetermined sensing operation, or performing a predetermined power management operation.

5 **[0133]** In certain embodiments, the predetermined transponder operation may include at least one predetermined communication operation in which the active tag communicates with an interrogator, and selecting (S12300) a predetermined transponder operation, also may include selecting (S12325) a selected communication technique, in accordance with a predetermined operational mode; selecting (S12335) a selected transponder communication protocol, in accordance with the predetermined
10 operational mode; or both. Correspondingly, performing (S12400) a predetermined transponder operation may include exchanging (S12425) an intelligent active tag message with the interrogator. In addition, in selected embodiments of method 12000, selecting (S12300) a predetermined transponder operation also may include one or more of selecting (S12330) a selected communication frequency band corresponding to the selected communication technique from among plural communication frequency
15 bands; selecting (S12335) a selected communication range corresponding to the selected communication technique from among plural communication ranges; or selecting (S12340) a network topology by which to communicate with the interrogator. Alternatively, selecting (S12300) a predetermined transponder operation may include selecting (S12350) a selected sensed physical quantity for sensing and, correspondingly, performing (S12400) the predetermined transponder operation may include
20 sensing (S12420) the selected sensed physical quantity. Furthermore, performing (S12400) also may include storing (S12430) a selected sensed physical quantity representation in a transponder memory. Embodiments of method 12000 may perform exchanging (S12425) an intelligent active tag message with the interrogator by receiving (S12435) an inbound intelligent active tag message from the interrogator or transmitting (S12440) an outbound intelligent active tag message to the interrogator. In
25 certain selected embodiments in which method 12000 includes activating (S12210) the transponder, the action of performing (S12400) may provide transmitting (S12450) an outbound intelligent active tag REGISTRATION message to the interrogator, in response to the activating (S12210).

30 **[0134]** In view of the foregoing, apparatus and methods in accordance with the present disclosure can be applicable for use with virtually every form of asset, including nearly every vertebrate species. In addition, apparatus and methods described herein may be implemented physically or
virtually, in hardware, in software, in firmware, or in a functional combination of hardware, software, or firmware. The above described example embodiments of the present invention are intended as teaching examples only. These example embodiments are in no way intended to be exhaustive of the scope of the present invention.

35

CLAIMS

What is claimed is:

1. An active tag for attaching to a monitored subject, comprising:
 - 5 a tag housing;
 - a substrate having a conductive portion within the tag housing;
 - a configurable transponder having transponder electrical circuitry coupled to the conductive portion, and including at least one transceiver configured to communicate a tag message using at least one selected communication technique; and
 - 10 an activation circuit coupled to the conductive portion, and configured to provide electrical power to a portion of the transponder electrical circuitry in self-activating response to the tag housing being attached to the monitored subject,
 - wherein the tag housing encloses the substrate, the configurable transponder and the activation circuit and
 - 15 wherein the tag message is one of an outbound tag message transmitted by the transceiver or an inbound tag message received by the transceiver.
2. The active tag of Claim 1, wherein the transponder further comprises:
 - 20 a configurable sensor sensingly coupled between the monitored subject and the transceiver, wherein the sensor is configured to sense a selected sensed physical quantity pertaining to the monitored subject and wherein a selected sensed physical quantity representation is included in the tag signal.
3. The active tag of Claim 2, further comprising:
 - 25 an antenna coupled to the at least one transceiver and configured to communicate the tag message on a selected frequency band corresponding to at least one selected communication technique.
4. The active tag of Claim 3, further comprising:
 - 30 a managed power source coupled to the conductive portion and the activation circuit, and configured to selectively supply electrical power to the transponder electrical circuitry after activation by the activation circuit.
5. The active tag of Claim 1, further comprising:
 - 35 an antenna coupled to the at least one transceiver and configured to operate on a selected frequency band corresponding to at least one selected communication technique;

a managed power source coupled to the conductive portion and the activation circuit, and configured to selectively supply electrical power to the transponder electrical circuitry: and

5 sensors sensingly coupled between the monitored subject and the transceiver, wherein a first sensor includes a position sensor that produces a sensed position parameter pertaining to the monitored subject, wherein a second sensor includes a biological parameter pertaining to the monitored subject, and wherein the tag message includes the sensed position parameter, the sensed biological parameter, or both.

10 6. The active tag of Claim 5, further comprising two or more transponders coupled to the conductive portion, wherein each of the two or more transponders include at least one transceiver respectively configured to communicate a tag message using a respective selected communication technique.

15 7. The active tag of Claim 5, wherein the managed power source further comprises an energy harvesting module configured to convert ambient energy into recovered electrical energy.

20 8. The active tag of Claim 5, wherein the transponder further comprises:
an operations mode manager coupled to at least one transceiver, at least one of the sensors, and the managed power source, and configured to select a predetermined operational state for the transponder, to select a predetermined transponder operation to be performed in the predetermined operational state, or both,

25 wherein the a predetermined transponder operation includes at least one predetermined communication operation, at least one predetermined sensing operation, or at least one predetermined power management operation, or a combination of at least two of a predetermined communication operation, a predetermined sensing operation, or a predetermined power management operation, and

30 wherein the predetermined operational mode is one of a predetermined transponder demand operational mode, a predetermined interrogator demand operational mode, or a predetermined periodic operational mode, or a predetermined combination operational mode.

35 9. The active tag of Claim 8 wherein the operations mode manager
configures the transponder to communicate an outbound tag message in response to the sensed position parameter, the sensed biological parameter, or both, or
selectively reconfigures the transponder from a first predetermined operational mode to a second predetermined operational mode responsive to an inbound tag message, or

both.

10. A transponder attachable to a monitored subject, comprising:
- 5 an RF module configured to exchange a message with an interrogator over two or more selected communication ranges, using one or more selected communication techniques;
- a sensor module configured to provide at least one selected sensed physical quantity pertaining to the monitored subject;
- a transponder control module in communication with the RF module and the sensor module and cooperatively including
- 10 an operations mode manager configured to operate the transponder in accordance with a predetermined operational mode,
- a communications manager configured to select one of the two or more selected communication ranges, and to select one of the one or more selected communication techniques; and
- 15 a processor that processes the sensed subject parameter, the message, or both, in accordance with a predetermined operational mode; and
- a self-activating power management module configured to selectively provide electric power in accordance with a predetermined operational mode to one or more of the RF module, the sensor module, or the transponder control module.
- 20
11. The transponder of Claim 10, wherein the RF module is configured to exchange the message in accordance with the selected communication technique using a selected collision avoidance protocol.
- 25
12. The transponder of Claim 10, wherein the selected communication technique comprises a first selectable communication technique and a second selectable communication technique, wherein the first selectable communication technique includes a WLAN-type communication technique having a selected communication range of at least about 1000 meters, and wherein the second selectable communication technique includes a WPAN-type communication technique having a selected communication range of up to about 30 meters.
- 30
13. The transponder of Claim 12, wherein the RF module is configured to exchange the message in accordance with one of the first selectable communication technique or the second selectable communication technique, and at least one of the first or second selectable communication techniques uses a selected collision avoidance protocol.
- 35

14. The transponder of Claim 11, further comprising an energy harvesting module configured to convert ambient energy to recovered electrical energy and electrically coupled to the self-activating power management module.
- 5 15. A subject management system for managing a monitored subject in a monitored region, comprising:
- an interrogator configured to communicate using at least one selected communication technique; and
- 10 an intelligent active tag intimately affixed to the monitored subject and having a transceiver configured to selectively exchange an intelligent active tag message with interrogator using the at least one selected communication technique,
- wherein the intelligent active tag includes a motion sensor producing a first selected sensed physical quantity indicative of a motion of the monitored subject in the monitored region and wherein the intelligent active tag includes a first selected sensed physical
- 15 quantity representation in an outbound intelligent active tag message transmitted to the interrogator.
16. The subject management system of Claim 15, wherein the intelligent active tag further comprises a biosensor producing a second selected sensed physical quantity indicative of a biological function of the monitored subject, wherein the intelligent active tag includes a second selected sensed physical quantity representation in an outbound intelligent active tag message transmitted to the interrogator.
- 20 17. An tag reader system for managing a monitored subject having an attached transponder, comprising:
- an interrogator module, including
- an interrogator RF module configured to exchange a transponder message with the transponder using a first selected communication technique and to produce a transponder image from a preselected transponder signal characteristic of a received
- 30 transponder message,
- an interrogator processing module coupled to the interrogator RF module having a controller configured to process the transponder image and to determine a monitored subject characteristic of the monitored subject, and
- an interrogator communication interface module coupled to the interrogator processing module and configured to communicate the monitored subject
- 35 characteristic; and
- a host module including

- a host interface coupled to the interrogator communication interface module and configured to receive the monitored subject characteristic,
- a host processor coupled to the host interface and configured to process the monitored subject characteristic, and
- 5 a host computer interface coupled to the host processor and having a host display configured to produce a perceptible characteristic representation of the monitored subject characteristic.
18. The tag reader system of Claim 17 wherein the preselected transponder signal characteristic is representative of a monitored subject spatial characteristic.
19. The tag reader system of Claim 18, wherein the received transponder message includes a selected sensed physical quantity representation pertaining to the monitored subject, wherein the interrogator module stores and communicates the selected sensed physical quantity to the host module, and wherein the host module provides a perceptible representation of the selected sensed physical quantity representation on the host display.
20. A method for operating an active tag including a transponder attached to a monitored subject, the method comprising:
- 20 selecting a predetermined operational mode for the transponder, wherein the transponder is a multimode transponder;
- supplying electrical power selectively to a portion of transponder electrical circuitry in accordance with the predetermined operational mode;
- selecting a predetermined transponder operation corresponding to the predetermined operational mode; and
- 25 performing the predetermined transponder operation in accordance with the predetermined operational mode, wherein the predetermined operational mode includes one of a predetermined periodic operational mode, a predetermined interrogator demand operational mode, a predetermined transponder demand operational mode, or a predetermined combination operational mode,
- 30 wherein performing the predetermined transponder operation includes performing at least one predetermined communication operation, performing at least one predetermined sensing operation, performing at least one predetermined power management operation, or performing a combination of at least two of performing a predetermined communication operation, performing a predetermined sensing operation, or performing a predetermined power management operation, and
- 35 wherein the active tag is an intelligent active tag.

21. The method of Claim 20, wherein selecting the predetermined transponder operation comprises at least one predetermined communication operation in which the active tag communicates with an interrogator, the method further comprising at least one of:
- 5 selecting a selected communication technique, in accordance with a predetermined operational mode, or
- selecting a selected transponder communication protocol, in accordance with the predetermined operational mode; and
- wherein performing the predetermined transponder operation further comprises
- 10 exchanging an intelligent active tag message with the interrogator.
22. The method of Claim 21, further comprising at least one of:
- selecting a selected communication frequency band corresponding to the selected communication technique from among plural communication frequency bands;
- 15 selecting a selected communication range corresponding to the selected communication technique from among plural communication ranges; or
- selecting a network topology by which to communicate with the interrogator.
23. The method of Claim 20, wherein selecting a predetermined transponder operation further comprises selecting a selected sensed physical quantity for sensing, and wherein performing the predetermined transponder operation further comprises sensing the selected sensed physical quantity.
- 20
24. The method of Claim 21, wherein exchanging an intelligent active tag message with the interrogator further comprises one of receiving an inbound intelligent active tag message from the interrogator or transmitting an outbound intelligent active tag message to the interrogator.
- 25
25. The method of Claim 21, wherein supplying electrical power further comprises activating the transponder by altering a conductive property of an activation circuit to couple a power source to the transponder, and wherein exchanging an intelligent active tag message further comprises transmitting an outbound intelligent active tag REGISTRATION message to the interrogator in response to the activating.
- 30

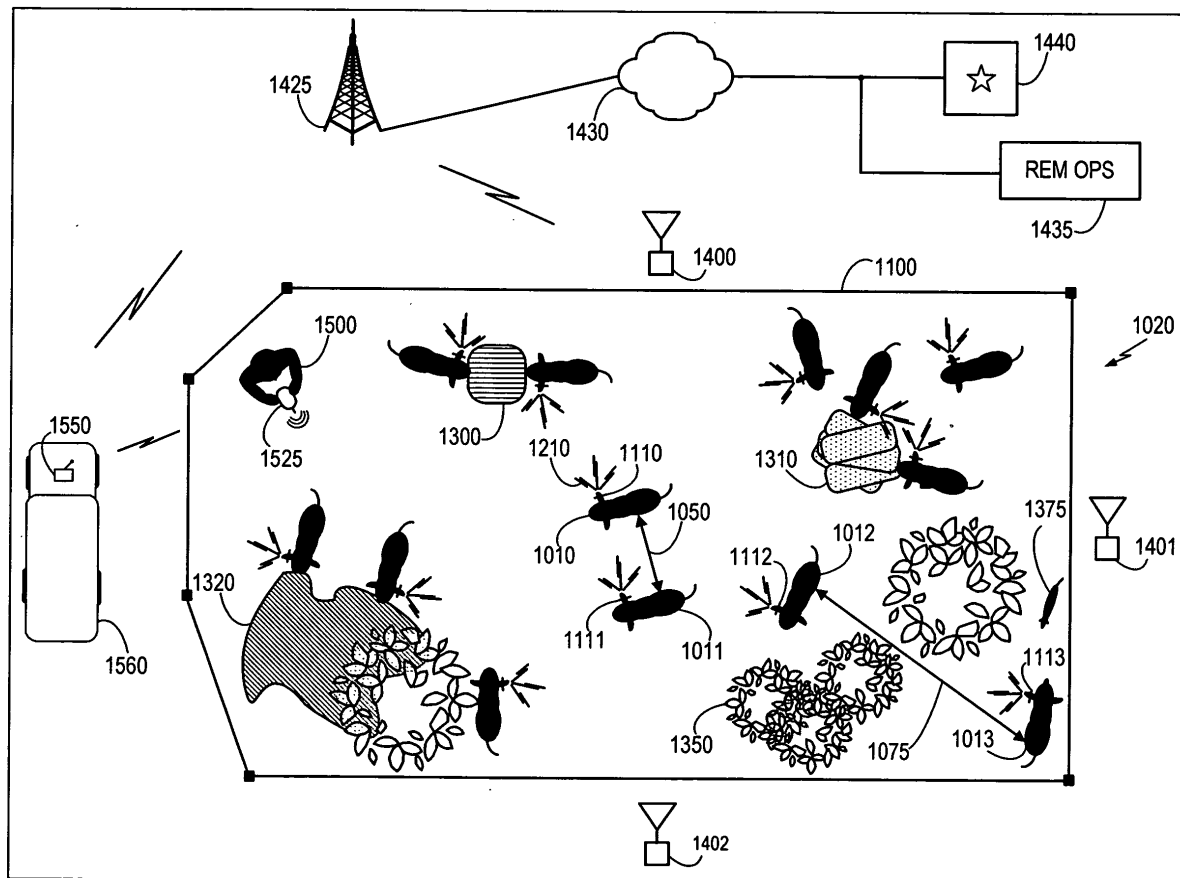


FIG. 1

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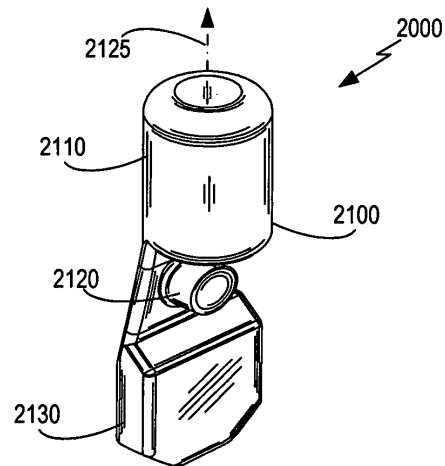


FIG. 2A

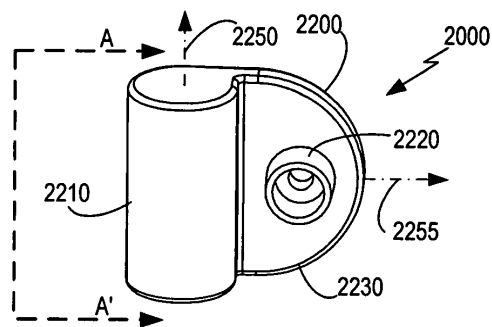


FIG. 2B

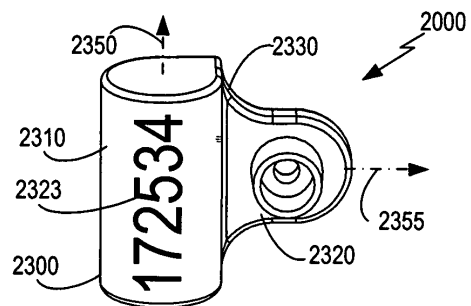


FIG. 2C

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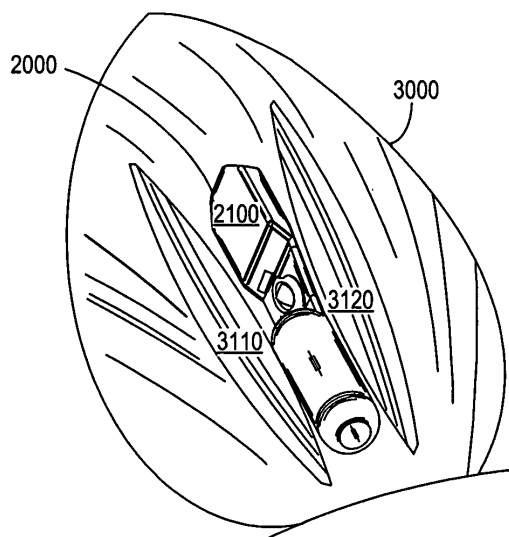


FIG. 3A

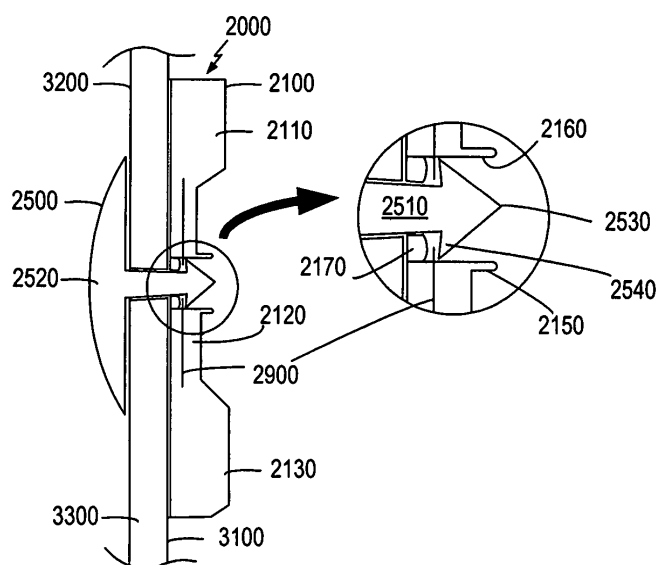


FIG. 3B

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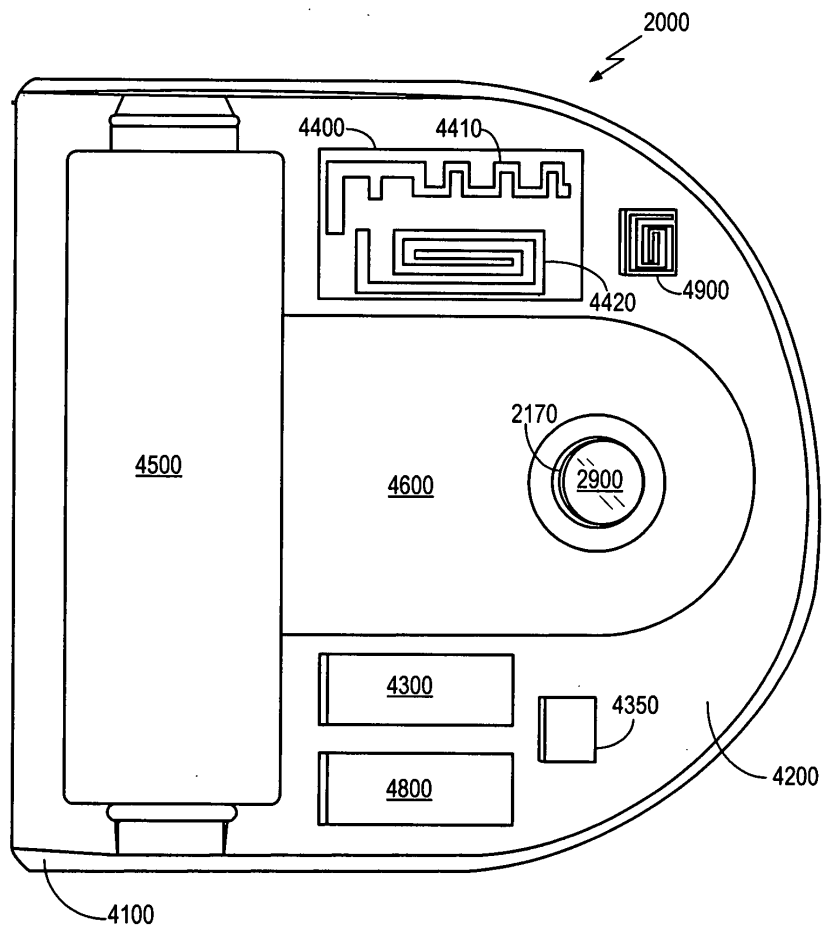


FIG. 4

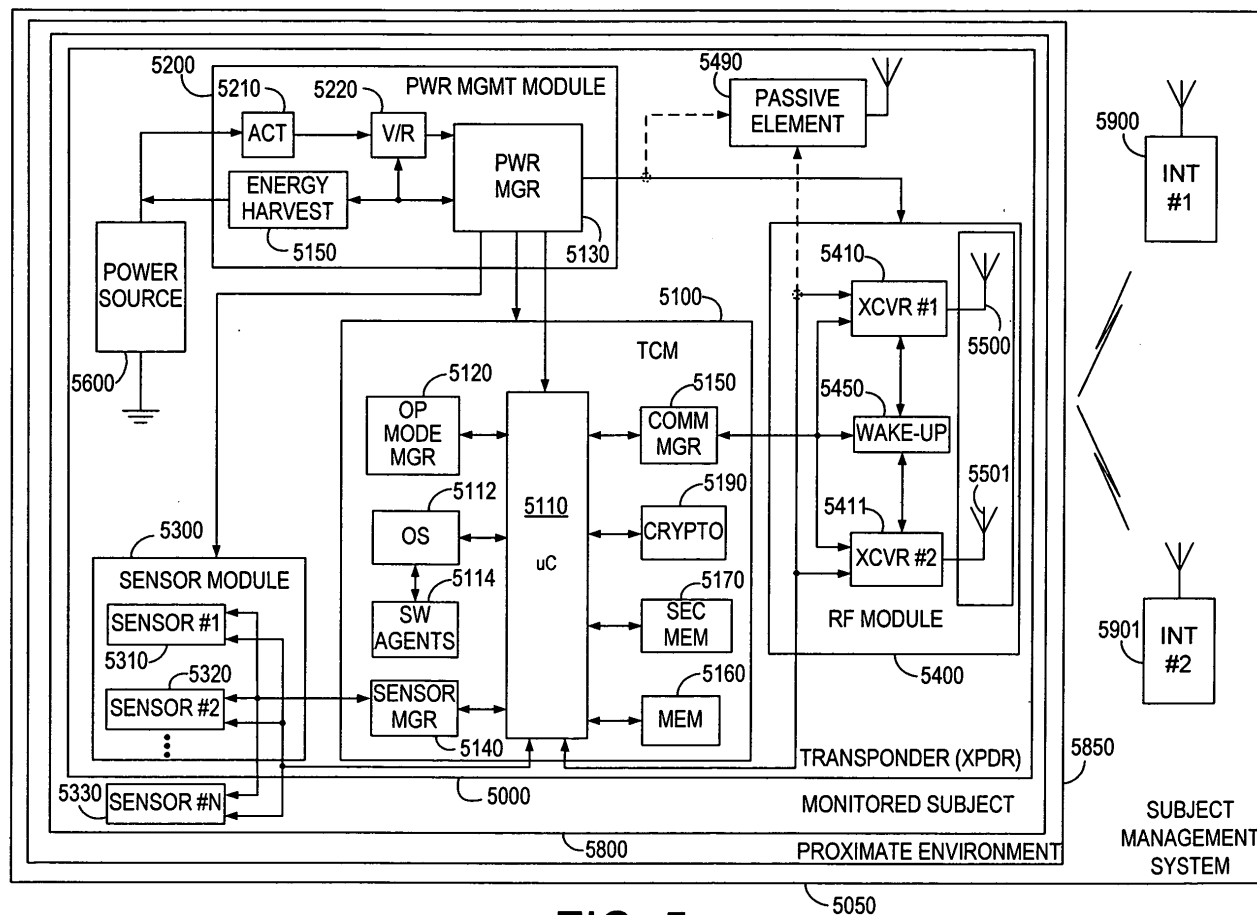


FIG. 5

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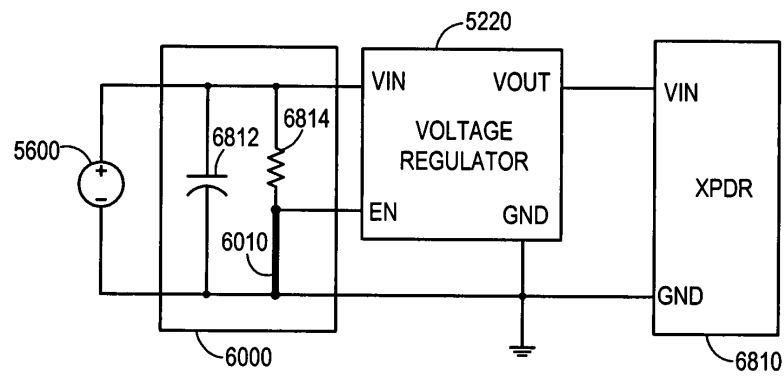


FIG. 6A

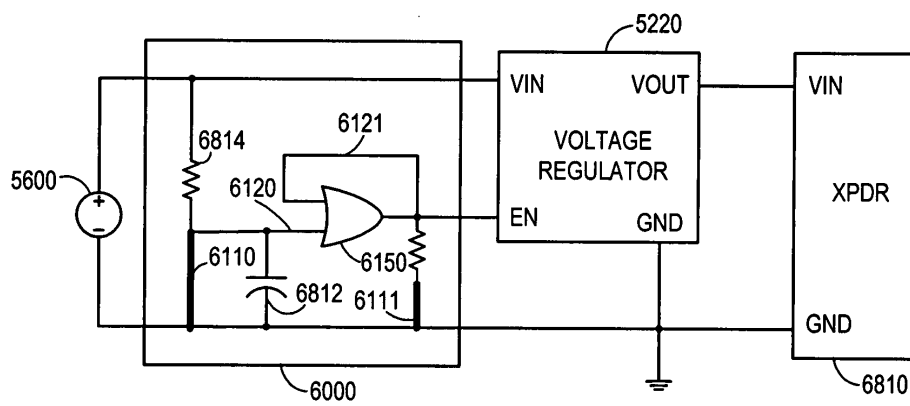


FIG. 6B

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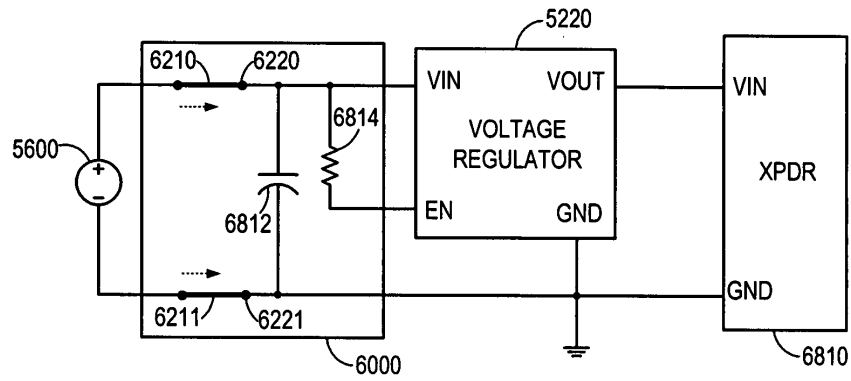


FIG. 6C

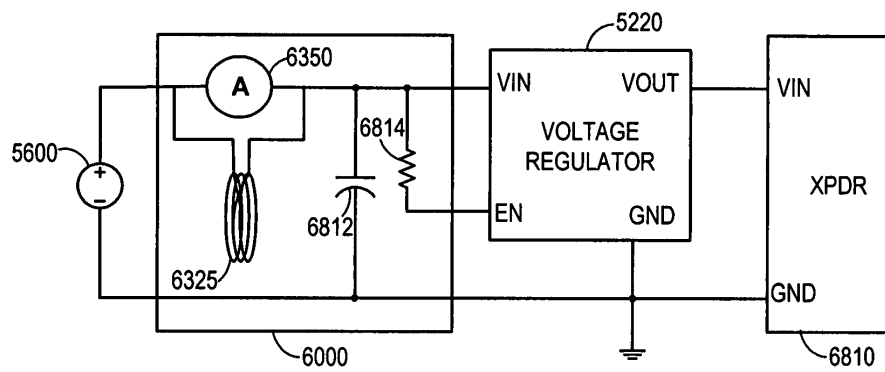


FIG. 6D

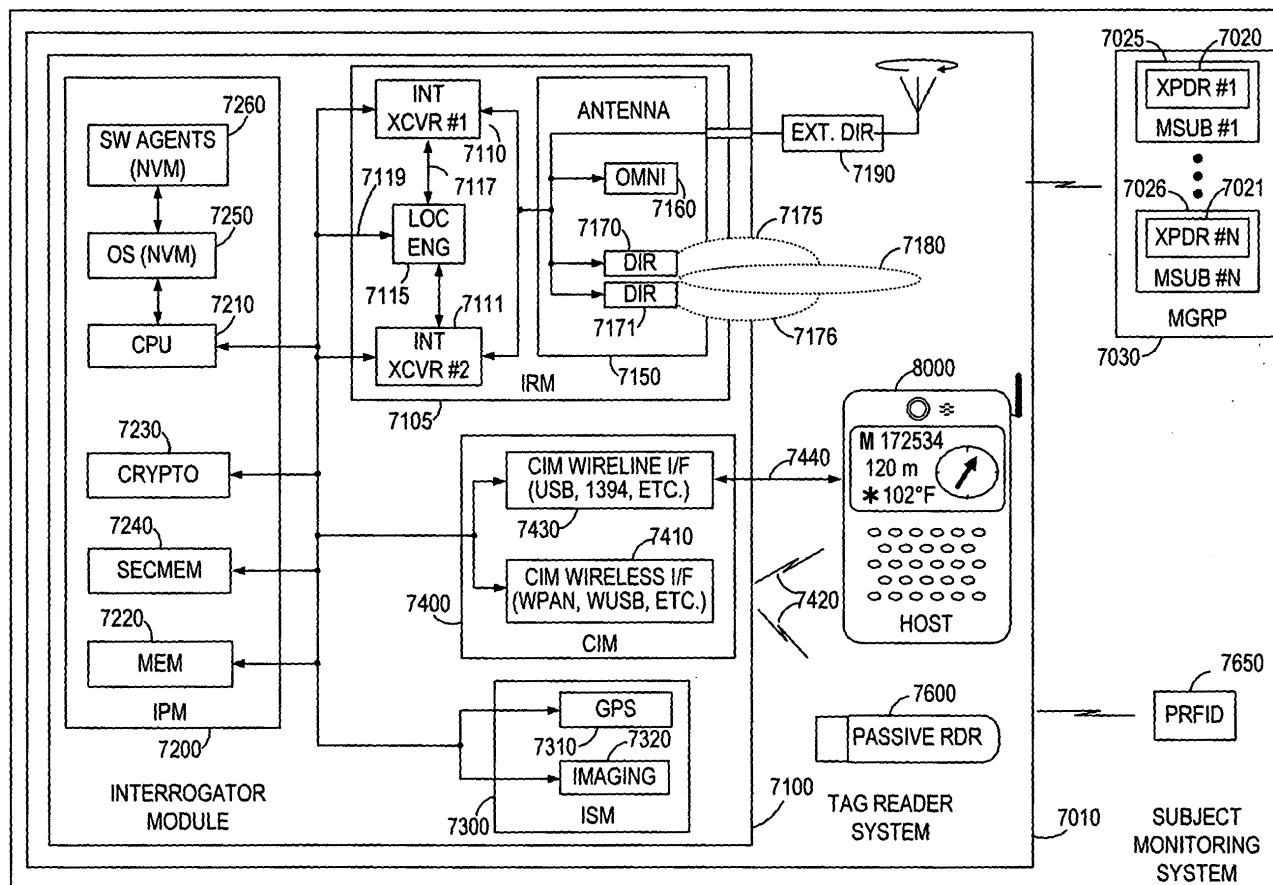


FIG. 7

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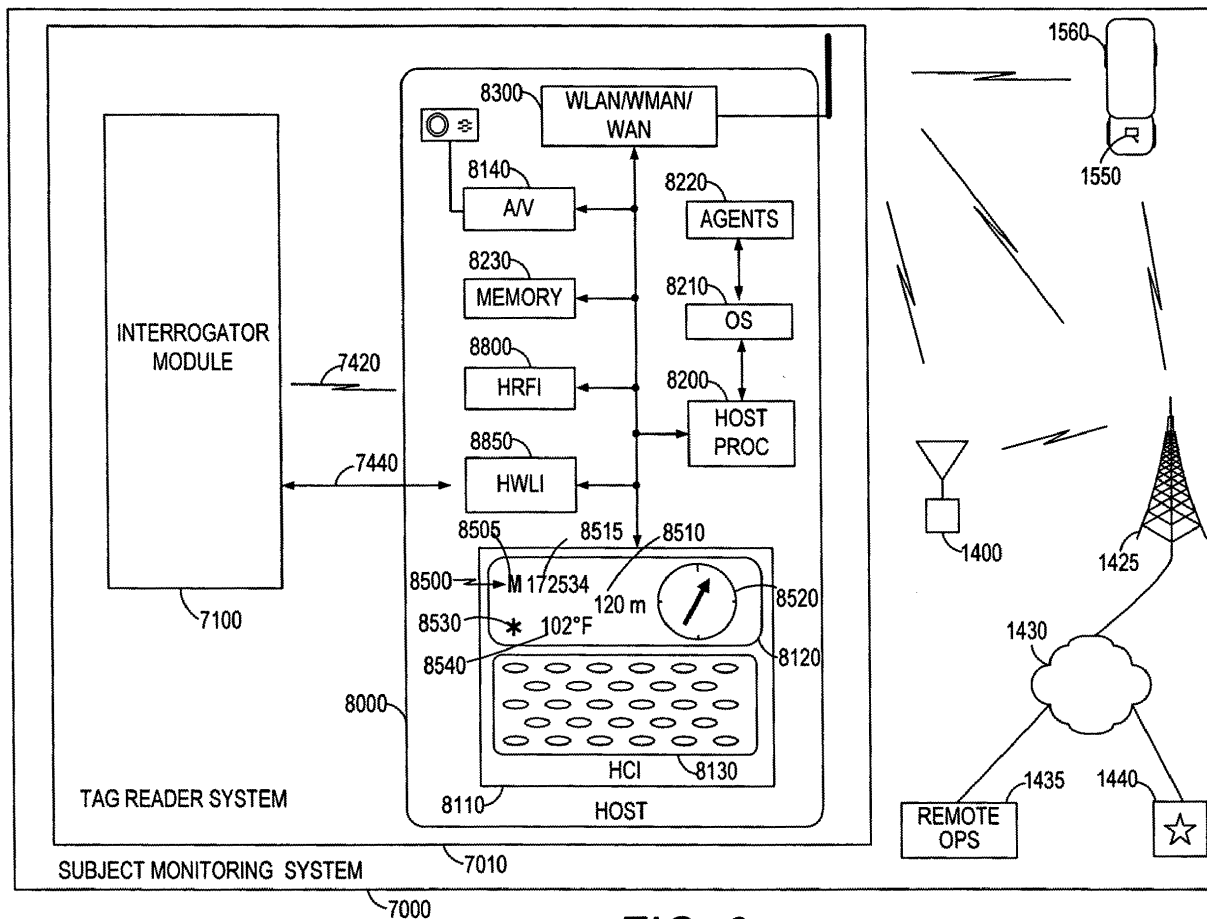


FIG. 8

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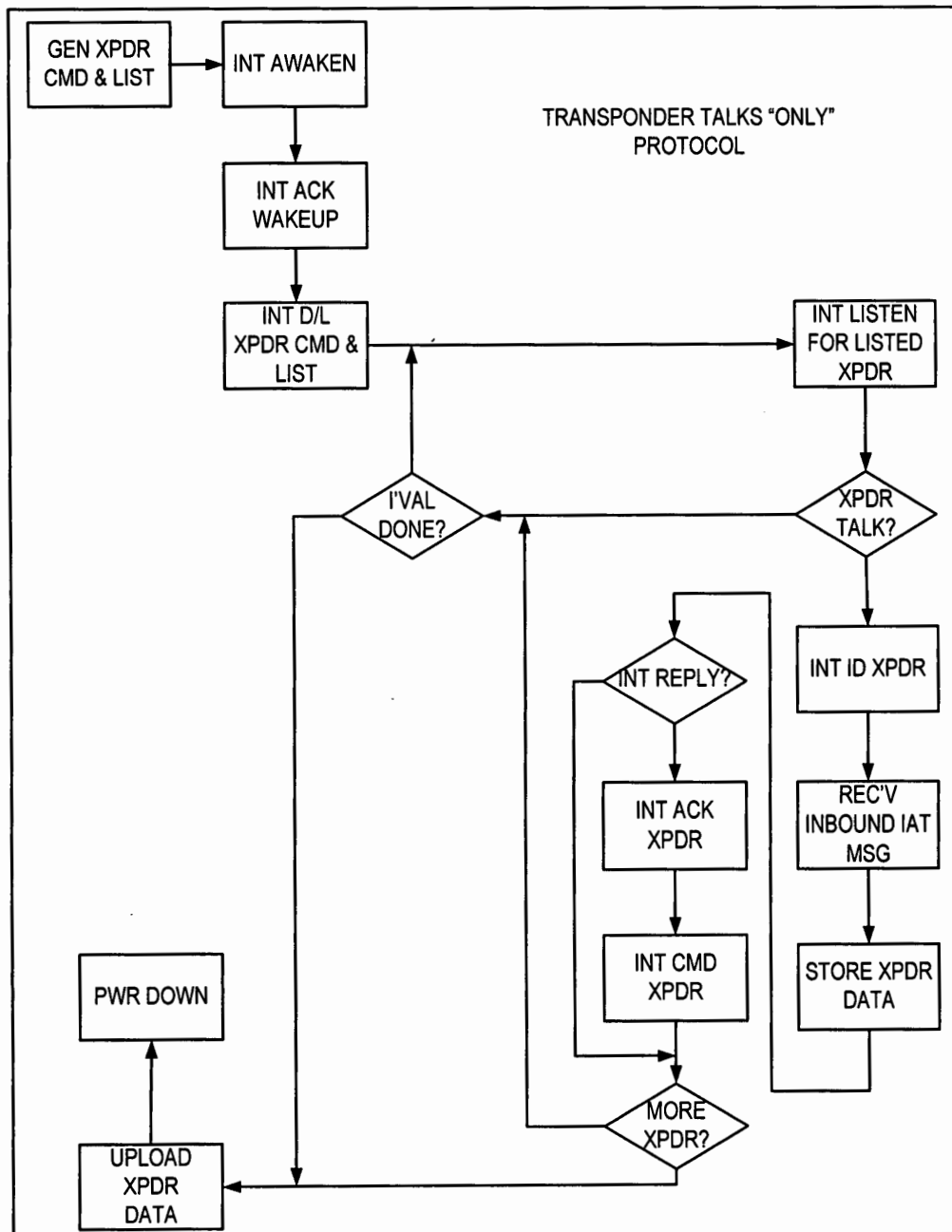


FIG. 9

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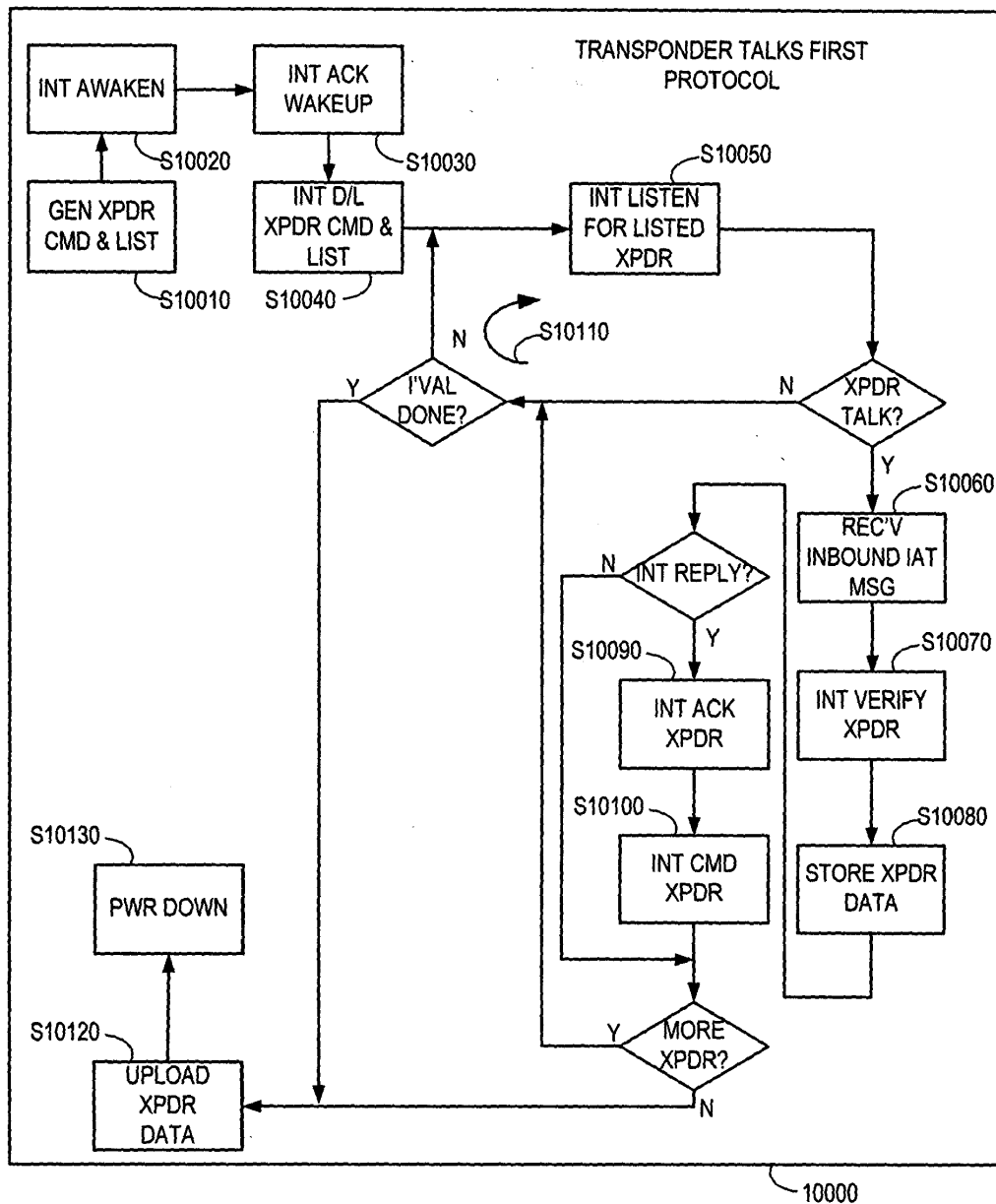
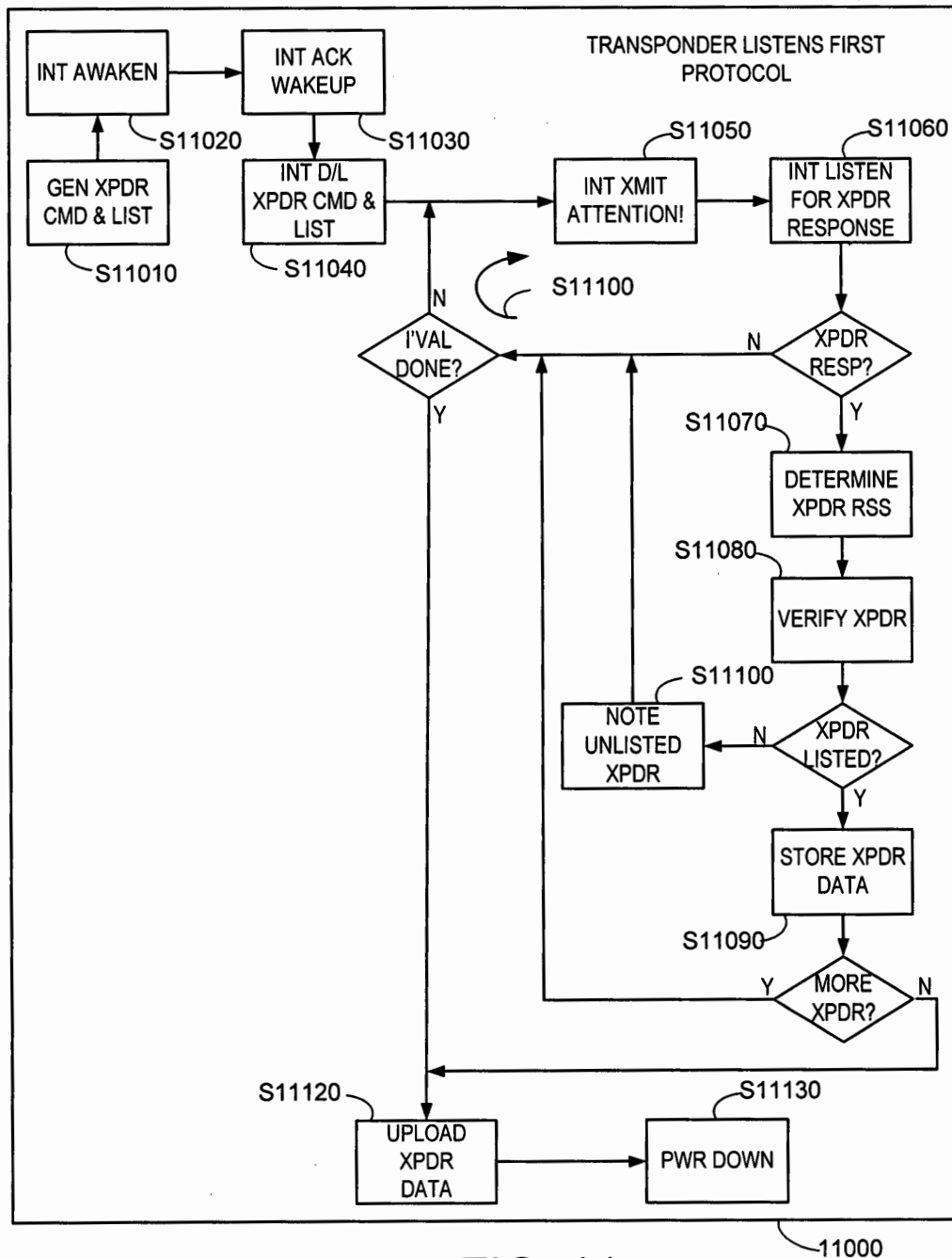


FIG. 10

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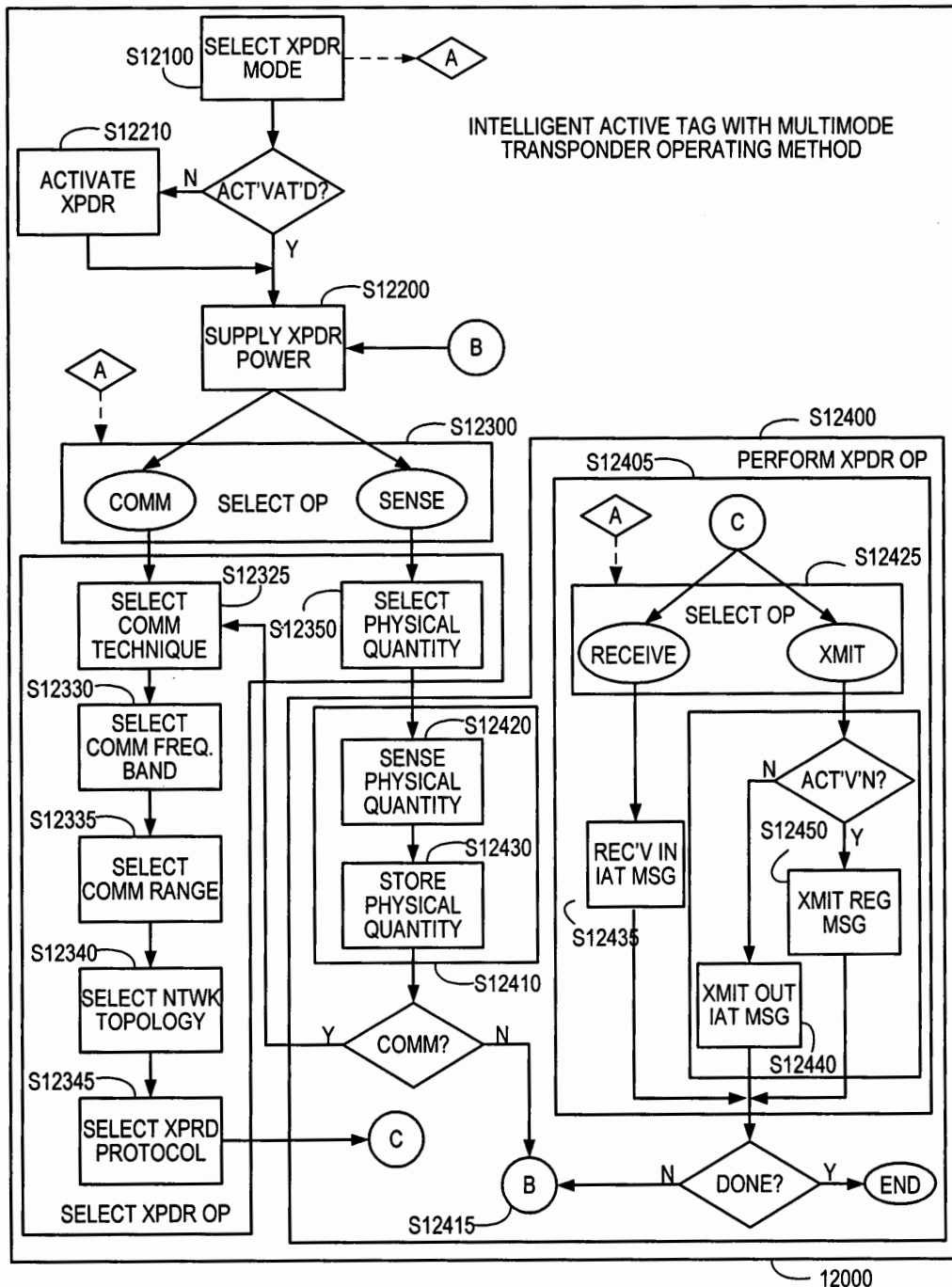


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 07/20918

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - G08B 23/00 (2008.01) USPC - 340/573.3 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) USPC: 340/573.3 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched USPC: 340/573.3 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Pub WEST (USPT, PGPB, EPAB, JPAB); Google Scholar Search terms: RFID, transceiver, transponder, solar, ambient, message, signal, monitored, characteristic, physical, property, frequencies, operational, modes, collision, TCP, ATM, housing, enclosure, registration, dual-frequency, livestock, active-tag		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/0025897 A1 (SHOSTAK et al.) 02 February 2006 (02.02.2006), entire document (especially Abstract, para [0004], [0072], [0091], [0301]-[0304], [0832]-[0835], [1008], [1138], [1157], [1311], [1530], and Fig. 11, 19A, 19B, 19C, 48A, 48B, 54)	1-4, 10-15, 20-25 — 5-9, 16-19
Y	US 2004/0155782 A1 (LETKOMILLER et al.) 12 August 2004 (12.08.2004), entire document (especially [0002], [0027], [0090] and Fig. 1)	5-9, 16-19
A	US 2005/0099270 A1 (DIORIO et al.) 12 May 2005 (12.05.2005)	1-25
A	US 2006/0202835 A1 (THIBAUT) 14 September 2006 (14.09.2006)	1-25
A	US 2004/0061324 A1 (HOWARD) 01 April 2004 (01.04.2004)	1-25
☐ Further documents are listed in the continuation of Box C. ☐		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 14 February 2008 (14.02.2008)		Date of mailing of the international search report 18 MAR 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201		Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (April 2007)