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Jacofsky et al.

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(54) **SYSTEMS AND METHODS FOR MONITORING AND PROVIDING THERAPEUTIC SUPPORT FOR A USER**

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A61B 5/00 (2006.01)
H04B 5/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***A61B 5/447*** (2013.01); ***A47C 27/083*** (2013.01); ***A47C 31/123*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC A61G 7/05769; A61G 2203/34; A47C 27/082; A47C 27/10; A47C 27/083;
(Continued)

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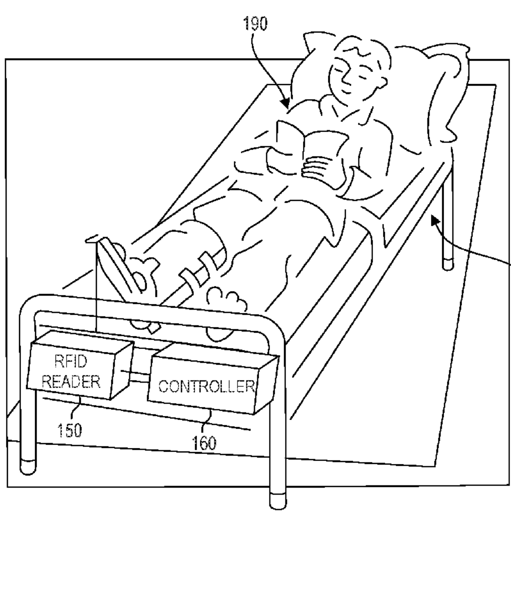
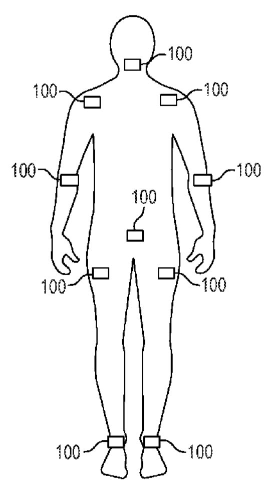
(57) **ABSTRACT**

Systems and methods for monitoring pressure exerted on an individual at one or more points by a support structure and adjusting the support structure in response to the monitored pressure are disclosed. The method for monitoring pressure may include the step of periodically receiving with at least three radio frequency readers, localized contact pressure data from a radio frequency addressable sensor placed on an individual. The method may further include, when an adjustment is required, calculating a radial distance defining a radius of the radio frequency addressable sensor to the at least three radio frequency readers, and calculating an intersection location or overlap of the radii such that the location of the radio frequency addressable sensor is determined. The method may also include, when the location of the radio frequency addressable sensor is determined, adjusting cells within a zone or subzone corresponding to the location.

22 Claims, 18 Drawing Sheets





PATIENT-REAR VIEW

(51) **Int. Cl.**

H04W 4/02	(2018.01)
A47C 27/08	(2006.01)
G05B 15/02	(2006.01)
A47C 31/12	(2006.01)
G06F 19/00	(2018.01)
G16H 40/63	(2018.01)
H04W 84/18	(2009.01)

(52) **U.S. Cl.**
CPC ***A61B 5/6832*** (2013.01); ***G05B 15/02*** (2013.01); ***G06F 19/3481*** (2013.01); ***G16H 40/63*** (2018.01); ***H04B 5/0031*** (2013.01); ***H04W 4/02*** (2013.01); *A61B 5/0022* (2013.01); *A61B 5/0024* (2013.01); *A61B 5/7275* (2013.01); *A61B 2562/028* (2013.01); *A61B 2562/0247* (2013.01); *A61G 2203/34* (2013.01); *F04C 2270/041* (2013.01); *H04W 84/18* (2013.01)

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CPC A47C 31/123; A61B 5/447; A61B 2562/0247; A61B 5/7275; A61B 5/0024; A61B 5/0022; A61B 2562/028; A61B 5/6832; G06F 19/00; G06F 19/3481; G16H 40/63; H04B 5/0031; G05B 15/02; F04C 2270/041; H04W 4/02; H04W 84/18
USPC 5/613, 713, 615, 715, 710–712
See application file for complete search history.

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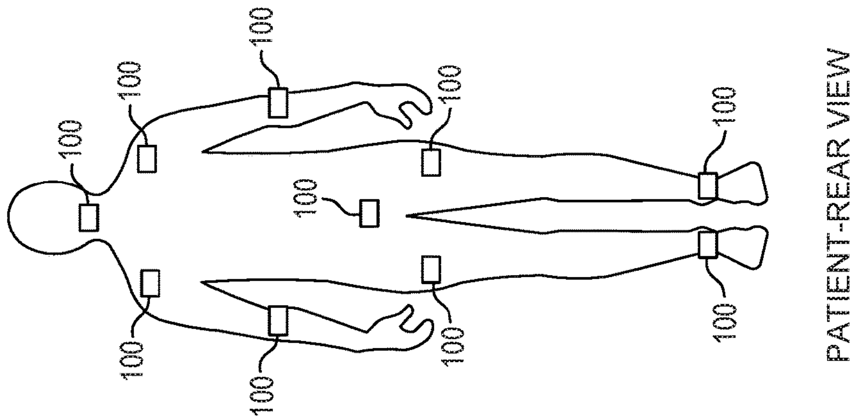
100
PATIENT-REAR VIEW

FIG. 1B

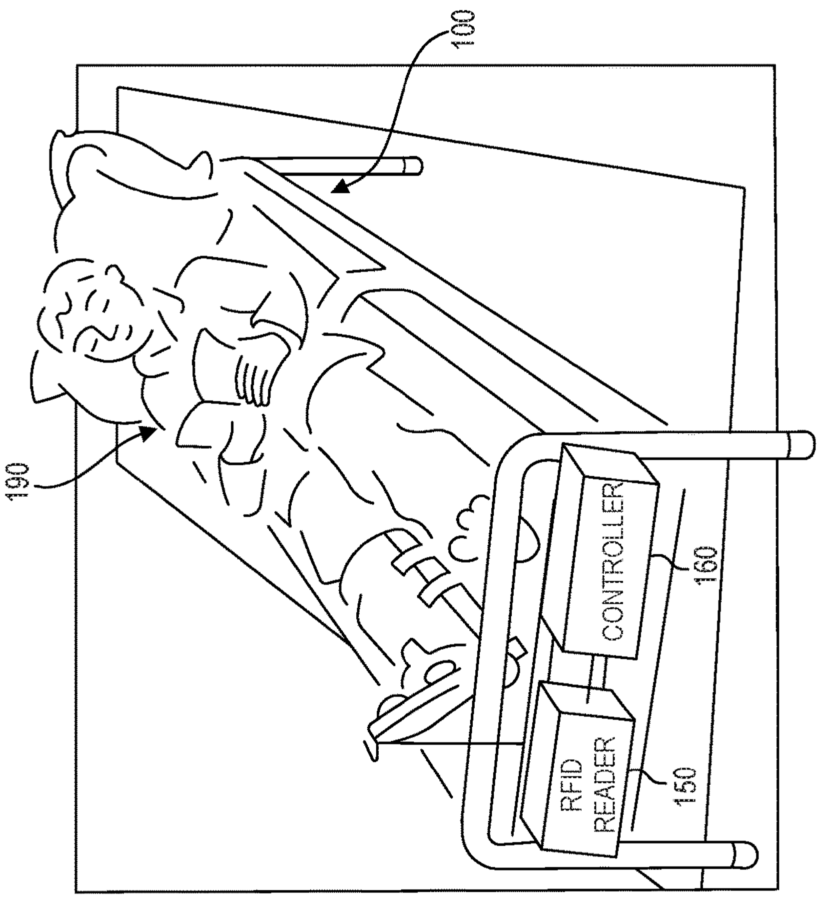
100
190
CONTROLLER
160
RFID READER
150

FIG. 1A

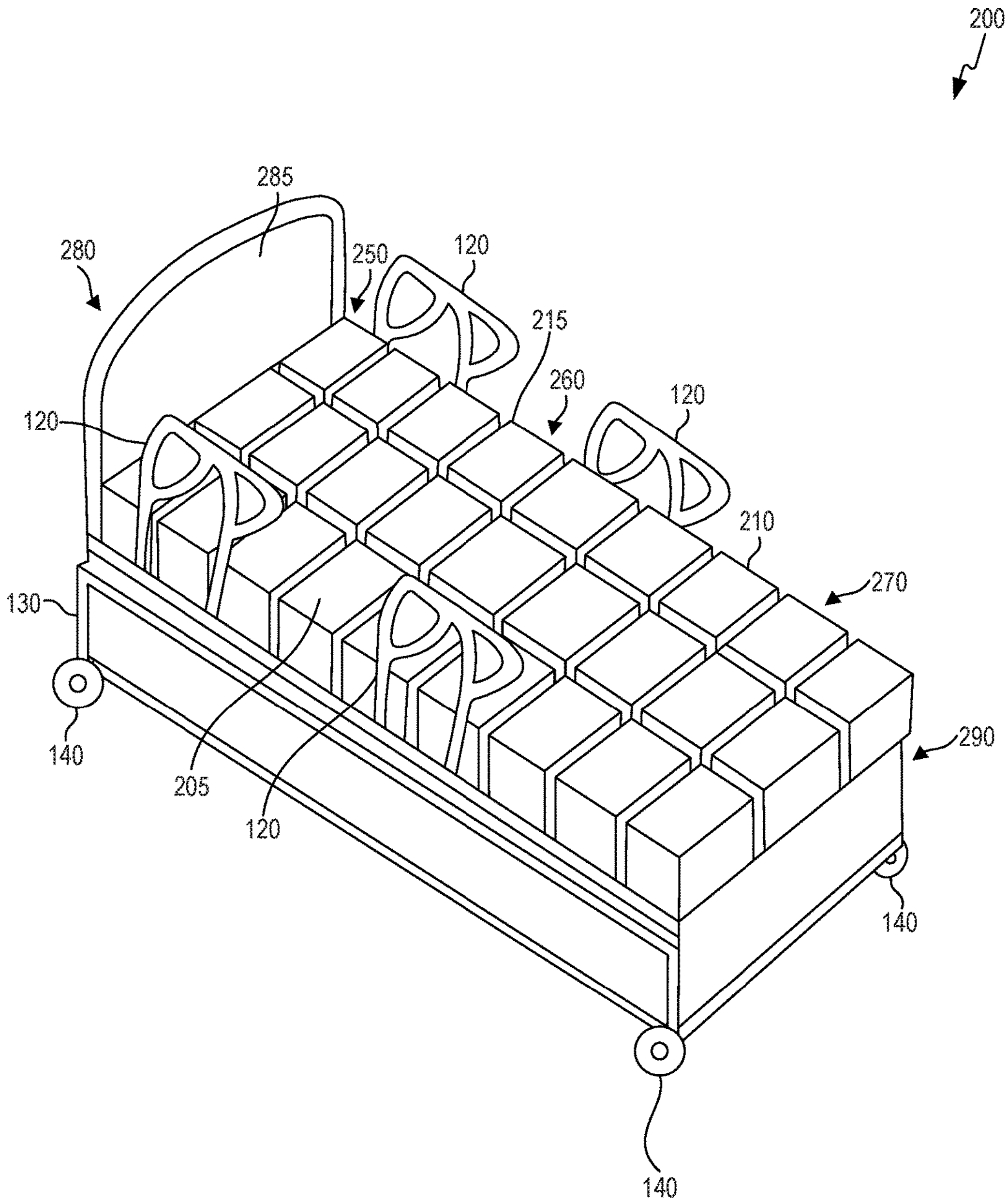
200
285
280
250
120
215
260
120
120
210
270
130
140
205
120
290
140
140

FIG. 2

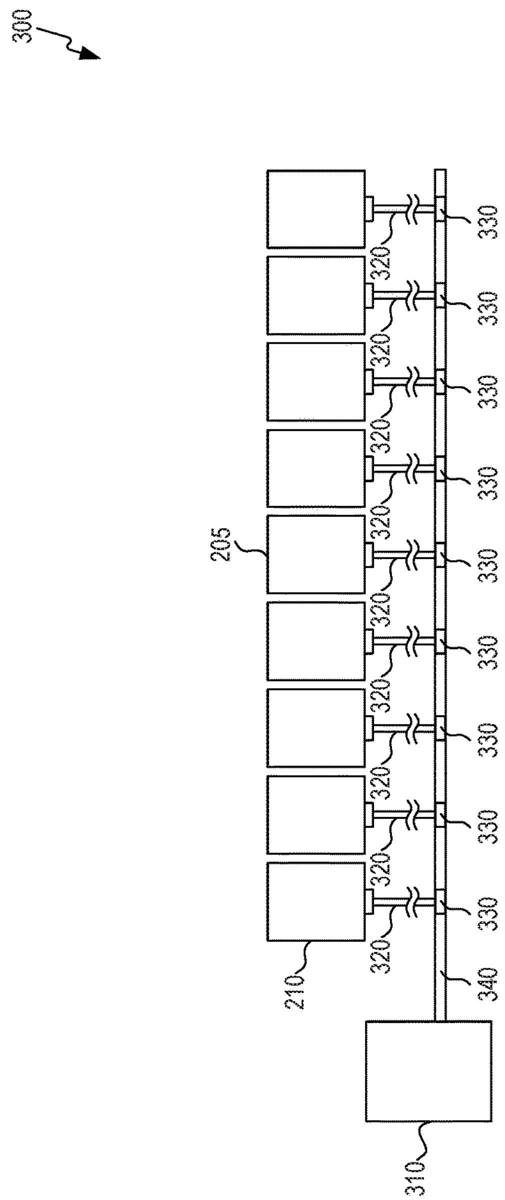

FIG. 3

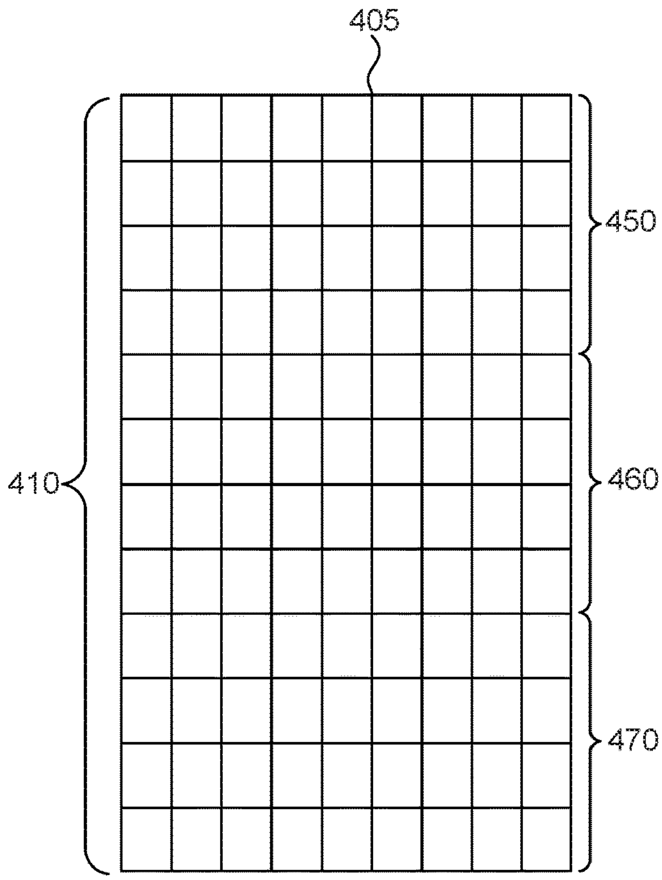

FIG. 4

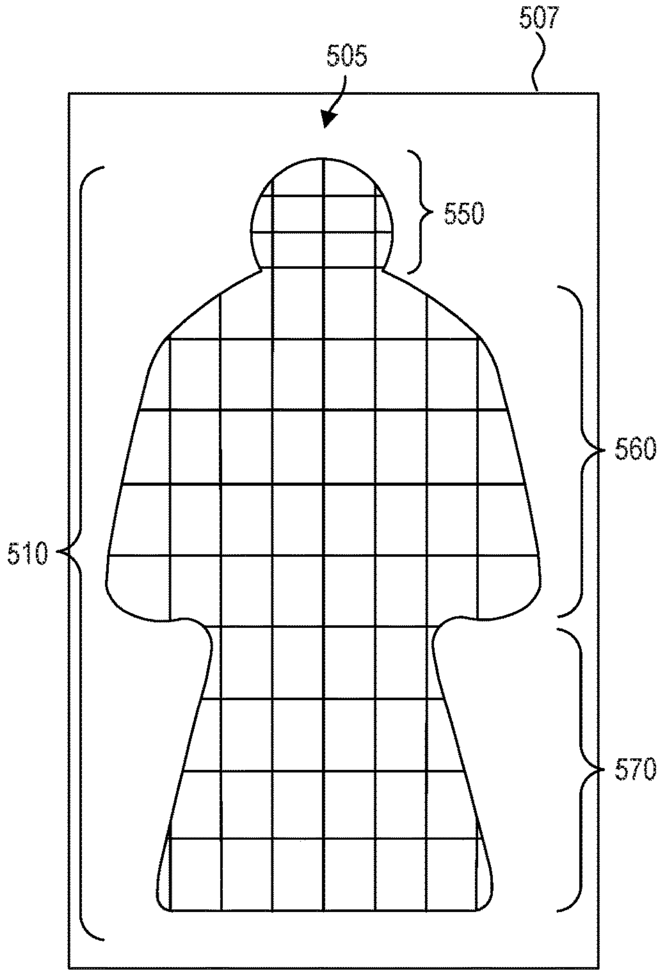

FIG. 5

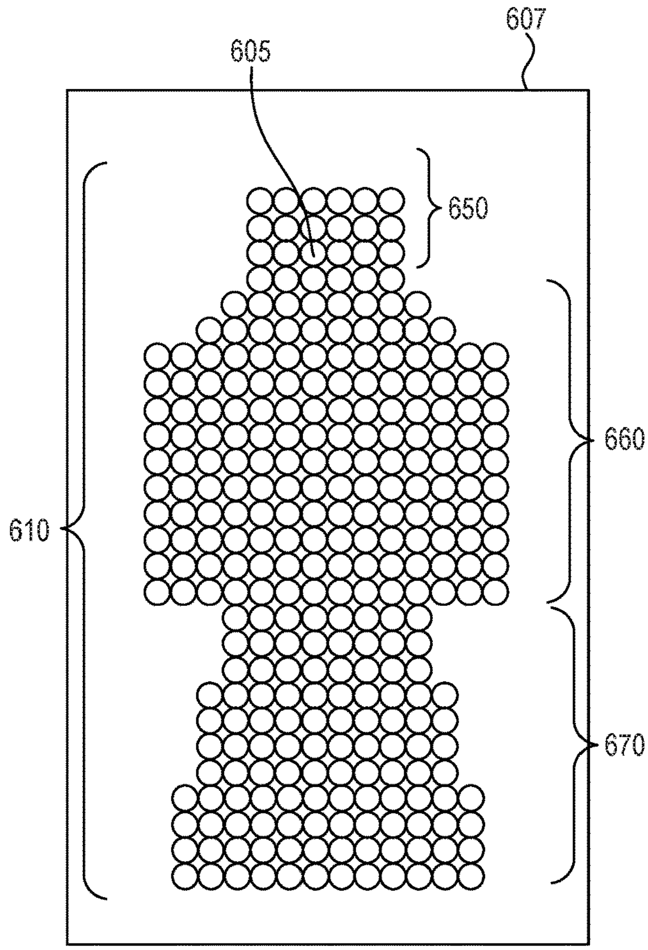

FIG. 6

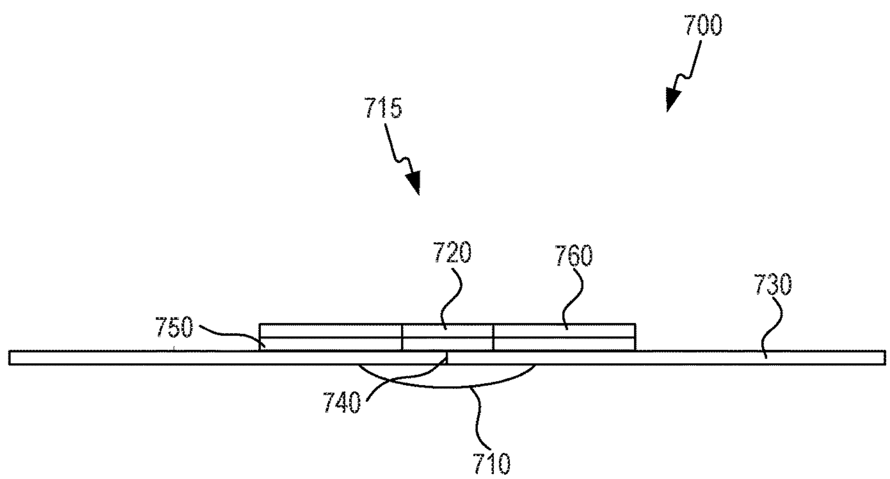

FIG. 7

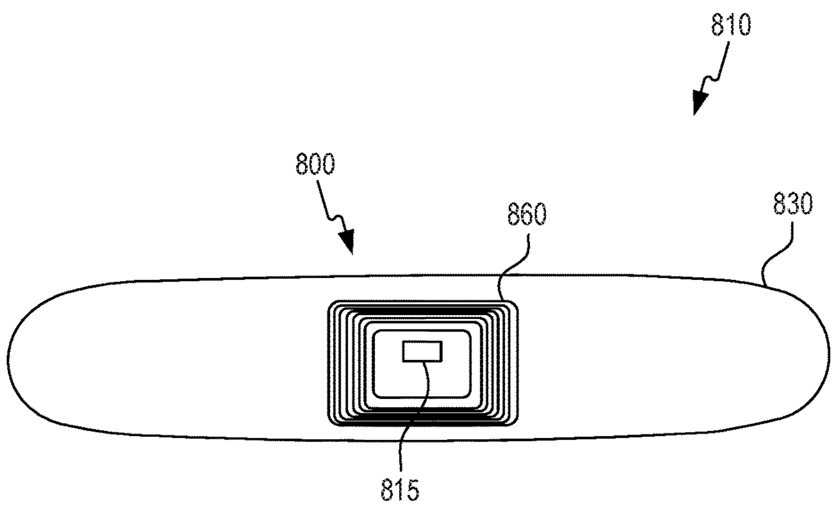

FIG. 8

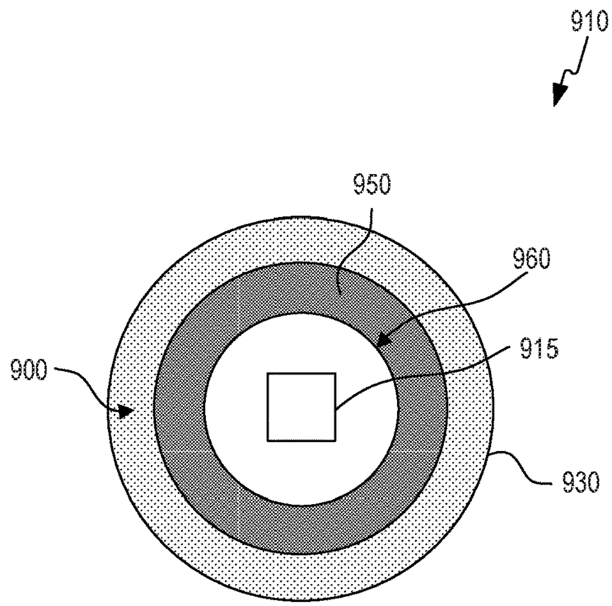

FIG. 9

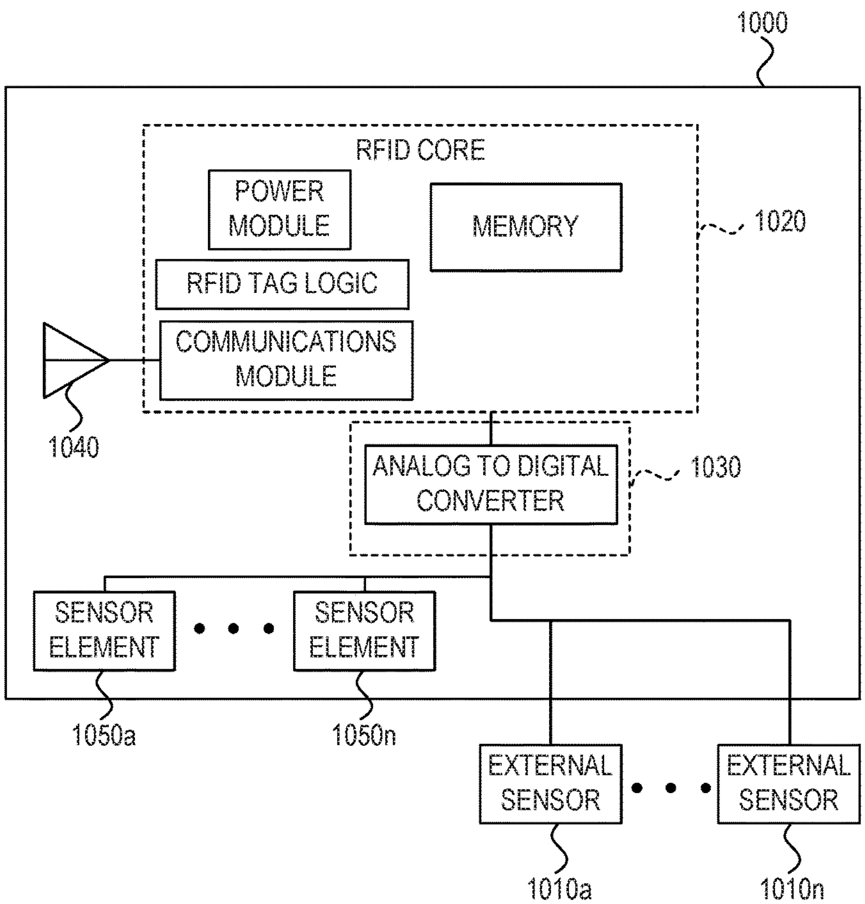
1000
RFID CORE
POWER MODULE
MEMORY
1020
RFID TAG LOGIC
COMMUNICATIONS MODULE
1040
ANALOG TO DIGITAL CONVERTER
1030
SENSOR ELEMENT
SENSOR ELEMENT
1050a
1050n
EXTERNAL SENSOR
EXTERNAL SENSOR
1010a
1010n

FIG. 10

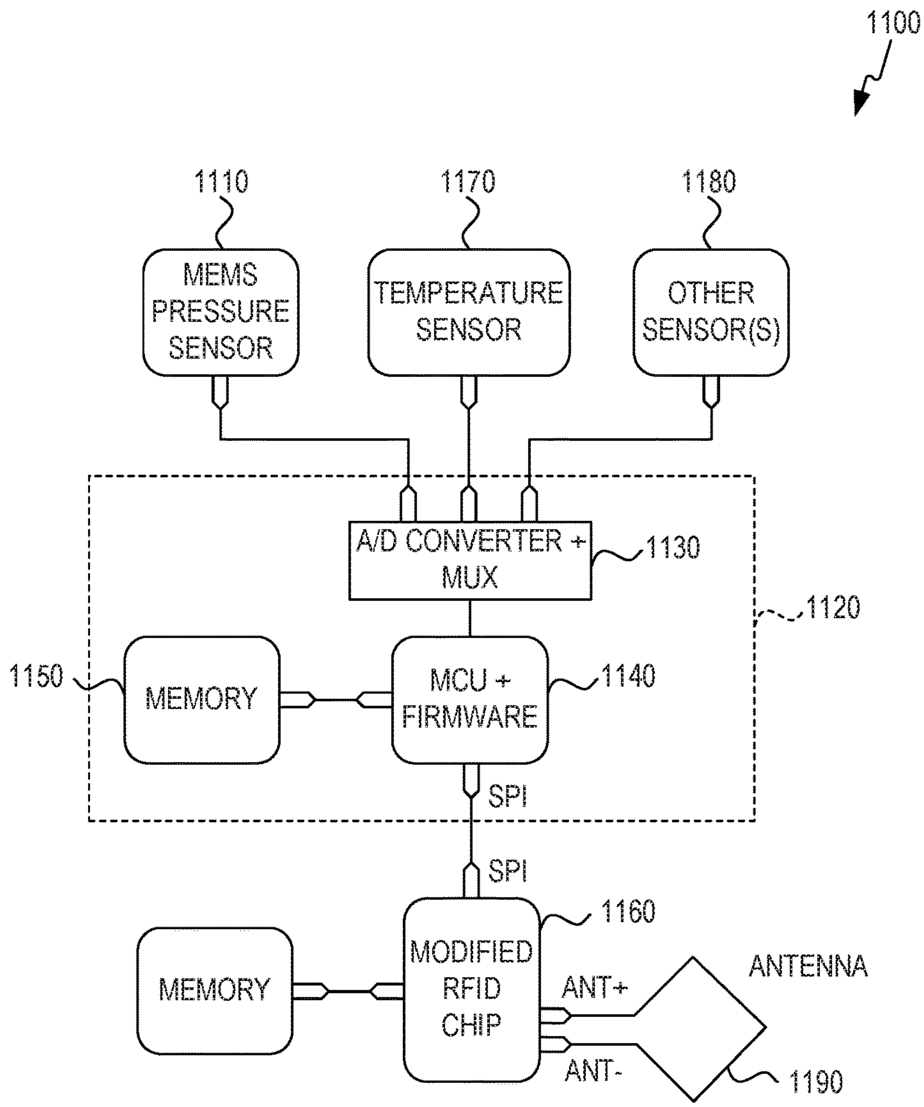
1100
1110
1170
1180
MEMS PRESSURE SENSOR
TEMPERATURE SENSOR
OTHER SENSOR(S)
A/D CONVERTER + MUX
1130
1120
1150
MEMORY
MCU + FIRMWARE
1140
SPI
SPI
1160
MEMORY
MODIFIED RFID CHIP
ANT+
ANT-
ANTENNA
1190

FIG. 11

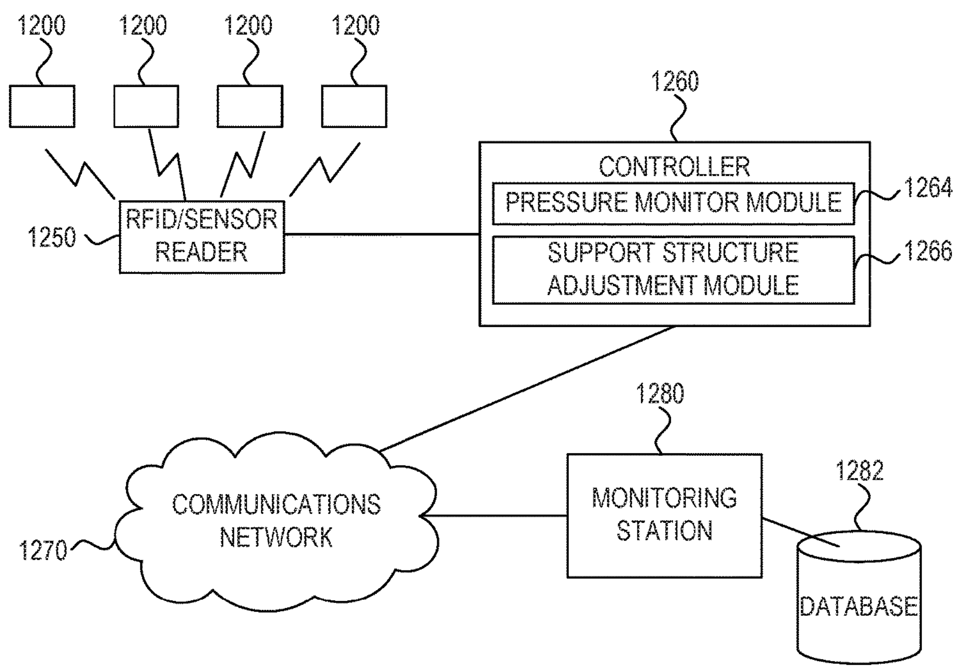
1200
1200
1200
1200
1260
CONTROLLER
PRESSURE MONITOR MODULE
1264
SUPPORT STRUCTURE ADJUSTMENT MODULE
1266
1250
RFID/SENSOR READER
1280
1282
COMMUNICATIONS NETWORK
1270
MONITORING STATION
DATABASE

FIG. 12

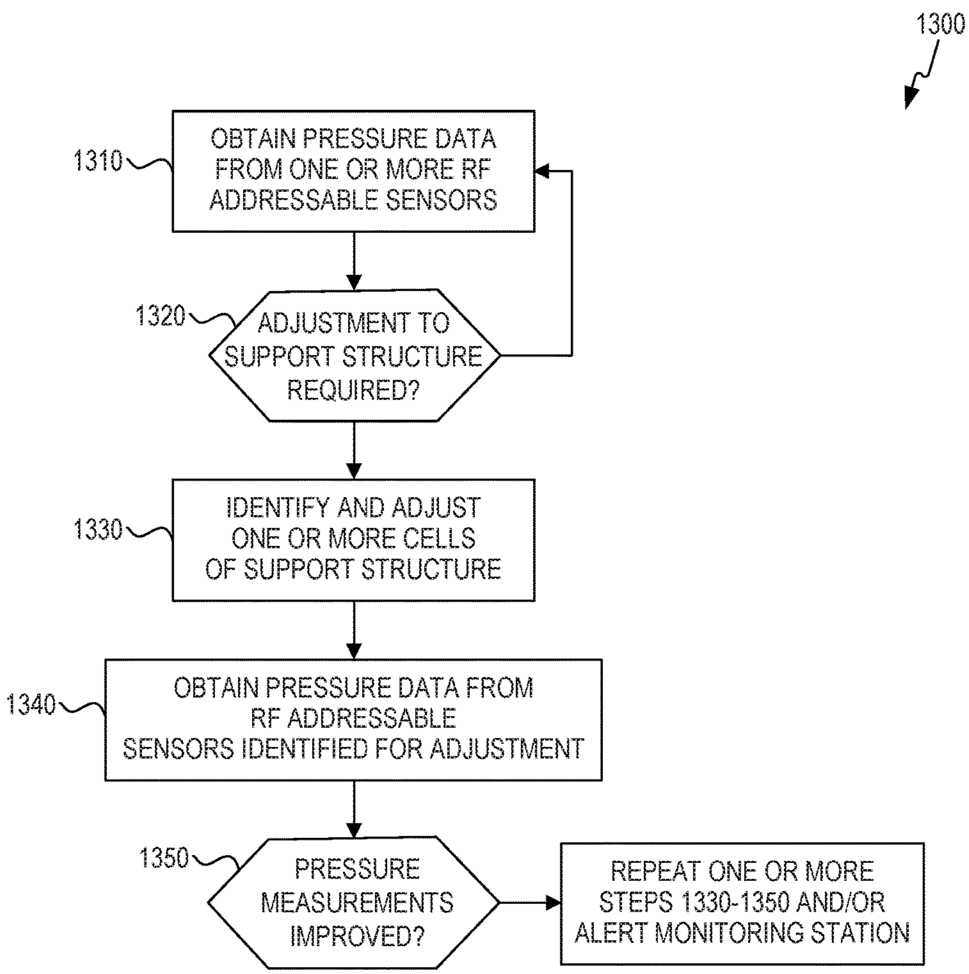
1300
1310
OBTAIN PRESSURE DATA FROM ONE OR MORE RF ADDRESSABLE SENSORS
1320
ADJUSTMENT TO SUPPORT STRUCTURE REQUIRED?
1330
IDENTIFY AND ADJUST ONE OR MORE CELLS OF SUPPORT STRUCTURE
1340
OBTAIN PRESSURE DATA FROM RF ADDRESSABLE SENSORS IDENTIFIED FOR ADJUSTMENT
1350
PRESSURE MEASUREMENTS IMPROVED?
REPEAT ONE OR MORE STEPS 1330-1350 AND/OR ALERT MONITORING STATION

FIG. 13

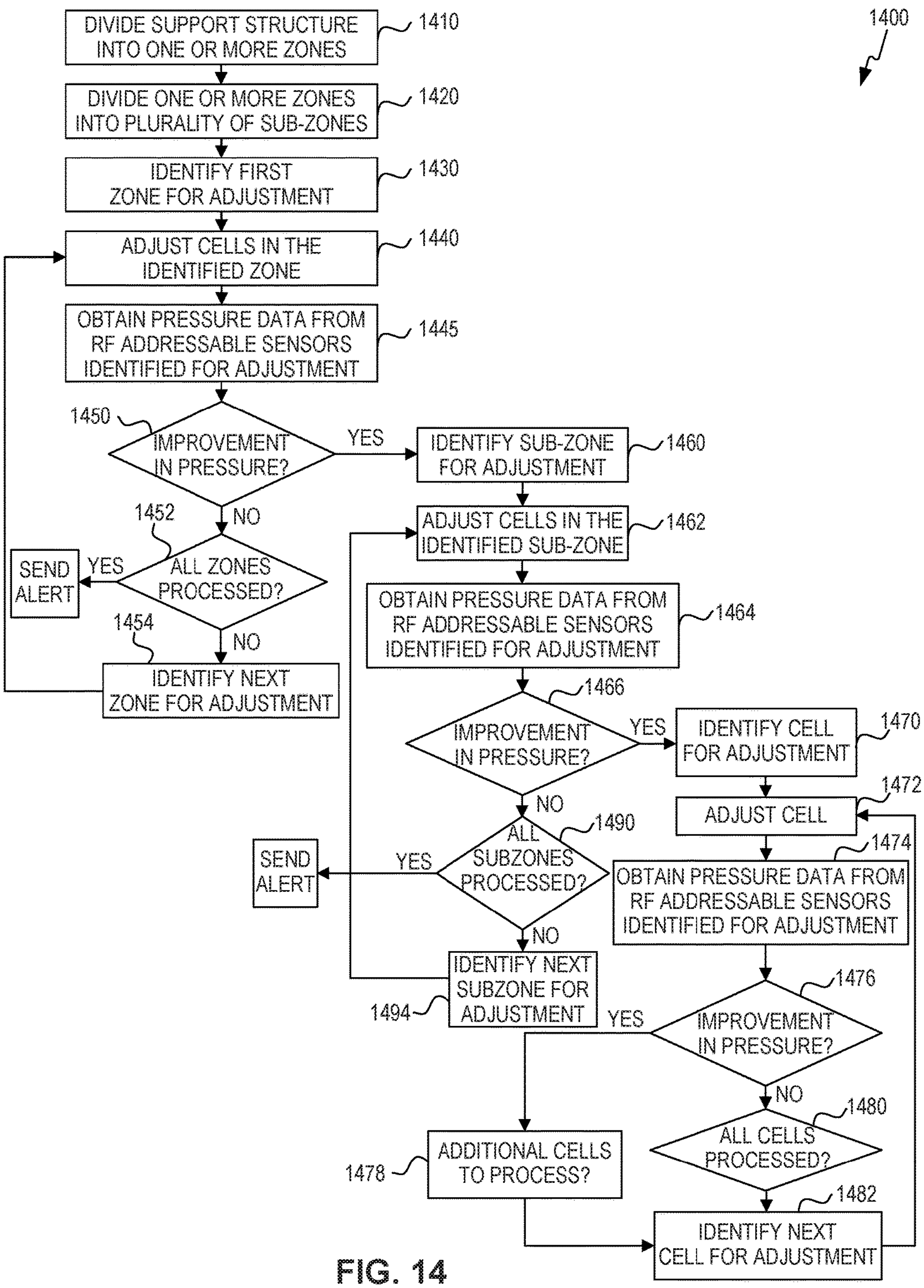
1400
DIVIDE SUPPORT STRUCTURE INTO ONE OR MORE ZONES
1410
DIVIDE ONE OR MORE ZONES INTO PLURALITY OF SUB-ZONES
1420
IDENTIFY FIRST ZONE FOR ADJUSTMENT
1430
ADJUST CELLS IN THE IDENTIFIED ZONE
1440
OBTAIN PRESSURE DATA FROM RF ADDRESSABLE SENSORS IDENTIFIED FOR ADJUSTMENT
1445
1450
IMPROVEMENT IN PRESSURE?
YES
NO
IDENTIFY SUB-ZONE FOR ADJUSTMENT
1460
1452
ALL ZONES PROCESSED?
YES
SEND ALERT
NO
1454
IDENTIFY NEXT ZONE FOR ADJUSTMENT
ADJUST CELLS IN THE IDENTIFIED SUB-ZONE
1462
OBTAIN PRESSURE DATA FROM RF ADDRESSABLE SENSORS IDENTIFIED FOR ADJUSTMENT
1464
1466
IMPROVEMENT IN PRESSURE?
YES
IDENTIFY CELL FOR ADJUSTMENT
1470
NO
ADJUST CELL
1472
ALL SUBZONES PROCESSED?
1490
YES
SEND ALERT
OBTAIN PRESSURE DATA FROM RF ADDRESSABLE SENSORS IDENTIFIED FOR ADJUSTMENT
1474
NO
IDENTIFY NEXT SUBZONE FOR ADJUSTMENT
1494
1476
YES
IMPROVEMENT IN PRESSURE?
NO
1480
ALL CELLS PROCESSED?
ADDITIONAL CELLS TO PROCESS?
1478
1482
IDENTIFY NEXT CELL FOR ADJUSTMENT

FIG. 14

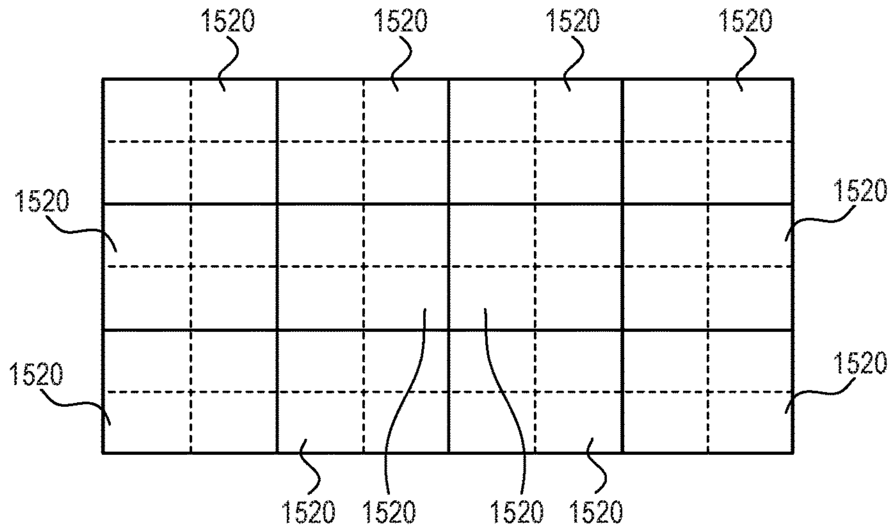

FIG. 15A

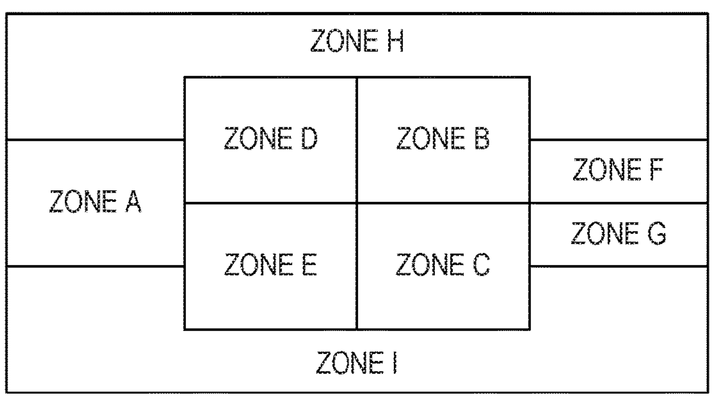

FIG. 15B

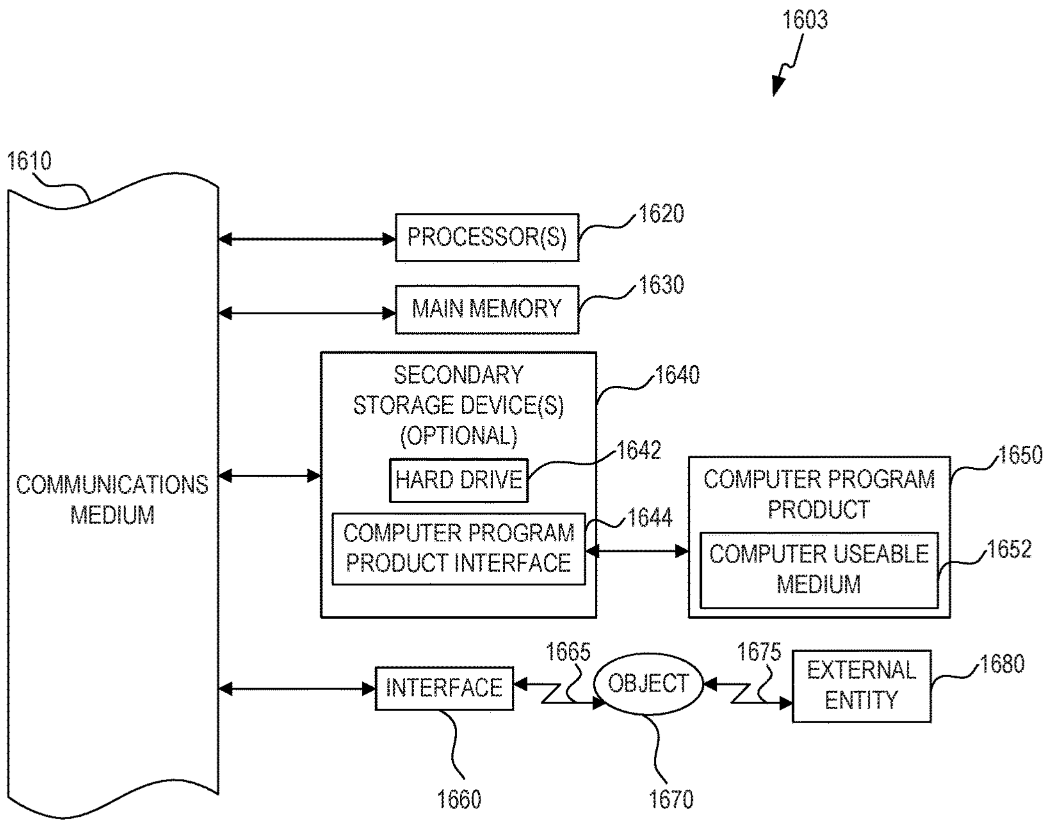
1603
1610
COMMUNICATIONS MEDIUM
PROCESSOR(S)
1620
MAIN MEMORY
1630
SECONDARY STORAGE DEVICE(S) (OPTIONAL)
1640
HARD DRIVE
1642
COMPUTER PROGRAM PRODUCT INTERFACE
1644
COMPUTER PROGRAM PRODUCT
1650
COMPUTER USEABLE MEDIUM
1652
INTERFACE
1660
1665
OBJECT
1670
1675
EXTERNAL ENTITY
1680

FIG. 16

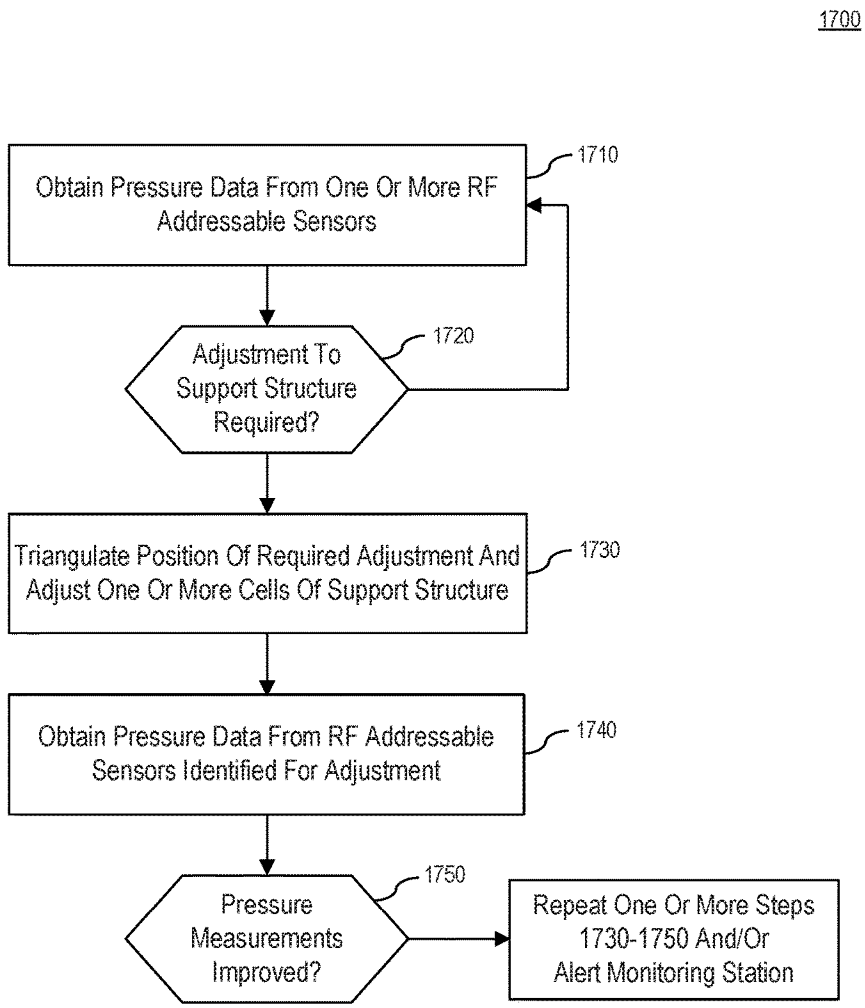
1700
Obtain Pressure Data From One Or More RF Addressable Sensors
1710
Adjustment To Support Structure Required?
1720
Triangulate Position Of Required Adjustment And Adjust One Or More Cells Of Support Structure
1730
Obtain Pressure Data From RF Addressable Sensors Identified For Adjustment
1740
Pressure Measurements Improved?
1750
Repeat One Or More Steps 1730-1750 And/Or Alert Monitoring Station

FIG. 17

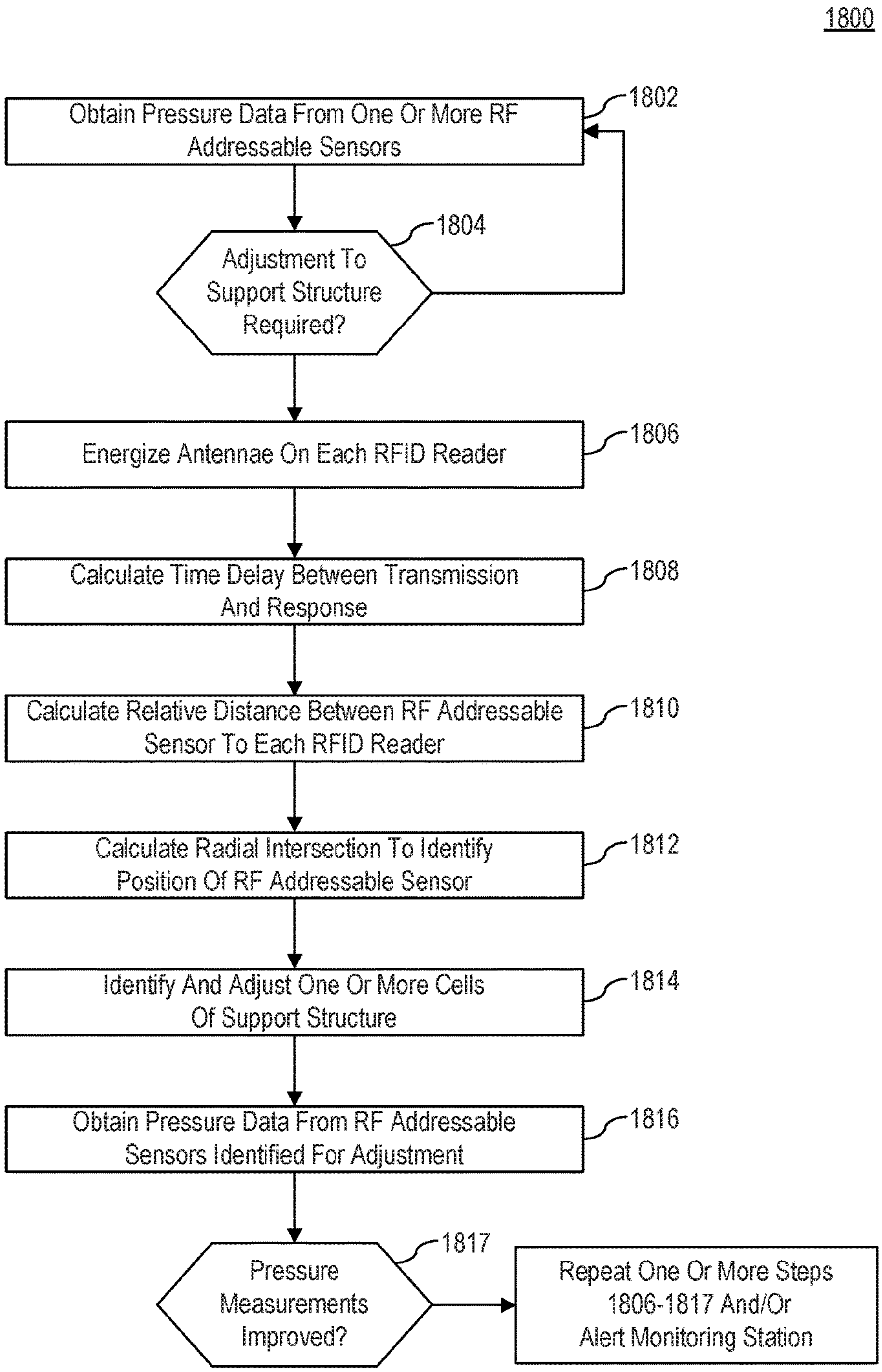
1800
Obtain Pressure Data From One Or More RF Addressable Sensors
1802
Adjustment To Support Structure Required?
1804
Energize Antennae On Each RFID Reader
1806
Calculate Time Delay Between Transmission And Response
1808
Calculate Relative Distance Between RF Addressable Sensor To Each RFID Reader
1810
Calculate Radial Intersection To Identify Position Of RF Addressable Sensor
1812
Identify And Adjust One Or More Cells Of Support Structure
1814
Obtain Pressure Data From RF Addressable Sensors Identified For Adjustment
1816
Pressure Measurements Improved?
1817
Repeat One Or More Steps 1806-1817 And/Or Alert Monitoring Station

FIG. 18

SYSTEMS AND METHODS FOR MONITORING AND PROVIDING THERAPEUTIC SUPPORT FOR A USER

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of and claims priority to U.S. application Ser. No. 13/188,721, filed Jul. 22, 2011, which is incorporated herein in its entirety by reference thereto.

FIELD OF THE INVENTION

The present invention is related to systems and methods for monitoring pressure exerted on an individual at one or more points by a support structure and adjusting the support structure, in response to the monitored pressure.

BACKGROUND

The prevention and treatment of bedsores (and similar pressure injuries) is a serious issue facing hospitals and other healthcare facilities. Bedsores (also known as decubitus ulcers or pressure sores) result from prolonged pressure on an area. For example, a bedsore is a tissue injury that develops when soft tissue is compressed between a bony prominence and an external surface for a prolonged period of time. Bedsores are most likely to form on the back of the head, the sacrum, heels, ankles, buttocks, or shoulders. Bedsores are painful and can be life-threatening to patients, particularly the elderly and disabled. Excessive pressure on recent surgical incisions can lead to wound healing complications with similar etiology. The National Decubitus Foundation estimated that as many as 16% of the population of U.S. hospitals, alone, suffered from some form of pressure wound such as a bedsore.

Bedsores are most common for patients confined to a bed, chair or wheelchair. These furniture support systems often include padding made from cotton, feathers, foam, or the like. Some techniques for preventing bedsores focus on the design of the furniture and padding. To ease pressure, furniture has been introduced that include a fixed quantity of air or liquid in one or more chambers to provide therapeutic benefits, including minimizing the severity of pressure points on a user's body. In addition, some of these support systems include manual or programmable adjustable cushion sections. However, these systems cannot be adjusted based on feedback about the current condition of a patient and therefore, a patient may still develop bedsores using therapeutic furniture. Once a bedsore develops it is important to mitigate continued excessive pressure to the region to facilitate the healing process.

Another typical method for preventing bedsores involves frequent repositioning of a patient. However, this method of prevention is highly time consuming for medical and care facilities, particularly facilities having a large number of disabled or immobile patients. What is therefore needed is a system that can automatically adjust a support structure (or external padding for furniture) based on pressure monitored on one or more areas of a patient.

BRIEF DESCRIPTION OF THE FIGURES

The accompanying drawings, which are incorporated herein, form part of the specification and illustrate embodiments of systems and methods for monitoring and providing therapeutic support for a user. Together with the description, the drawings further serve to explain the principles of, and to enable a person skilled in the relevant art(s) to make and use the systems and methods described herein. In the drawings, like reference numbers indicate identical or functionally similar elements.

FIGS. **1**A and B illustrate an exemplary operating environment for a system for monitoring pressure for an individual confined for a period of time to a support structure, such as a bed or a chair, according to embodiments of the present invention.

FIG. **2** is a perspective view of a support system incorporating a system for monitoring and providing therapeutic support for a user, in accordance with an embodiment of the present invention.

FIG. **3** is a schematic view of an air hose assembly of the support system of FIG. **2** in accordance with an embodiment of the present invention.

FIG. **4** is a schematic view of a support surface in accordance with an embodiment of the present invention.

FIG. **5** is a schematic view of a support surface in accordance with an embodiment of the present invention.

FIG. **6** is a schematic view of a support surface in accordance with an embodiment of the present invention.

FIG. **7** is a schematic view of a pressure monitor in accordance with an embodiment of the present invention.

FIG. **8** is a top view of a bandage incorporating a pressure monitor in accordance with an embodiment of the present invention.

FIG. **9** is a top view of an alternate embodiment of a bandage incorporating a monitor in accordance with an embodiment of the present invention.

FIG. **10** is an RF device in accordance with an embodiment of the present invention.

FIG. **11** depicts an exemplary system having a modified RFID chip, in accordance with an embodiment.

FIG. **12** is a block diagram of an illustrative network for remotely monitoring one or more sensors integrated with RF devices, in accordance with an embodiment of the present invention.

FIG. **13** is a flowchart illustrating a method of monitoring pressure, in accordance with an embodiment.

FIG. **14** is a flowchart showing a method for linking identifiers to create transparent and secure wireless monitoring of a user, in accordance with an embodiment.

FIG. **15**A depicts an exemplary support structure.

FIG. **15**B depicts an exemplary support structure.

FIG. **16** illustrates a block diagram of a data processing unit that can be used to implement portions of the RFID reader/sensor or controller illustrated in FIG. **12**.

FIG. **17** illustrates a flowchart showing a method of monitoring pressure at a point on an individual and automatically adjusting a section of a support structure according to an embodiment.

FIG. **18** illustrates a flowchart showing a method of monitoring pressure at a point on an individual and automatically adjusting a section of a support structure according to an embodiment.

DETAILED DESCRIPTION

The following detailed description of systems and methods for monitoring and providing therapeutic support for a user refers to the accompanying drawings that illustrate exemplary embodiments. Unless otherwise noted, all embodiments and examples should be considered prophetic examples. Other embodiments are possible. Modifications can be made to the embodiments described herein without departing from the spirit and scope of the present invention. Therefore, the following detailed description is not meant to be limiting. Further, it would be apparent to one of skill in the art that the systems and methods described below can be implemented in many different embodiments of hardware, software, and/or firmware. Any actual hardware, software, and/or firmware described are not meant to be limiting.

Presented herein are embodiments of systems and methods for monitoring pressure on a patient and adjusting a support structure accordingly. In one embodiment, a pressure monitor can continuously (or semi-continuously) measure contact pressures between a portion of a user's body and a section of a support surface of a support system, such as a hospital bed. For example, the pressure monitor can measure contact pressure between a support surface and the user's head, arms, legs, feet, arms, torso, or any other suitable location on the user.

In embodiments, a pressure monitor can be configured to transmit measured pressure data to a networkable device (e.g., a laptop computer, PDA, cell phone, a processor located in the bed, or other patient monitor) using RF communications. The networkable device can then send a signal to actuators located within the bed to adjust the pressure of one or more sections in the support surface of the bed. The networkable device can additionally communicate the user's status and condition to a healthcare provider station (e.g., staffed by nurses, doctors, and other hospital personnel) or directly to a healthcare providers' wireless networkable device (e.g. cell phone, pager, or personal digital assistant (PDA)) through a communication network such as a local area network (LAN), wide area network (WAN), or the like. This communication allows the healthcare provider to remotely monitor a user, such as a hospital patient and take action when certain conditions are indicated. The networkable device, or associated computing system, can additionally record and display temporal trends, minima, and maxima in the pressure data and optionally log the data to the patient's electronic health records. The networkable device, or associated computing system, can also compare the pressure data to the patient's diastolic blood pressure or other measurement, and calculate relevant clinical gradients in real time.

FIGS. **1**A and B illustrate an exemplary operating environment for a system for monitoring pressure for an individual confined to a support structure for a period of time, such as a bed or a chair, according to an embodiment of the present invention. As shown in FIG. **1**A, the system includes a support system **110**. In the example of FIG. **1**A, the support system is depicted as a bed. However, as discussed in detail below, the support system may be a mattress pad, a chair such as wheelchair or a similar form of support. An individual, e.g., patient **190**, comes into direct or indirect contact with the support system. As shown in FIG. **1**A, the individual is lying on structure **110**. However, in other embodiments, the individual may be sitting or reclining in a different position.

Prior to placement on the support structure, one or more RF addressable pressure sensors **100** are placed on the individual. These pressure sensors may be placed at locations highly susceptible to pressure injuries such as the sacrum, back of the head, elbows, shoulders, ankles, etc. In an embodiment, these sensors are placed on the skin of the patient in a location most likely to have direct or indirect contact with the support structure or upon which the support structure is likely to exert pressure. FIG. **1**B is the rear view of a patient depicting exemplary placement of a plurality of RF addressable pressure sensors, according to embodiments of the present invention. RF addressable pressure sensors **100** are described in further detail below.

The system further includes an RFID reader **150** and a controller **160**. Although depicted as separate components, RFID reader **150** and controller **160** could be implemented in a single structure. RFID reader **150** is configured to communicate with the one or more RF addressable pressure sensors **100** and obtain data therefrom. RFID reader **150** is placed proximate to the individual. Although FIG. **1**A depicts the reader **150** attached to the foot of the bed, the RFID reader may be placed at any location to permit detection and access to the RF addressable sensors. For example, RFID reader **150** may be placed on the support structure, under the support structure, above the support structure, or next to the support structure (e.g., on a mobile station).

RFID reader **150** is coupled to a controller **160**. In an embodiment, controller **160** is configured to receive data from reader **150** and to determine whether adjustments should be made to support structure to reduce pressure in one or more areas. In an alternative embodiment, reader **150** includes the logic to determine whether adjustments should be made to support structure. Controller **160** is further configured to cause adjustments to be made to the support structure.

In addition, RFID reader **150** and/or controller **160** may be connected to an external monitoring station. The communication infrastructure is described in further detail below.

Support Systems

FIG. **2** is a perspective view of a support system **200** incorporating a system for monitoring and providing therapeutic support for a user, in accordance with an embodiment of the present invention. Support system **200** can be one of many forms, including but not limited to, a bed including a mattress and bed frame, such as a hospital bed configured for use during or after medical procedures, a conventional bed used for sleeping, a mattress for a bed, a mattress cover configured to be placed on top of a mattress, a chair such as a wheelchair, couch, or any other suitable support system having a support surface.

In some embodiments, support system **200** comprises conventional components of a hospital bed, for example mattress **215**, head end **280** on one side of the mattress, including headboard **285**, foot end **290** on the opposite side of mattress **215**, bed frame **130** disposed underneath and supporting mattress **215**, and side rails **120** for constraining a user within support system **200**. Support system **200** can further include wheels **140** to facilitate moving the system. Alternatively, the support system can be in the form of a padded layer to be placed on top of a mattress, chair, couch, or other surface.

In some embodiments, mattress **215** can include a support surface **205** which includes areas corresponding to a conventionally sized user's body. For example, head portion **250** can be configured to receive the user's head, torso portion **260** can be configured to receive the user's torso, and leg portion **270** can be configured to receive the user's legs and feet. Mattress **215** can further include a plurality of adjustable sections **210**. In some embodiments, each of adjustable sections **210** are in the shape of a square and are arranged to form a square grid, in other embodiments, one or more of adjustable sections **210** can be in the form of a shape other than a square. For example, a non-square rectangle, an oval, a sphere, a cylinder, or any other suitable geometric shape. In some embodiments, one or more sections can be shaped to contour the shape of the user's body. For example, mattress **215** can include a single adjustable section or a plurality of adjacent adjustable sections formed to provide a recess contour for the user's head.

In some embodiments, adjustable sections **210** of mattress **215** include a confined gas, liquid or other suitable flowable material. The support characteristics, such as inflation level can be adjusted with the aid of an air or liquid supply means, such as one or more pumps or a centralized facility air supply. In some embodiments, a single pump provides air to each of the sections. In other embodiments, multiple pumps provide air to multiple sections.

FIG. **3** is a schematic view of air hose assembly **300** of the support system of FIG. **2**. In some embodiments, adjustable sections **210** are operatively connected to air pump assembly **310** to allow for inflation and deflation of adjustable sections **210**. For example, air hose assembly **300** can be attached to central air line **340**, which is then delivered through branch air lines **320** via line connections **330**. Branch air lines **320** are also operatively connected to adjustable sections **210** to provide for inflation and deflation. Line connections **330** may include individual solenoid valves or other means of controlling flow into or out of each chamber.

FIG. **4** is a schematic view of a support surface **405** in accordance with an embodiment. Like support surface **205** of FIG. **2**, support surface **405** comprises portions corresponding to a conventionally sized user's body. For example, head portion **450** can be configured to receive the user's head, torso portion **460** can be configured to receive the user's torso, and leg portion **470** can be configured to receive the user's legs and feet. Adjustable sections **410** can be smaller in size compared to adjustable sections **210** of support surface **205** shown in FIG. **2**. Adjustable sections **210** can be of any suitable size and shape.

FIG. **5** is a schematic view of a support surface **505** in accordance with an embodiment. Like support surface **205** of FIG. **2**, support surface **505** comprises portions corresponding to a conventionally sized user's body. For example, head portion **550** can be configured to receive the user's head, torso portion **560** can be configured to receive the user's torso, and leg portion **570** can be configured to receive the user's legs and feet. Adjustable sections **510** can be arranged to generally follow the outline of the user's body in various conventional positions, as shown for Example in FIG. **2**. In some embodiments, support surface **505** can further comprise an outer section **507** that surrounds the adjustable sections. Outer section **507** can comprise conventional bedding materials, such as foam or other padding, can alternatively comprise additional adjustable sections, non-adjustable inflated sections, or any suitable combination thereof.

FIG. **6** is a schematic view of a support surface **605** in accordance with an embodiment. Like support surface **205** of FIG. **2**, support surface **605** comprises portions corresponding to a conventionally sized user's body. For example, head portion **650** can be configured to receive the user's head, torso portion **660** can be configured to receive the user's torso, and leg portion **670** can be configured to receive the user's leg and feet. Adjustable sections **610** can be arranged to generally follow the outline of the user's body in various conventional positions, as shown, for example, in FIG. **2**. In some embodiments, support surface **605** can further comprise an outer section **607** that surrounds the adjustable sections. Outer section **607** can comprise conventional bedding materials, such as foam or other padding, can alternatively comprise additional adjustable sections, non-adjustable inflated sections, or any suitable combination thereof. Adjustable sections **610** can be rectangular in shape and smaller in size compared to adjustable sections **210** shown in FIG. **2** and adjustable sections **410** shown in FIG. **4**. Adjustable sections **610** can be of any suitable size and shape.

RF Addressable Pressure Monitor

FIG. **7** is a schematic view of an RF addressable pressure monitor **700** in accordance with an embodiment presented herein. In some embodiments, RF addressable pressure monitor **700** is configured to be placed on a user and comprises a pressure sensor **710** operatively connected to an RFID device **715** disposed on a substrate **730**. In some embodiments, pressure sensor **710** is a microelectromechanical system (MEMS) sensor on the order of 1 mm. The relatively small size of a MEMS pressure sensor allows easy placement on the user. Such MEMS sensors use a change in resistance, change in capacitance, change in voltage, or a piezoelectric effect to convert changes in pressure on a sensing membrane to a voltage, current, or frequency change in the output signal.

Pressure sensor **710** is coupled to a wire **740** coupled to a radiofrequency (RF) device **715** on substrate **730**, which can be in the form of a surface patch or bandage. Substrate **730** can include an adhesive material on one surface for affixing to the skin of the patient. Substrate **730** can further include multiple layers. In some embodiments, RF device **715** and RF antenna **760** can be integrated within layers of substrate **730**.

In some embodiments, pressure sensor **710** could be an air or fluid filled contained volume coupled to an appropriate sensor through a tube communicating with the sensing membrane. The sensor could therefore be separate from the bandage packaging.

In some embodiments, RF device **715** comprises a RF antenna **760** and a battery **750** coupled to RFID chip **720** to provide power and to transmit data. RF device **715** powers pressure sensor **710**, and interprets or relays the data from pressure sensor **710** to an interrogating reader. The RF device can be passive, pass-active (battery assisted), or fully active (battery dependent) depending upon the frequency of desired reads, the estimated distance of the interrogating device from the RF device, and the power consumption needs of the RF device. In alternative embodiments, the pressure sensor is integrated with Bluetooth, ZIGBEE or other radios compatible with wireless devices such as cell phones.

Substrate **730** (e.g., a layer of an adhesive bandage) is used to maintain RF device **715** and battery **750** on the surface of the user's skin or clothing. In some embodiments, sterile gauze can be placed between the electronic components and the surface of the skin.

In operation, a pressure change between pressure sensor **710** and the support surface is registered at pressure sensor **710**. In the embodiment shown, the pressure data is then communicated to RF device **715** coupled to pressure sensor **710**. In the embodiment shown, pressure sensor **710** and RF device **715** are powered by battery **750**. Battery **750** can be substantially rigid or can be flexible. As would be appreciated by persons of skill in the art, RF device **715** and/or pressure sensor **710** can be powered by other techniques. Adhesive bandage material can be used to house and maintain RF device **715**, battery **750**, and pressure sensor **710**. Additional external sensors can further be included in pressure monitor **700**, e.g., in the adhesive bandage material or on substrate **730**. Sterile gauze can be present in between adhesive bandage or substrate **730** and the surface of the user's skin or clothing.

FIG. **8** is a top view of a bandage **810** incorporating a pressure monitor **800** and substrate **830** in accordance with an embodiment presented herein. Similar to the pressure monitor shown, for example, in FIG. **7**, pressure monitor **800** can comprise an RF device **815** and RF antenna **860**. In the embodiment illustrated in FIG. **8**, the RF device is placed on top of substrate **830**. In FIG. **8** the bandage is an oval shape, of course the bandage could be any other suitable shape. Bandage **810** can be used with any of the pressure monitors described above.

FIG. **9** is a top view of a bandage **910** incorporating a pressure monitor **900** and substrate **930** in accordance with an embodiment presented herein. Similar to the pressure monitor shown, for example, in FIG. **7**, pressure monitor **900** can comprise an RF device **915**, RF antenna **960**, and battery **950**.

FIG. **10** is an RF device **1000** according to an embodiment. RF device **1000** is coupled to one or more external sensors **1010***a*-**1010***n*. RF device **1000** includes RF core **1020**, an analog to digital converter (ADC) **1030**, and one or more antennas **1040**. These components are mounted or formed on a substrate. Additionally, the RF core **1020** and/or ADC **1030** can be included in an integrated circuit. RF device **1000** can also include one or more sensor elements **1050***a*-**1050***n*. Sensor elements **1050***a*-**1050***n* can be included in the integrated circuit, on the substrate, external to substrate, or in any combination of the above. Any compatible sensor element can be used as sensor element.

External sensors **1010***a*-**1010***n* include the sensors (e.g., MEMS sensor) described above for measuring compartment pressure. These external pressure sensors can be coupled to a pressure probe through a wire connector or an inelastic fluid filled tube. In an alternate embodiment, a fiber optic connection can be used.

Various types of sensor elements can be implemented as sensors **1050***a*-**1050***n* or external sensors **1010***a*-**1010***n*. For example, integrated or external sensor can include a temperature sensor element that generate information indicating ambient temperature; a pH sensor element; or other biological or chemical sensors. The system can include other types of sensor elements or combinations thereof, as would be apparent to persons skilled in the relevant art(s). Testing has shown that some RFID reader chips are not well suited to read complex RFID sensors due to timing and/or power issues. The readers are essentially meant to read ID numbers and have a very short interrogation/response cycle time. Furthermore when the technology is passive (as is the case for most RFID) substantial power fluctuations occur on the RFID chip and this affects sensor accuracy.

RFID core **1020** includes a communications module coupled to antenna **1040**, an RFID tag logic module, a power module and memory. In an embodiment, the memory stores an identifier for the RFID tag associated with the pressure sensor. The tag identifier, for example, may be used to associate the RF addressable sensor with an individual. In this example, a provider could maintain a database mapping tag identifiers to individuals.

A modified RFID chip can be used to facilitate these readers to read the pressure monitors comprising a complex MEMS sensor. Such a modified chip includes a serial peripheral interface (SPI) port and allows pre-processed sensor data to be stored in memory directly linked to the ID interrogation process of the RFID tag. This type of RFID tag therefore serves as a low cost "pass-through" radio. This design and method allows any sensor to be connected to common RFID technology and be read directly with current RFID enabled cell phones. The technology can be configured for ISO 15693 tags for example and is directly compatible with multiprotocol 13.56 MHz RFID reader chips for cell phones such as the PN 544 C2 reader chip made by NXP.

Different circuit designs and options are possible for the pass through method. FIG. **11** depicts an exemplary system **1100** having a modified RFID chip, and antenna **1190** according to an embodiment. FIG. **11** illustrates how complex sensors can be handled using a passive modified RFID radio, where the processed sensor data is passed through the RFID core as part of the standard interrogation—transmission of RFID data. The system **1100** includes a plurality of external sensors. In embodiments, the plurality of external sensors includes a complex calibrated external MEMS sensor **1110** and an ultra-precise external thermistor to allow medical grade combined pressure and temperature sensor measurements.

Each of the plurality of external sensors is coupled to a sensor interface **1120**. Sensor interface **1120** includes an analog to digital converter (ADC) and multiplexer **1130**, an external microprocessor (MCU) and firmware **1140**, and memory **1150**. Using an external microprocessor and firmware allows compression of complex sensor data and extremely fast passage of information via the RFID chip, well within the limits of current standard RFID reader chips. Sensor interface **1120** further includes an external power source (e.g. battery, energy harvesting, solar, chemical, motion, etc.) that also can include a reference voltage calibration circuit. In an embodiment, sensor interface **1120** is included in a separate chip.

Sensor interface **1120** is coupled to modified RFID chip **1160**. The command set for the external MCU **1140** is passed through the RFID chip **1160**. The memory on the RFID chip is cleared either when full or bumped with each new interrogation or sensor data download or by external command from the RFID interrogator (e.g., a cell phone, or other wireless networkable device).

The RFID chip **1160** and sensor interface **1120** of FIG. **11** can be integrated into a single hybrid chip, whereby the packaged sensor data is placed in memory and where the main processor would be powered by the external power source and the communication part built to handle the constraints imposed by current RFID interrogators. Alternatively, the components of sensor interface **1120** can be included in a separate integrated circuit chip.

Various designs are possible for the fully integrated chip. The system of FIG. **11** illustrates the combination of an external temperature sensor **1170**, external MEMS sensor **1110**, and other sensor(s) **1180**. For temperature on chip a single calibration point digital sensor can be used. Such sensor technology is described in U.S. Pat. No. 7,461,972 that is included by reference in its entirety.

Network

FIG. **12** is a block diagram of an illustrative network for monitoring one or more pressure sensors integrated with RF devices and adjusting a support structure to accommodate for changes in pressure, in accordance with an embodiment of the present invention. The network includes one or more RF addressable sensors **1200**, one or more RFID/sensor readers **1250** and a controller **1260**. Exemplary RF addressable sensors are described above. The network may optionally include a communications network **1270** coupled to the controller **1260** and a remote monitoring station **1280**.

Communications network **1270** is a publicly accessible communications network. Communications network **1270** may be a wired network, wireless network, or a combination therefore. In another embodiment, communications network **1270** is a private network or a hybrid network including public and private portions. Persons skilled in the relevant art(s) will recognize that various network architectures could be used for communication network **1270**.

Wireless RFID/sensor reader **1250** includes logic to read sensor data and RFID tag data transmitted by RF addressable sensor **1200**. In an embodiment, wireless RFID/sensor reader **1250** also includes logic to process the received sensor data. Wireless RFID/sensor reader **1250** can be any wireless device capable of communicating via an air interface protocol with RF addressable sensor **1200**. In some embodiments, wireless RFID/sensor reader **1250** could be a wireless phone, a personal digital assistant (PDA), a computer having wireless communications capabilities, or other type of mobile, handheld, and/or computing device (e.g., an iPAD).

According to an embodiment, signals are exchanged between the wireless RFID/sensor reader **1250** and RF addressable sensor **1200** according to one or more protocols. In an embodiment, reader **1250** and the RF addressable sensor **1200** communicate via a single protocol for both RFID tag communications and sensor communications. In an alternate embodiment, reader **1250** and RF addressable sensor **1200** communicate via a first protocol for RFID tag communications and via a second protocol for sensor communications. Examples of protocols used for RFID tag communications include binary tree traversal, HF ISO 15693 and EPC global Gen 2. An embodiment is also applicable to any other types of communication protocols between tags and readers otherwise known or yet to be developed.

RFID/sensor reader **1250** is coupled to a controller **1260**. RFID/sensor reader **1250** communicates data obtained from the one or more RF addressable sensors **1200** to controller **1260**. Controller **1260** includes a pressure monitoring module **1264** and a support structure adjustment module **1266**.

Pressure monitoring module **1264** is configured to determine whether a pressure adjustment needs to be made to the support structure and isolates one or more cells to adjust. In an alternative embodiment, pressure monitoring module **1264** may be included as a component of RFID/sensor reader **1250** or distributed between the RFID/sensor reader and the controller **1260**. Pressure monitoring module **1264** communicates adjustment information to support structure adjustment module **1266**.

Support structure adjustment module **1266** is configured to adjust one or more cells in the support structure. In an embodiment, support structure adjustment module **1266** includes logic to determine the amount of adjustment to make to a specific cell. In an alternate embodiment, pressure monitoring module **1264** determines the amount of adjustment to make to a specific cell.

In an embodiment, controller **1260** and/or RFID/sensor reader **1264** communicates data to an external monitoring station. Controller **1260** and/or RFID/sensor reader **1250** may communicate all data obtained to external monitoring station **1280**. In addition or alternatively, controller **1260** and/or RFID/sensor reader **1250** may communicate only when certain conditions are detected. For example, controller **1260** and/or RFID/sensor reader **1250** may alert the external monitoring station **1280** when pressure in a certain area remains elevated and/or is not reduced after a series of adjustments.

External monitoring station **1280** receives sensor data over network **1270**, and processes the data. In an embodiment, the system associates tag identification data for an RF addressable sensor with an individual. External monitoring station **1280** may store data for each RF addressable sensors associated with an individual. The external monitoring station **1280** may analyze the pressure data associated with the individual and make an independent assessment of whether adjustments should be made to the support structure. External monitoring station **1280** may further be configured to communicate a request to adjust the structure to reduce pressure measurements for one or more tags associated with an individual. Records for individuals may be stored in a database **1282** coupled to external monitoring station **1280**.

In an embodiment, a healthcare provider determines if medical intervention is necessary based on alerts from RFID/sensor reader **1264**, controller **1266**, and/or external monitoring station **1280**. External monitoring station **1280** can display historical data or trends for one or more individuals.

Methods

FIG. **13** is a flowchart **1300** of a method for monitoring pressure and adjusting a support structure to compensate for measured pressure, according to embodiments of the present invention. Flowchart **1300** is described with reference to the embodiment of FIG. **12**. However, flowchart **1300** is not limited to that embodiment.

In step **1310**, pressure monitoring module **1264** obtains pressure data from one or more RF addressable sensors **1200** placed on an individual. The pressure monitoring module **1264** may also obtain a tag identification number associated with the RF addressable sensor **1200** providing sensor data. In an embodiment, RFID/sensor reader **1250** polls the one or more RF addressable sensors **1200**. In an alternate embodiment, the one or more RF addressable sensors **1200** are configured to periodically send data to RFID/sensor reader **1250**. RFID/sensor reader **1250** then communicates the received data to pressure monitoring module **1264**. In embodiments RFID/sensor reader **1250** may process the sensor data, e.g., to calibrate or smooth the received data, prior to communicating the data to pressure monitoring module **1264**.

In step **1320**, a determination is made whether the pressure data indicates an adjustment is required. In an embodiment, this determination is made on a per RF addressable sensor basis. For example, pressure monitoring module **1364** may determine for an RF addressable sensor whether the pressure data exceeds a threshold. In addition, or alternatively, the determination may be based on a historical trend for the RF addressable sensor. For example, if the pressure data has been consistently increasing over a predetermined period of time, an adjustment may be indicated for the RF addressable sensor. The networkable device, or associated computing system, can also compare the pressure data to the patient's diastolic blood pressure or other measurement, and calculate relevant clinical gradients in real time. As would be appreciated by persons of skill in the art, other techniques for determining whether an adjustment is required may be used with the present invention. If an adjustment is required, operation proceeds to step **1330**. If no adjustment is required, operation returns to step **1310**.

In step **1330**, one or more cells of the support structure to be adjusted are identified and adjusted. One method for identifying the cell or cells to adjust is discussed in FIG. **14**. As would be appreciated by persons of skill in the art, other techniques may be used in the present invention, e.g. triangulation of the sensors position by multiple RFID interrogators.

In step **1340**, pressure monitoring module **1264** obtains pressure data from the RF addressable sensors identified for adjustment. In an embodiment, pressure data may be obtained from all RF addressable sensors, as in step **1310**.

In step **1350**, a determination is made whether the pressure measurements in the RF addressable sensors identified for adjustment has improved. If pressure measurements indicate that the pressure data still indicates adjustment is necessary, pressure monitoring module may repeat step **1340** and **1350** over a pre-defined period of time after an initial adjustment is made. If improvement is not realized over that period of time, pressure monitoring module **1264** may repeat step **1330** to alter the adjustments. Additionally, if no improvement is achieved, the pressure monitoring module **1264** may alert external monitoring station **1280** of a potential bedsore/pressure sore risk.

If pressure measurements indicate an improvement, the adjustments made in step **1330** may be maintained for a specific period of time. After that time has expired, the system may return the cell or cells to their status prior to the adjustment.

FIG. **14** illustrates a flowchart **1400** for a method for determining an adjustment for one or more cells in a support structure, in accordance with embodiments of the present invention. FIG. **14** is described with reference to the embodiments of FIG. **12**. However, the method is not limited to that embodiment.

In step **1410**, the support structure is divided into one or more zones or clusters. FIG. **15**A depicts an exemplary support structure. As shown in FIG. **15**A, the support structure is divided into a plurality of zones **1520**. The zones may be of equal size and shape as shown in FIG. **15**A. Alternatively, the zones may be defined based on the likely position of an individual on the support structure, as depicted in FIG. **15**B. As would be appreciated by persons of skill in the art, other arrangements for zones could be used with the present invention.

In step **1420**, one or more zones may be further divided into a plurality of sub-zones. FIG. **15**A depicts a zone **1520** having a plurality of sub-zones. In embodiments, a sub-zone may be furthered divided into clusters. Step **1420** is optional.

In step **1430**, a first zone for adjustment is identified. In an embodiment, the pressure monitoring module **1264** prioritizes zones based on likelihood of a pressure injury occurring in the zone. For example, the zone associated with an individual's sacrum may be prioritized first.

In step **1440**, cells in the identified zone are adjusted. For example, the cells may be adjusted as described above in FIG. **3**.

In step **1445**, pressure data is obtained from RF addressable sensors identified for adjustment.

In step **1450**, a determination is made whether an improvement in pressure is reflected in the obtained data. If an improvement is indicated, operation proceeds to step **1460**. If no improvement is indicated by the data, operation proceeds to step **1452**.

Note that steps **1440** and **1450** may be repeated over a pre-determined period of time before an action is taken to give time for pressure changes to be reflected.

In step **1452**, a determination is made whether all zones in the support structure have been processed. If all zones have been processed, an alert may be sent to external monitoring station **1280** and processing of flowchart **1400** ends. If additional zones remain to be processed, operation proceeds to step **1454**.

In step **1454**, the next zone is identified. In embodiments, pressure monitoring module **1264** includes data specifying an order to process zones.

Operation then returns to step **1440**.

In step **1460** (if improvement is indicated in step **1450**), a sub-zone within the zone is identified. As with the zone, the pressure monitoring module **1264** may include data specifying an order to process sub-zones within a zone. Step **1460** is optional.

In step **1462**, cells in the sub-zone are adjusted. For example, the cells may be adjusted as described above in FIG. **3**.

In step **1464**, pressure data is obtained from RF addressable sensor identified for adjustment.

In step **1466**, a determination is made whether an improvement in pressure is reflected in the obtained data. If an improvement is indicated, operation proceeds to step **1470**. If no improvement is indicated by the data, operation proceeds to step **1490**.

Note that steps **1464** and **1466** may be repeated over a pre-determined period of time before an action is taken to give time for pressure changes to be reflected.

In step **1470**, a first cell within the sub-zone (or zone) is identified. As with the zone, the pressure monitoring module **1264** may include data specifying an order to process cells within a zone or sub-zone.

In step **1472**, the cell is adjusted. For example, the cell may be adjusted as described in FIG. **3**.

In step **1474**, pressure data is obtained from the RF addressable sensor identified for adjustment.

In step **1476**, a determination is made whether an improvement in pressure is reflected in the obtained data. If an improvement is indicated, operation proceeds to step **1478**. If no improvement is indicated by the data, operation proceeds to step **1480**.

Note that steps **1474** and **1476** may be repeated over a pre-determined period of time before an action is taken to give time for pressure changes to be reflected.

In step **1478**, a determination is made whether additional cells should be processed. If additional cells should be processed, operation proceeds to step **1480**. If no additional cells are to be processed, operation ends.

In step **1480**, a determination is made whether all cells in zone or sub-zone have been processed. If all cells have been processed, an alert may be sent to external monitoring station **1280** and processing of flowchart **1400** ends. If additional cells remain to be processed, operation proceeds to step **1482**.

In step **1482**, the next cell for adjustment is determined and operation returns to step **1472**.

In step **1490**, a determination is made whether all sub-zones in the support structure have been processed. If all sub-zones have been processed, an alert may be sent to external monitoring station **1280** and processing of flowchart **1400** ends. If additional sub-zones remain to be processed, operation proceeds to step **1494**.

In step **1494**, the next sub-zone is identified. In embodiments, pressure monitoring module **1264** includes data specifying an order to process zones.

Operation then returns to step **1462**.

Computer Architecture

FIG. **16** illustrates a block diagram of a data processing unit **1603** that can be used to implement portions of the RFID reader/sensor or controller illustrated in FIG. **12**. It is noted that the entities shown in FIG. **12** may be implemented using any number of data processing units **1603**, and the configuration actually used is implementation specific.

Data processing unit **1603** may represent a computer, a hand-held computer, a lap top computer, a personal digital assistant, a mobile phone, and/or any other type of data processing device. The type of data processing device used to implement the entities shown in FIG. **12** is implementation specific.

Data processing unit **1603** includes a communications medium **1610** (such as a bus, for example) to which other modules are attached.

Data processing unit **1603** also includes one or more processors **1620** and a main memory **1630**. Main memory **1630** may be RAM, ROM, or any other memory type, or combinations thereof.

Data processing unit **1603** may also include secondary storage devices **1640** such as but not limited to hard drives **1642** or computer program product interfaces **1644**. Computer program product interfaces **1644** are devices that access objects (such as information and/or software) stored in computer program products **1650**. Examples of computer program product interfaces **1644** include, but are not limited to, floppy drives, CD drives, DVD drives, ZIP drives, JAZ drives, optical storage devices, universal serial bus (USB), etc. Examples of computer program products **1650** include, but are not limited to, floppy disks, CDs, DVDs, ZIP and JAZ disks, memory sticks, memory cards, or any other medium on which objects may be stored.

The computer program products **1650** include a computer useable medium **1652** on which objects may be stored, such as but not limited to optical mediums, magnetic mediums, etc.

Control logic or software may be stored in main memory **1630**, second storage device(s) **1640**, and/or computer program products **1650**.

More generally, the term "computer program product" refers to any device in which control logic (software) is stored, so in this context a computer program product could be any memory device having control logic stored therein. The invention is directed to computer program products having stored therein software that enables a computer/processor to perform functions of the invention as described herein.

The data processing unit **1603** may also include an interface **1660** which may receive objects (such as data, applications, software, images, etc.) from external entities **1680** via any communications media including wired and wireless communications media. In such cases, objects **1670** are transported between external entities **1680** and interface **1660** via signals **1665**, **1675**. In other words, signals **1665**, **1675** include or represent control logic for enabling a processor or computer to perform the functions of the invention. According to embodiments of the invention, such signals **1665**, **1675** are also considered to be computer program products, and the invention is directed to such computer program products.

Geolocation

As discussed above with reference to at least FIGS. **1**A, **1**B, and **12-14**, an in particular with reference to step **1330** of the method shown in FIG. **12**, one or more cells of the support structure to be adjusted may be identified and adjusted. One method for identifying the cells to adjust includes geolocation of the sensors. In some embodiments, geolocation of a particular sensor may be advantageous in that the number of zones and subzones that may need to be adjusted to provide treatment may be minimized due to increased accuracy of geolocation. This may be achieved, for example, by methods involving triangulation of the sensor's position using multiple RFID interrogators. In one embodiment, the sensor may be an RF addressable sensor **100**/**1200**, or the like, which may measure the patient contact pressure with a bed. In another embodiment the RFID interrogators may be RFID/sensor readers **150**/**1250**, or the like. Disclosed embodiments of RF addressable sensors and RFID sensors/readers may be interchanged as would be appreciated by those of ordinary skill in the art.

In some embodiments, using a process such as triangulation may decrease the time it would take to adjust zones and subsequent subzones whose pressures may need to be altered. For example certain zones or subzones may be unlikely to be in the immediate vicinity of a pressure sensor affixed to a patient in a region that requires protection from pressure. Those zones and subzones could then be quickly identified and omitted from adjustment. With only iterative adjustments of broader zones and then subzones, there is a potential for a patient to experience an undesirable pressure level prior to the proper zone being identified. Minimizing the time to adjust zones and subzones to mitigate undesirable pressure will lead to improved patient care with less risk of bed sores, and improved management of existing bed sores.

As discussed with reference to FIGS. **1**A and **1**B, in some embodiments, the system includes an RFID reader **150** and a controller **160**. Although depicted as separate components, RFID reader **150** and controller **160** could be implemented in a single structure. RFID reader **150** is configured to communicate with the one or more RF addressable pressure sensors **100** and obtain data therefrom. RFID reader **150** is placed proximate to the individual. Although FIG. **1**A depicts the reader **150** attached to the foot of the bed, the RFID reader may be placed at any location to permit detection and access to the RF addressable sensors. For example, RFID reader **150** may be placed on the support structure, under the support structure, above the support structure, or next to the support structure (e.g., on a mobile station).

FIG. **17** illustrates a flowchart **1700** for a method for determining an adjustment for one or more cells in a support structure, in accordance with embodiments of the present invention. FIG. **17** is described with reference to the embodiments of FIGS. **1** and **12**, and may include aspects of other disclosed methods. However, the method is not limited to those embodiments.

In step **1710**, pressure monitoring module obtains pressure data from one or more RF addressable sensors **100** placed on an individual. The pressure monitoring module may also obtain a tag identification number associated with the RF addressable sensor **100** providing sensor data. In an embodiment, RFID/sensor reader **150** polls the one or more RF addressable sensors **100**. In an alternate embodiment, the one or more RF addressable sensors **100** are configured to periodically send data to RFID/sensor reader **150**. RFID/sensor reader **150** then communicates the received data to pressure monitoring module. In embodiments RFID/sensor reader **150** may process the sensor data, e.g., to calibrate or smooth the received data, prior to communicating the data to pressure monitoring module.

In step **1720**, a determination is made whether the pressure data indicates an adjustment is required. In an embodiment, this determination is made on a per RF addressable sensor basis. For example, pressure monitoring module may determine for an RF addressable sensor whether the pressure data exceeds a threshold. In addition, or alternatively, the determination may be based on a historical trend for the RF addressable sensor. For example, if the pressure data has been consistently increasing over a predetermined period of time, an adjustment may be indicated for the RF addressable sensor. The networkable device, or associated computing system, can also compare the pressure data to the patient's diastolic blood pressure or other measurement, and calculate relevant clinical gradients in real time. As would be appreciated by persons of skill in the art, other techniques for determining whether an adjustment is required may be used with the present invention. If an adjustment is required, operation proceeds to step **1730**. If no adjustment is required, operation returns to step **1710**.

In step **1730**, if an adjustment is required, pressure monitoring module triangulates a position of required adjustment and adjusts one or more cells of support structure corresponding to that position.

Once adjusted, in step **1740** pressure monitoring module obtains pressure data from one or more RF addressable sensors **100**.

Pressure monitoring module determines in step **1750** whether the pressure measurements have improved. If there is no improvement, the system may adjust cells proximate the adjusted cell, or further adjust the adjusted cell. Steps **1730-1750** may be repeated as required.

In some embodiments, multiple RFID readers **150** may be placed about a patient support structure. For example, in one embodiment, multiple RFID readers **150** may be placed beneath a mattress, at the 4 corners of a support pad.

FIG. **18** illustrates a flowchart **1800** for a method for determining an adjustment for one or more cells in a support structure, in accordance with embodiments of the present invention. FIG. **18** is described with reference to the embodiments of FIGS. **1** and **12**, and may include aspects of other disclosed methods. However, the method is not limited to those embodiments.

In step **1802**, as in similar disclosed methods, pressure monitoring module obtains pressure data from one or more RF addressable sensors **100** placed on an individual. In some embodiments, the system or method may utilize a synchronized clock time between processors associated with each RFID reader **150**, (e.g., each active antenna/RF Interrogator). In one embodiment, all antennae may be energized as in step **1806**, and configured to receive a response from RF addressable sensor **100**. When a response is received, the system may assess a time delay between the transmission and arrival of the response as in step **1808**. When a time delay is assessed, the system may process relative distance between RF addressable sensor **100** and each RFID reader **150** as in step **1810**. The system may then calculate a radius of RF addressable sensor **100** to each RFID reader **150** as in step **1812** and the system may then calculate an intersection location or overlap using at least 3 RFID readers, such that the location of RF addressable sensor **100** is determined. Once a location is determined, controller **160** may adjust only the zone or subzone within which the triangulated location lies, at step **1814**. The system may detect whether or not there is a change in detected pressure from RF addressable sensor **100**, and if there is no change in pressure, the controller may adjust an adjacent subzone until response in pressure is obtained as in steps **1814-1817**. In some embodiments, additional adjacent subzones may be adjusted until a response in pressure is obtained. Steps **1806-1817** may be repeated as necessary.

In some embodiments, the system may simultaneously energize all antennae on RFID readers **150** (e.g., in parallel) and each one may be configured to receive a response from the transmitter/RF addressable sensor **100**. In one embodiment, the system may be able to assess time delay between arrival of the responses.

In some embodiments, the system may energize each antenna discretely (e.g., serially) and calculate a delay in response of each transmitter/RF addressable sensor **100**. The system may serially energize and calculate delays through a plurality of antennae/RFID readers **150** and store a response time for each. After all distances between antenna/RFID readers **150** and transmitter/RF addressable sensor **100** are determined, the system may proceed as described above with calculation of location and adjustment of pressure. In this regard, one processor may control all interrogators/RFID readers **150** without the need to synchronize clocks.

Because the distances between each antenna/RFID readers **150** and transmitter/RF addressable sensor **100** are small, a relatively high time resolution may be required, as the relative difference in arrival times may be very small (as compared to GPS triangulation systems and methods where the transmitters are satellites). Thus, in some embodiments, signal intensity may be used as a proxy for distance, rather than delay in arrival time. Because the signals involved may be low energy signals, their intensity decay over a particular distance through a particular medium would be significant, and is predictive of distance with reasonable accuracy (e.g., higher intensity received indicates the RF addressable sensor is closer, where as a lower intensity received indicates the RF addressable sensor is further away). In some embodiments, the system may calculate a decay rate function of the transmitted signals on a particular medium (for example, a typical mattress, or other common support surface) along with particular sizes and shapes, and use this data to triangulate the location based on signal intensity at each antenna/RFID reader **150**.

In some embodiments, RFID reader **150** may receive and analyze information regarding an initial incoming wave front of one or more alternating current RF waves transmitted by the RF addressable sensor **100**. By way of example, a 13.56 MHz RF wave and a 433 MHz RF wave may be generated simultaneously such that their first rising peak is in phase, that is, rising together. Because the wavelength of the 13.56 MHz wave is approximately 22.11 meters and the wavelength of the 433 MHz wave is approximately 0.69 meters, an interference pattern is created. As the distance from the transmitter of the RF addressable sensor **100** increases, the difference in arrival time of the 2 wave peaks will increase proportionally to the distance between the RF addressable sensor **100** and RFID reader **150**. By examining the interference pattern between the waveforms, known as interferometry, the distance between the transmitter and receiver can be accurately calculated.

In an embodiment, the system may measure the fluctuation in signal intensity compared to a pure sine wave of the fundamental frequency, which represents the interference pattern of the two waves. In another embodiment, the system may look for the arrival time of the wave peak, or through of each of the 2 fundamental frequencies being broadcast. This interference pattern will form a repeating sequence over time and space, and if measured at longer distances (e.g., hundreds of meters) would lead to multiple potential solutions for the location of the transmitter. However, because the typical support structure may be smaller than the approximately 22.11 meter wavelength of the 13.56 MHz wave, there will be only one solution within the confines of the support surface. The two frequencies used in this example are for illustrative purposes only, and as such other frequencies may be used in the systems and methods described herein. The system may therefore utilize wave front interferometry techniques in order to further resolve position determination of the RF addressable sensor **100**.

In some embodiments, addressable sensors and readers may be used, such that a single sensor may utilize dual frequency transmitting antennas and utilize the interference pattern (e.g., difference in arrival time of discrete peaks/troughs) received at the reader in order to determine the position of the sensor. In some embodiments, the sensors may be RF addressable sensors configured to transmit dual frequencies. Utilization of these discrete frequencies as two carrier waves enables the system to obtain very high resolution of location

As discussed above, in an embodiment, the memory may store an identifier for the RFID tag associated with the pressure sensor. The tag identifier, for example, may be used to associate the RF addressable sensor with an individual, or a body position for an individual (e.g., left leg, right leg, right forearm, etc.). In some embodiments, these identifiers could be used by the system to further refine position determination, for example, by initially searching in a given set of zones based on identifier. For example, the system may use an identifier such as "left leg" to initially focus on zones and subzones where it is likely that a "left leg" identified tag may be positioned. In this regard, it may be possible to optimize processing time during the aforementioned triangulation operation and position determinations. In this example, a provider could maintain a database mapping tag identifiers to individuals and or locations. Multiple tags may be utilized such that each tag has a unique identifier and is associated with a different area that requires pressure adjustment. Using the aforementioned geolocation/triangulation techniques, each RF addressable sensor may be located to the zone or subzone level to minimize the time required to address problematic pressure readings.

CONCLUSION

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A method for monitoring pressure at a point on an individual and automatically adjusting a section of a support structure having a plurality of adjustable cells, wherein the support structure is divided into a plurality of zones and one or more of the zones is divided into a plurality of subzones, the method comprising:

periodically receiving with at least three radio frequency readers disposed such that they are substantially co-planar, localized contact pressure data from a radio frequency addressable sensor placed on an individual;

determining whether an adjustment in the support structure is required using the received localized contact pressure data;

when an adjustment is required, calculating a radial distance defining a radius of the radio frequency addressable sensor to the at least three radio frequency readers, and calculating an intersection location or overlap of the radii such that the location of the radio frequency addressable sensor is determined; and

when the location of the radio frequency addressable sensor is determined, adjusting cells within a zone or subzone corresponding to the location.

2. The method of claim **1**, further comprising:

measuring a time delay between when an antenna of a radio frequency reader is energized and when a response signal from the radio frequency addressable sensor is received to calculate the radial distance defining the radius of the radio frequency addressable sensor to the radio frequency reader.

3. The method of claim **2**, wherein the antennae of the at least three radio frequency readers are energized in series.

4. The method of claim **2**, wherein the antennae of the at least three radio frequency readers are energized in parallel.

5. The method of claim **1**, further comprising:

measuring signal intensity received at the radio frequency reader; and

applying a decay function to the signal intensity to calculate the radial distance defining the radius of the radio frequency addressable sensor to the radio frequency reader.

6. The method of claim **5**, wherein the antennae of the at least three radio frequency readers are energized in series.

7. The method of claim **5**, wherein the antennae of the at least three radio frequency readers are energized in parallel.

8. The method of claim **1**, further comprising:

applying wave front interferometry such that the resolution of the location of the radio frequency addressable sensor is increased.

9. The method of claim **1**, further comprising:

receiving an identifier corresponding to a body position of an individual of the radio frequency addressable sensor; and

applying the identifier to identify a likely position of the radio frequency addressable sensor on the support structure.

10. The method of claim **1**, further comprising:

analyzing an interference pattern of at least two discrete signals transmitted by the radio frequency addressable sensor to the calculate the radial distance defining the radius of the radio frequency addressable sensor to the radio frequency reader.

11. The method of claim **1**, further comprising:

maintaining the adjustments for a predetermined period of time; and

receiving updated localized contact pressure data from the one or more radio frequency addressable sensors.

12. The method of claim 11, further comprising:

returning one or more of the adjustable sections to a pre-adjusted level if the localized contact pressure data is not improved after the predetermined period of time.

13. The method of claim 11, further comprising:

adjusting an adjacent adjustable section if the localized contact pressure data is not improved after the predetermined period of time.

14. The method of claim 1, further comprising:

alerting an external monitoring station if the localized contact pressure data does not approve after a predetermined number of adjustments.

15. A system for preventing and/or treating pressure wounds on an individual, the system comprising:

a support structure including a plurality of adjustable cells, wherein the support structure is divided into a plurality of zones and one or more of the zones is divided into a plurality of subzones;

at least three radio frequency sensor readers disposed on respective corners of a support pad and configured to receive localized contact pressure data from an radio frequency addressable sensor placed adjacent to the skin of the individual;

a processor coupled to the support structure and each of the radio frequency sensor readers, wherein the processor is configured to:

determine whether the localized contact pressure data in the radio frequency addressable sensor exceeds a predetermined threshold, and

isolate a location on the individual of the radio frequency addressable sensor by calculating a radial distance defining a radius of the radio frequency addressable sensor to the at least three radio frequency readers, and calculating an intersection location or overlap of the radii such that the location of the radio frequency addressable sensor is determined, and

when the location of the radio frequency addressable sensor is determined, adjusting cells within a zone or subzone corresponding to the location.

16. The system of claim 15, the processor further configured to measure a time delay between when an antenna of a radio frequency reader is energized and when a response signal from the radio frequency addressable sensor is received to calculate the radial distance defining the radius of the radio frequency addressable sensor to the radio frequency reader.

17. The system of claim 15, the processor further configured to maintain the adjustments for a predetermined period of time, and to receive updated localized contact pressure data from the radio frequency addressable sensor.

18. The system of claim 17, the processor further configured to return one or more of the adjustable sections to a pre-adjusted level if the localized contact pressure data is not improved after the predetermined period of time.

19. The system of claim 17, the processor further configured to adjust an adjacent adjustable section if the localized contact pressure data is not improved after the predetermined period of time.

20. The system of claim 15, wherein the radio frequency addressable sensor is included in a bandage affixed to the skin of the individual.

21. The system of claim 15, wherein the support structure is selected from a bed, pad configured for use on a bed, chair, wheel chair, or pad configured for use on a chair.

22. A method for monitoring pressure at a point on an individual and automatically adjusting a section of a support structure having a plurality of adjustable cells, wherein the support structure is divided into a plurality of zones and one or more of the zones is divided into a plurality of subzones, the method comprising:

periodically receiving with at least three radio frequency readers, localized contact pressure data from a radio frequency addressable sensor placed on an individual;

determining whether an adjustment in the support structure is required using the received localized contact pressure data;

receiving an identifier corresponding to a body position of an individual of the radio frequency addressable sensor; and

applying the identifier to identify a likely position of the radio frequency addressable sensor on the support structure;

calculating a radial distance defining a radius of the radio frequency addressable sensor to the at least three radio frequency readers, and calculating an intersection location or overlap of the radii such that the location of the radio frequency addressable sensor is determined when an adjustment is required; and

adjusting cells within a zone or subzone corresponding to the location when the location of the radio frequency addressable sensor is determined.

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