



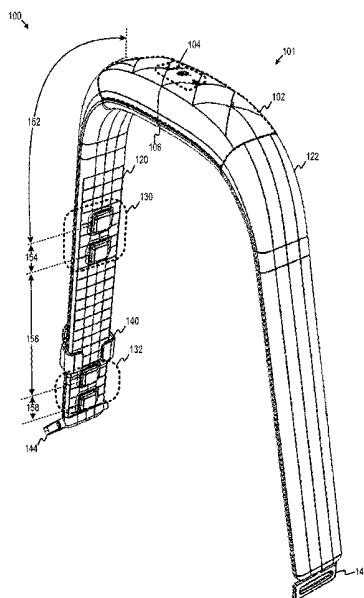
US 20150359491A1

(19) **United States**(12) **Patent Application Publication**  
**Luna et al.**(10) **Pub. No.: US 2015/0359491 A1**(43) **Pub. Date: Dec. 17, 2015**(54) **PHYSIOLOGICAL CHARACTERISTIC  
DETERMINATION BASED ON SIGNAL  
CORRELATION**ation-in-part of application No. 13/802,305, filed on  
Mar. 13, 2013, Continuation-in-part of application No.  
13/802,319, filed on Mar. 13, 2013.(71) Applicants: **Michael Edward Smith Luna**, San  
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Singleton**, Palm Harbor, PA (US);  
**Piyush Savalia**, San Francisco, CA  
(US); **Prasad Panchalan**, San Francisco,  
CA (US); **Sheila Nabanja**, San Jose, CA  
(US); **Sylvia Hou-Yan Cheng**, San  
Francisco, CA (US); **Ilyas Mohammad**,  
San Francisco, CA (US); **Sumit  
Sharma**, San Francisco, CA (US)(72) Inventors: **Michael Edward Smith Luna**, San  
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Mountain View, CA (US); **John M.  
Stivorcic**, Pittsburgh, PA (US); **Chris  
Singleton**, Palm Harbor, PA (US);  
**Piyush Savalia**, San Francisco, CA  
(US); **Prasad Panchalan**, San Francisco,  
CA (US); **Sheila Nabanja**, San Jose, CA  
(US); **Sylvia Hou-Yan Cheng**, San  
Francisco, CA (US); **Ilyas Mohammad**,  
San Francisco, CA (US); **Sumit  
Sharma**, San Francisco, CA (US)(73) Assignee: **AliphCom**, San Francisco, CA (US)(21) Appl. No.: **14/121,947**(22) Filed: **Nov. 4, 2014****Related U.S. Application Data**(63) Continuation-in-part of application No. 14/480,628,  
filed on Sep. 8, 2014, Continuation-in-part of applica-  
tion No. 13/831,260, filed on Mar. 14, 2013, Continu-(30) **Foreign Application Priority Data**

Sep. 29, 2012 (CN) ..... 201220513278.5

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(2013.01); **A61B 5/7221** (2013.01); **A61B**  
**5/7278** (2013.01); **A61B 5/0205** (2013.01);  
**A61B 5/165** (2013.01); **A61B 5/4866**  
(2013.01); **A61B 5/7203** (2013.01); **A61B**  
**5/681** (2013.01); **A61B 5/0245** (2013.01)(57) **ABSTRACT**

Embodiments relate generally to a wearable device implementing a touch-sensitive interface in a metal pod cover and/or bioimpedance sensing to determine physiological characteristics, such as heart rate. According to an embodiment, a method includes receiving an amplified signal including a portion of the physiological-related signal component including data representing a physiological characteristic, the amplified signal being derived from bioimpedance signal based on an impedance value of a tissue, and identifying a magnitude of a portion of the physiological-related signal component. Also, the method can compare the magnitude of the portion against another magnitude of a data model (e.g., in a time-domain) to form a matched value. Also, the method can determine a confidence indicator value representative of a degree of likelihood that the matched value is representative of the physiological characteristic, and determining a value of the physiological characteristic based on the matched value and the confidence indicator value.



**FIG. 1**

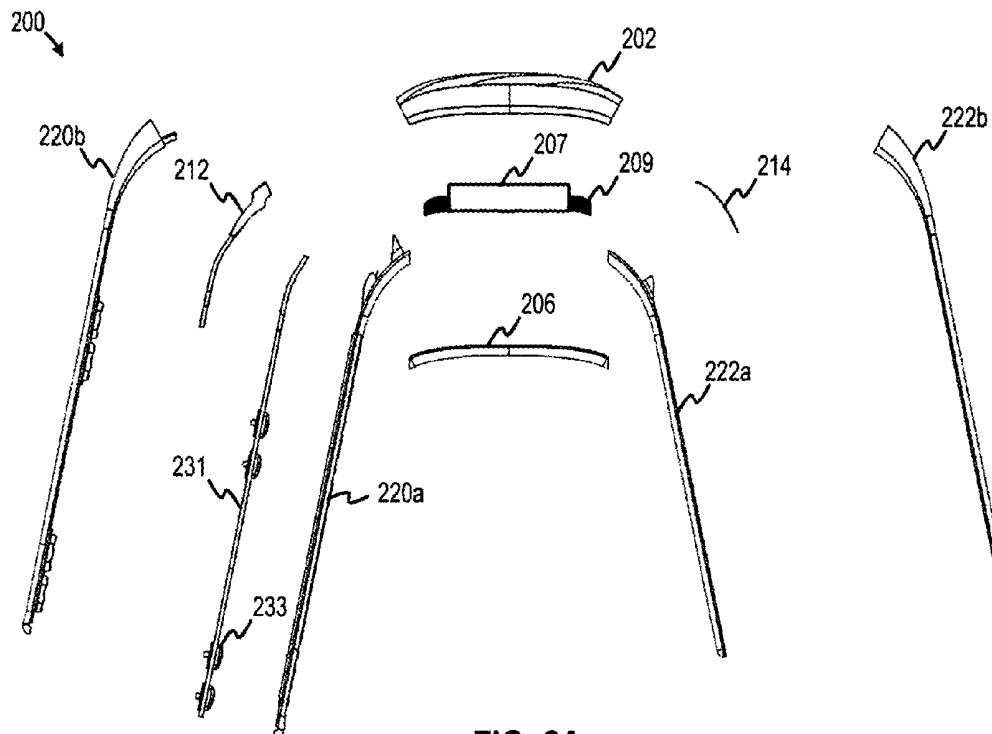


FIG. 2A

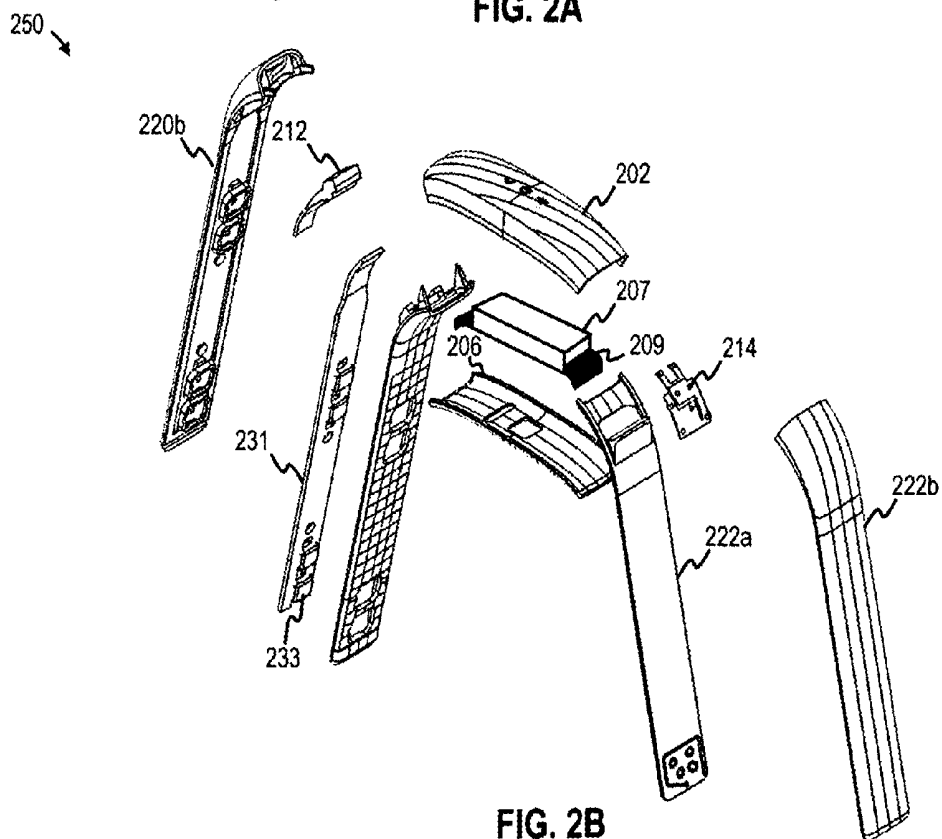


FIG. 2B

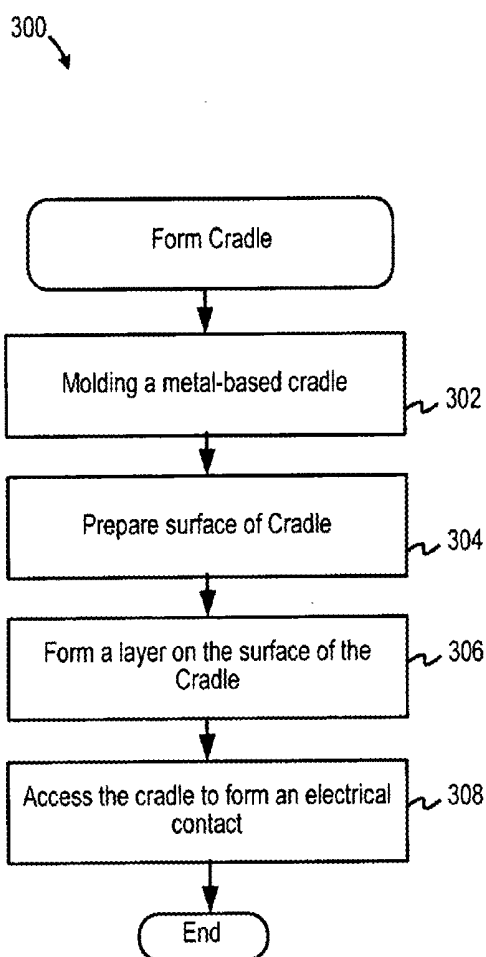


FIG. 3

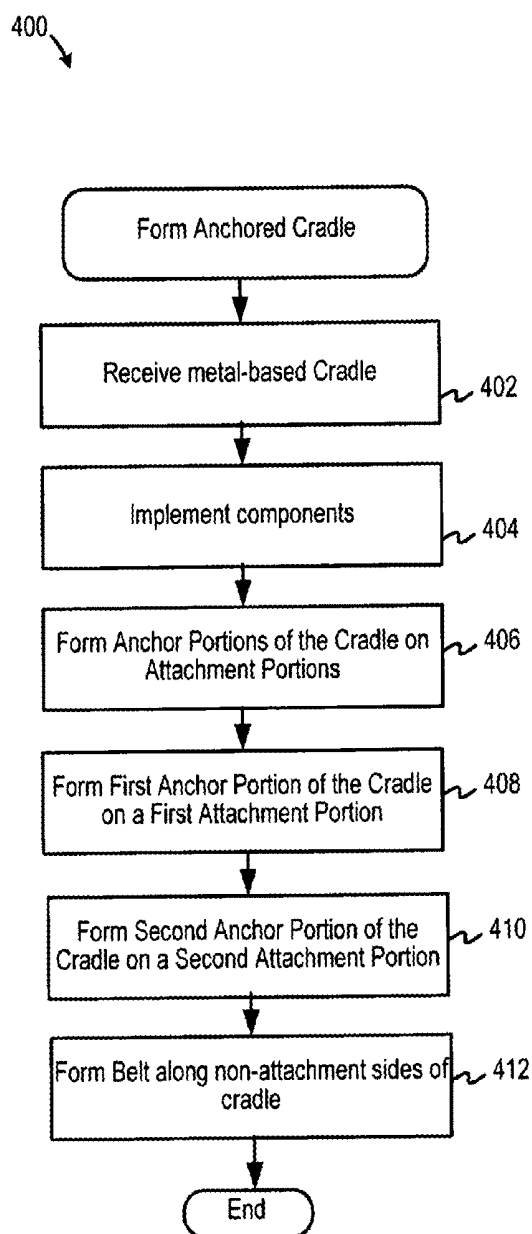


FIG. 4

500

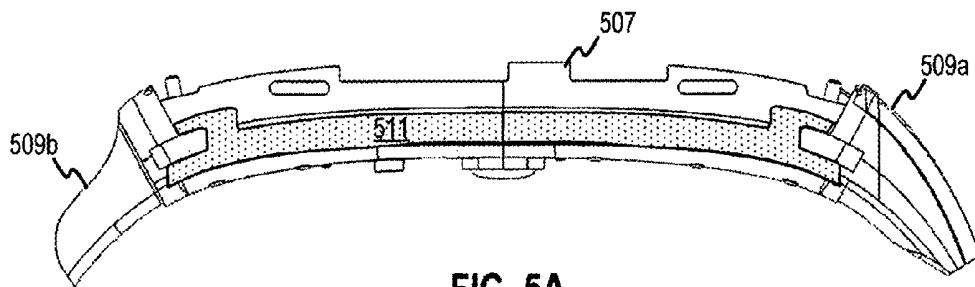


FIG. 5A

550

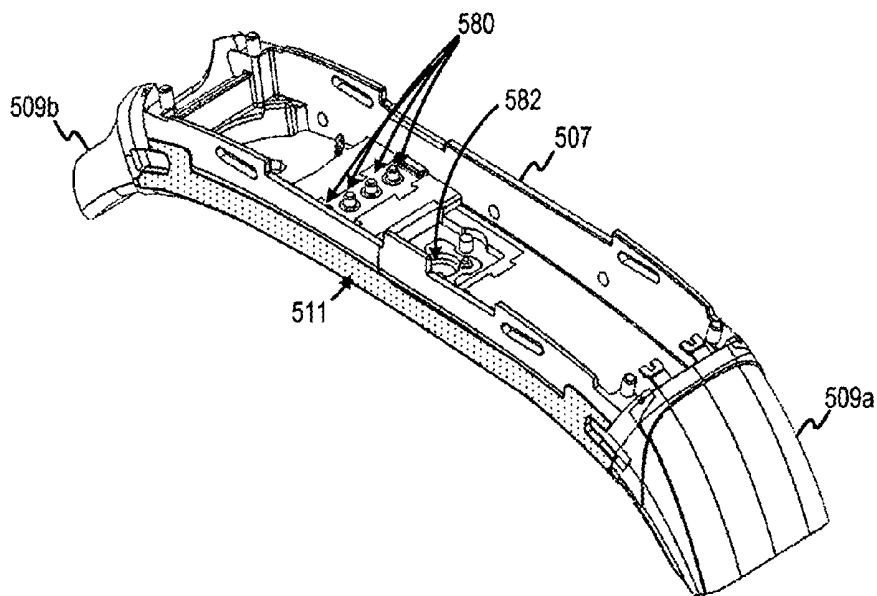


FIG. 5B

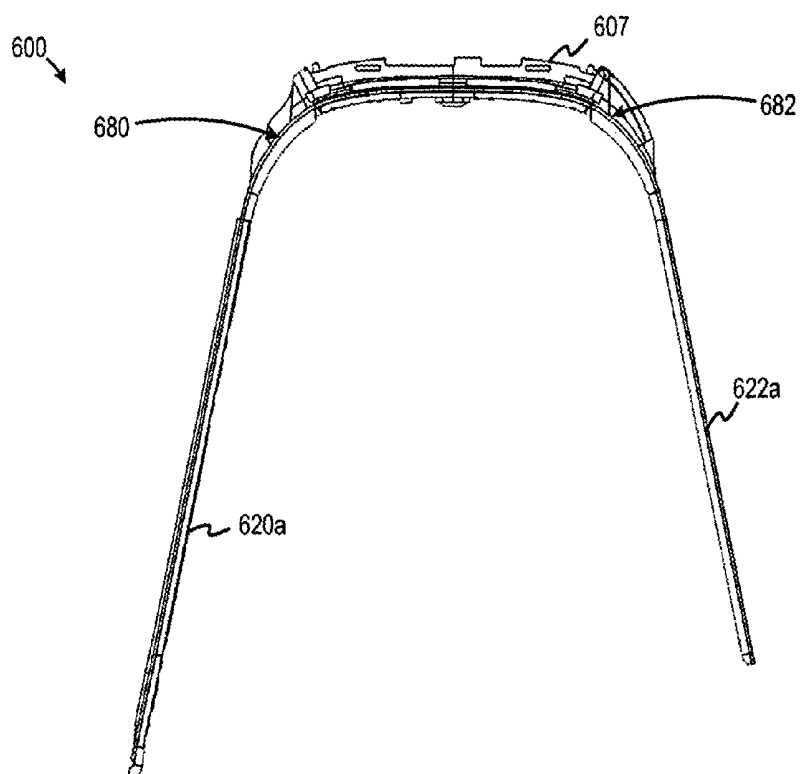


FIG. 6A

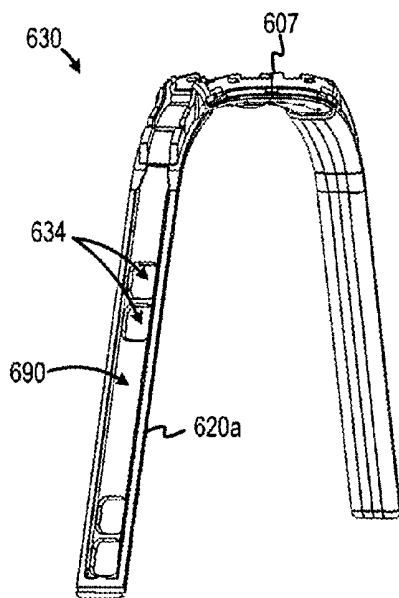


FIG. 6B

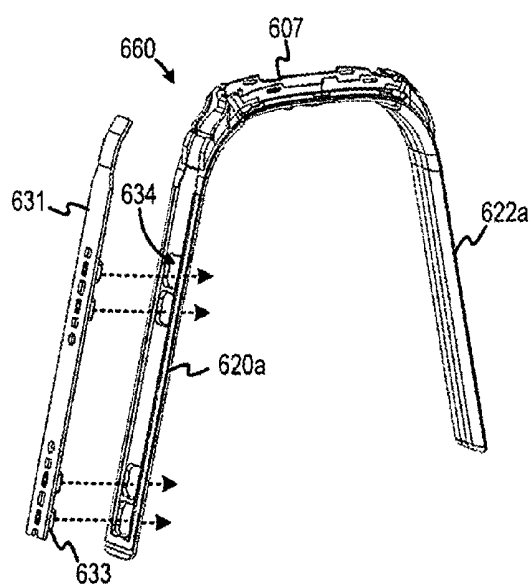
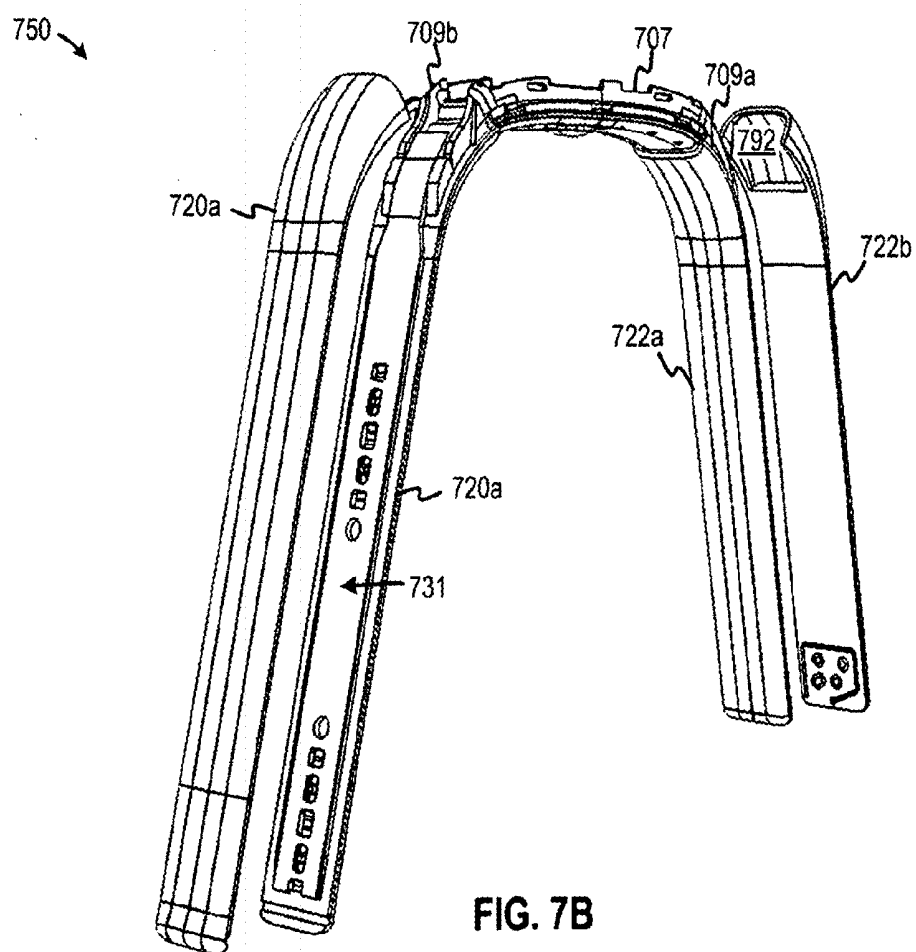
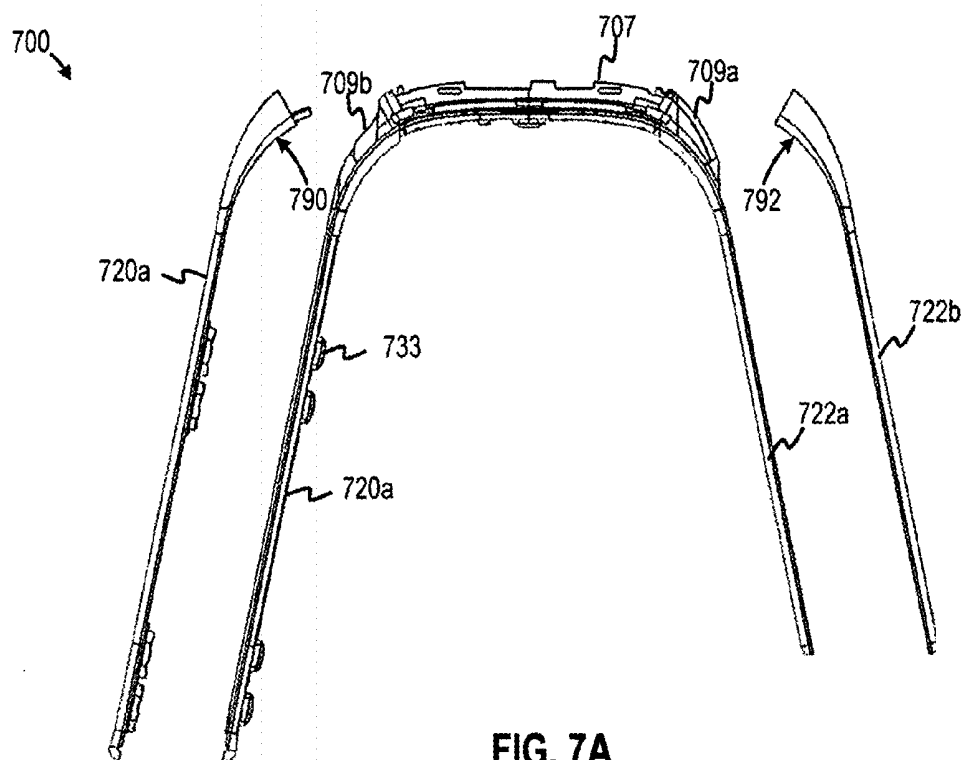


FIG. 6C



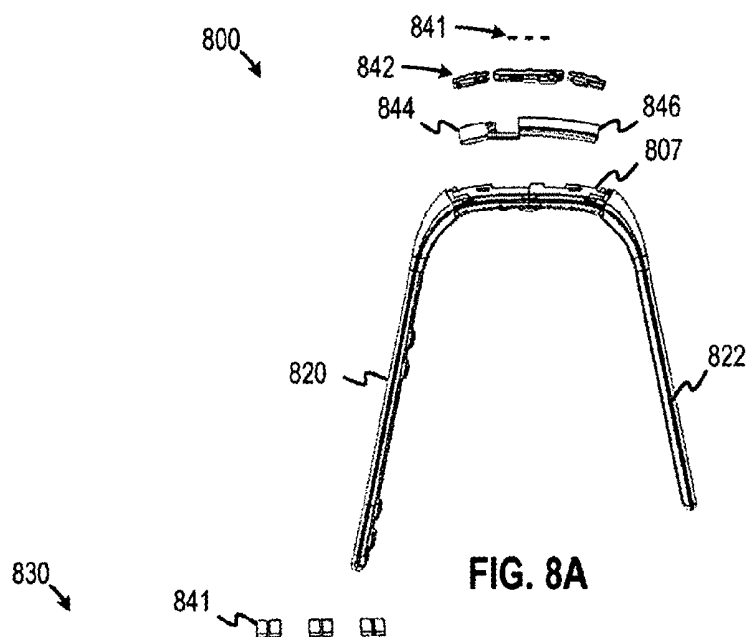


FIG. 8A

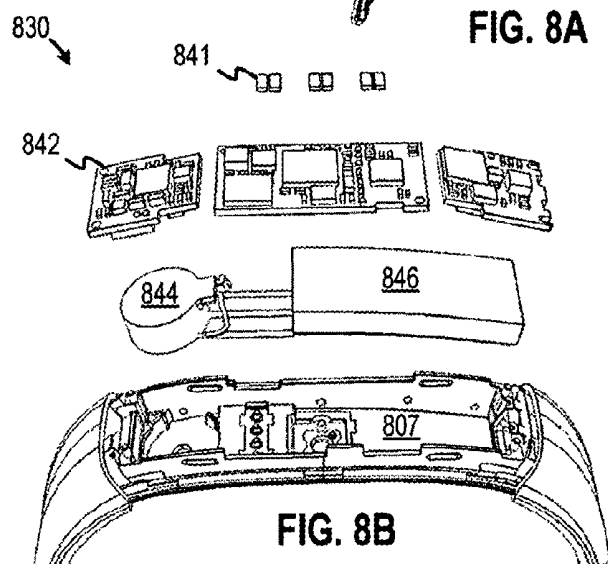


FIG. 8B

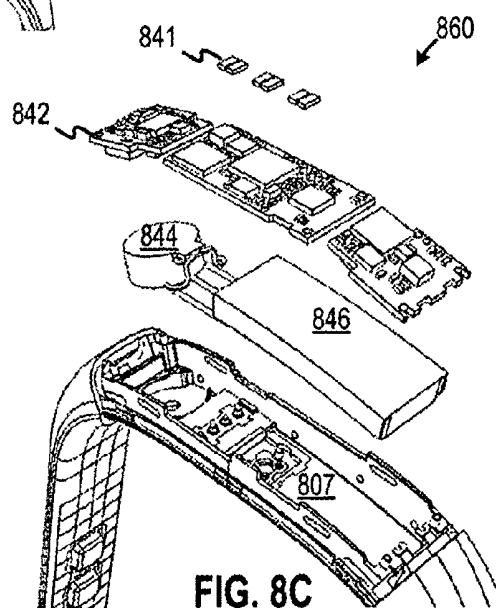
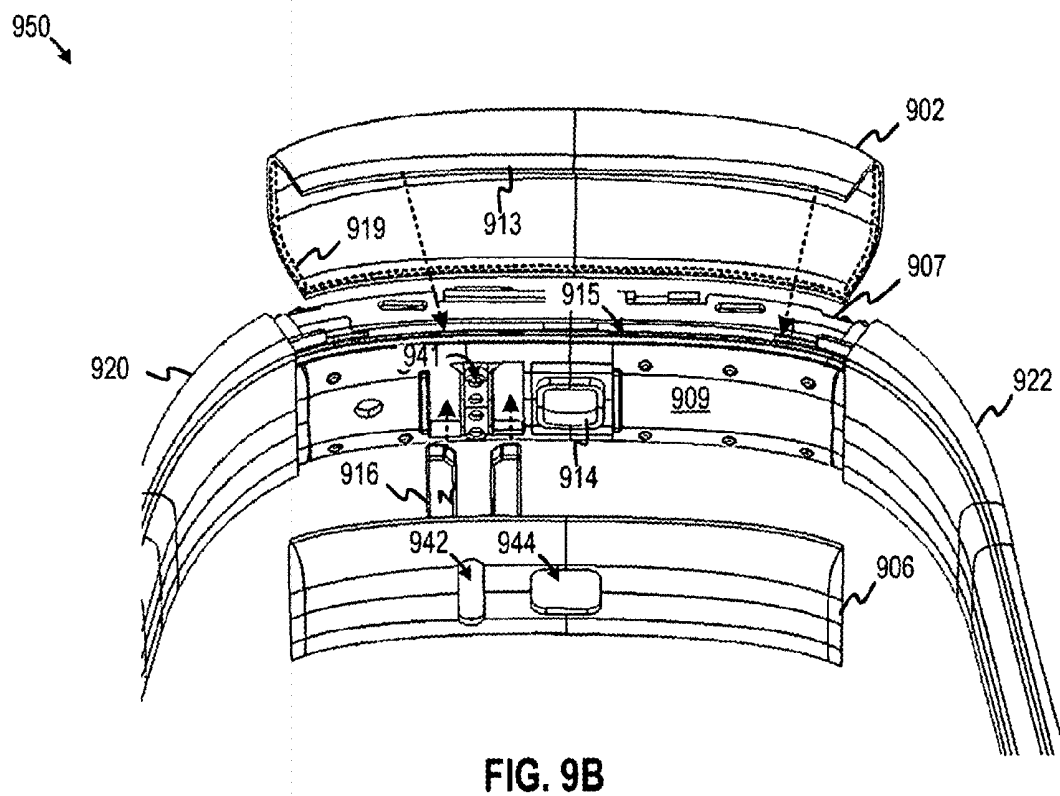
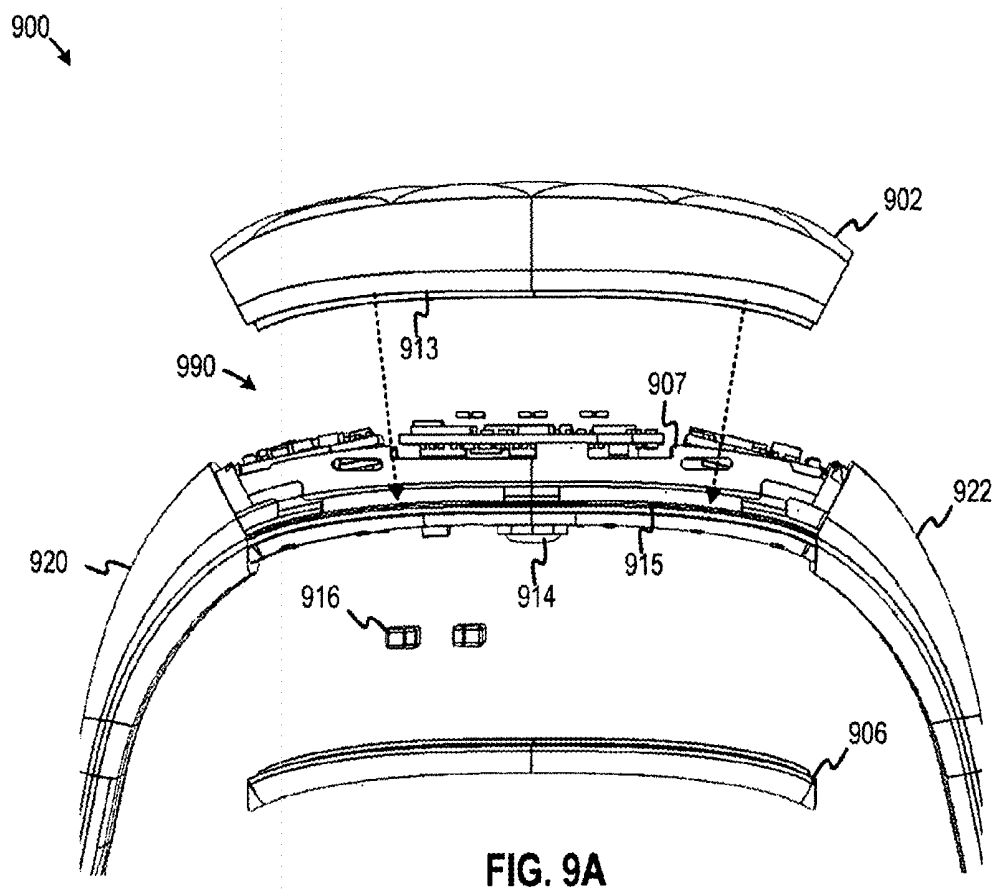


FIG. 8C





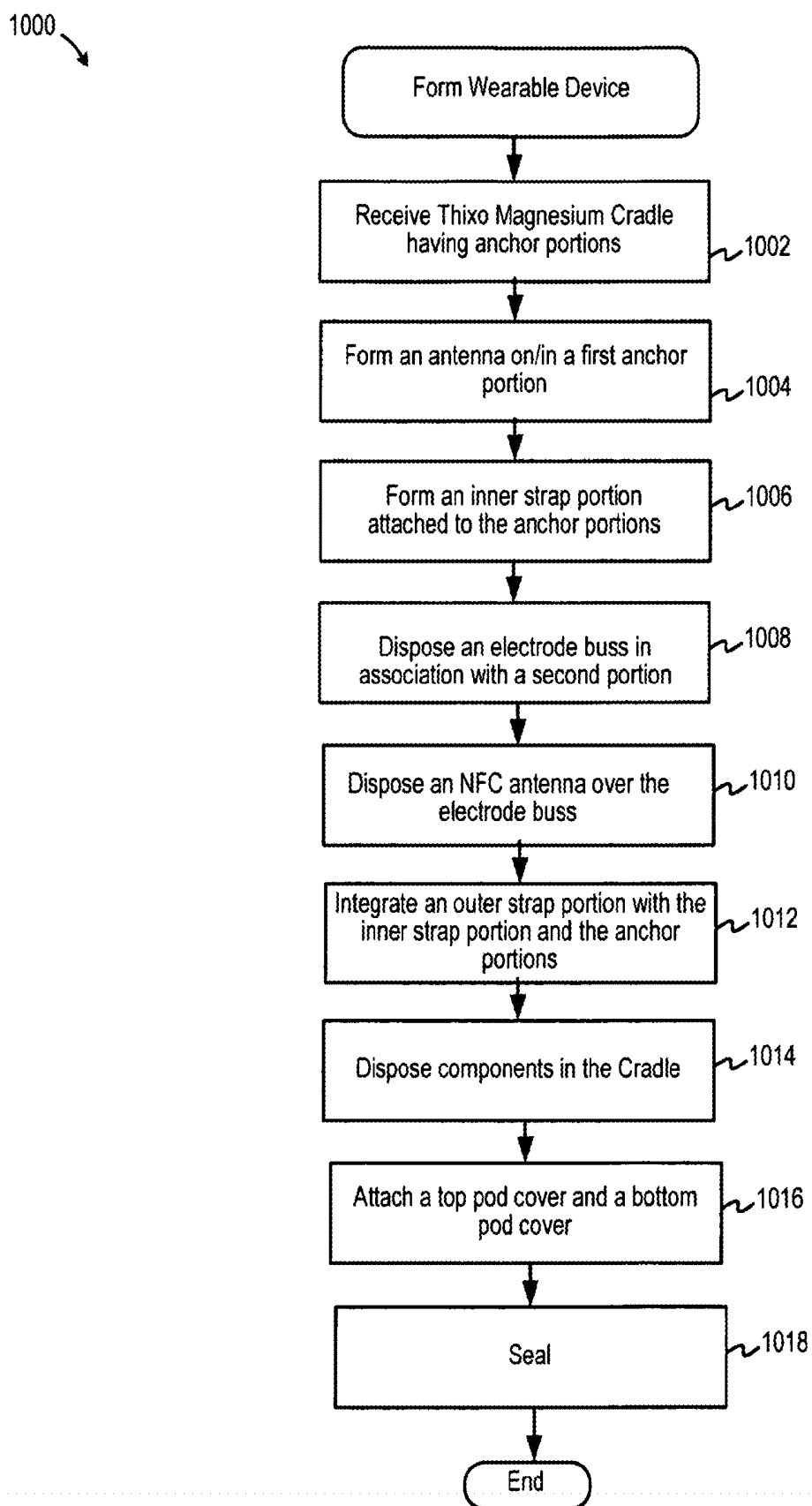


FIG. 10

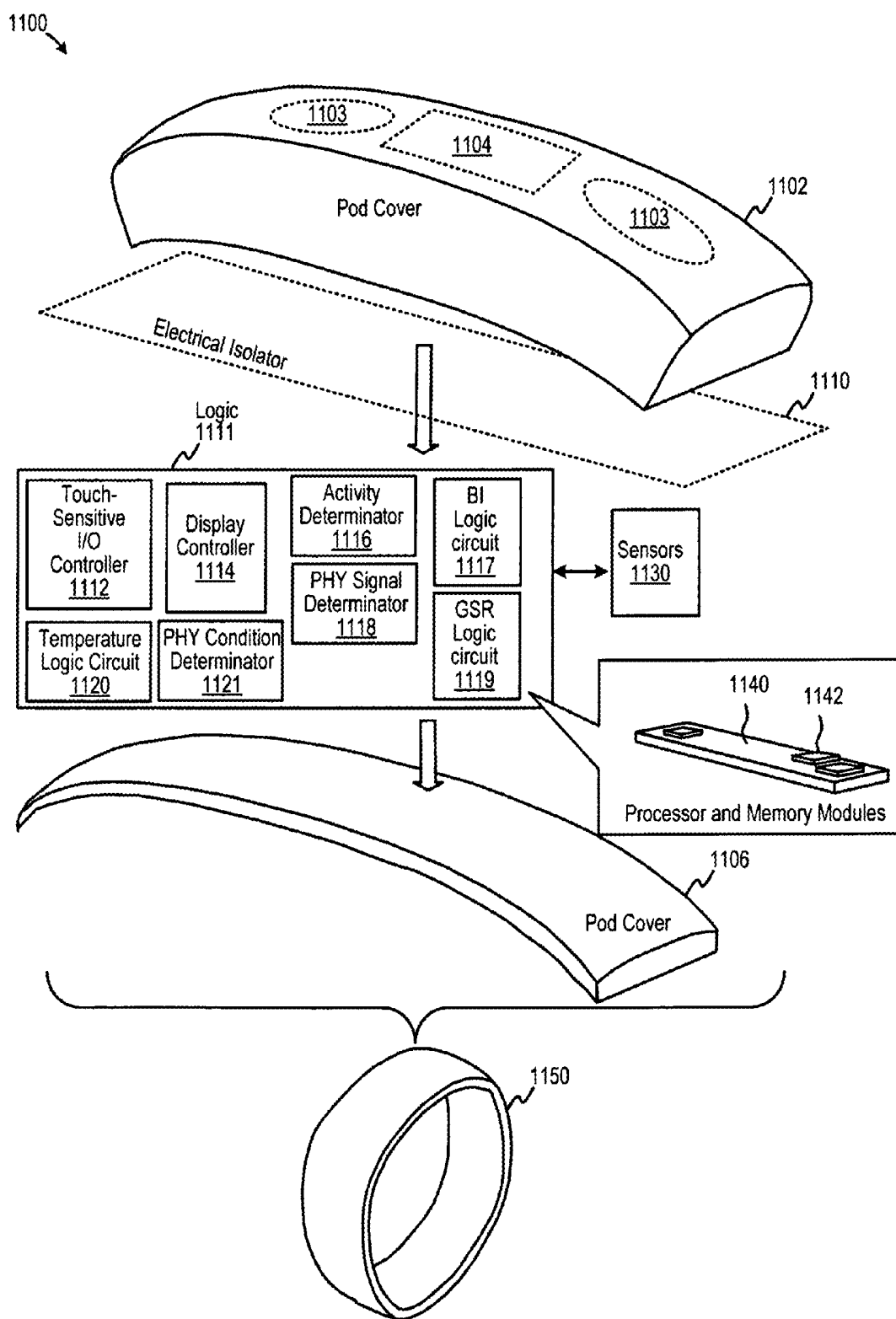


FIG. 11

1200

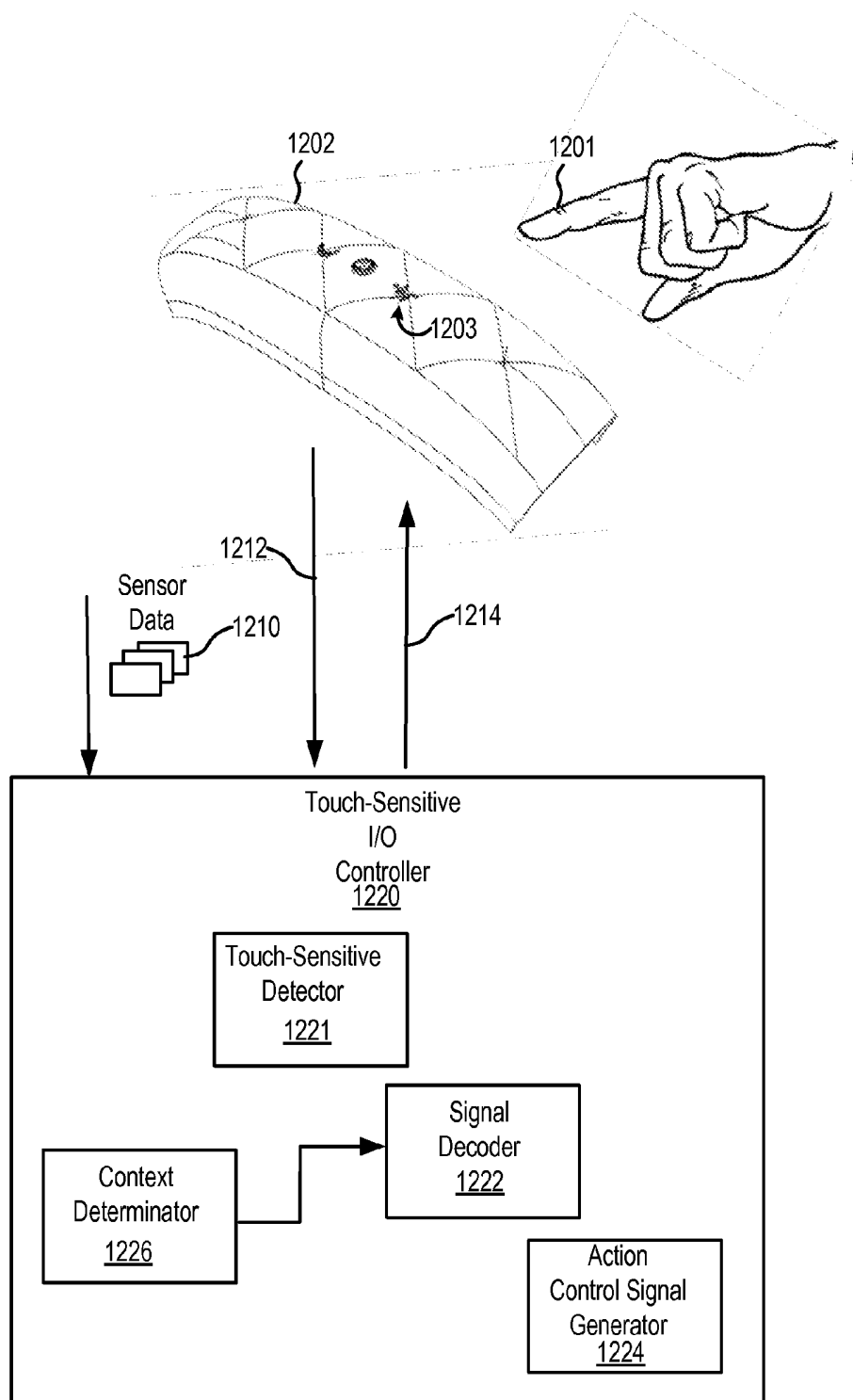


FIG. 12

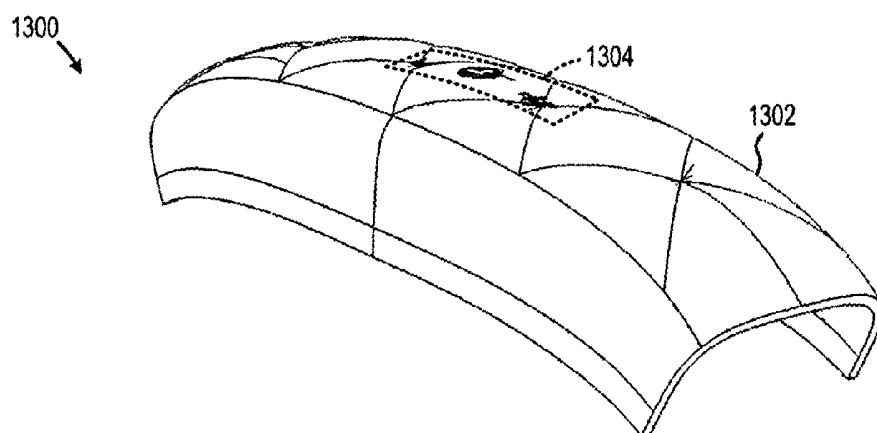


FIG. 13A

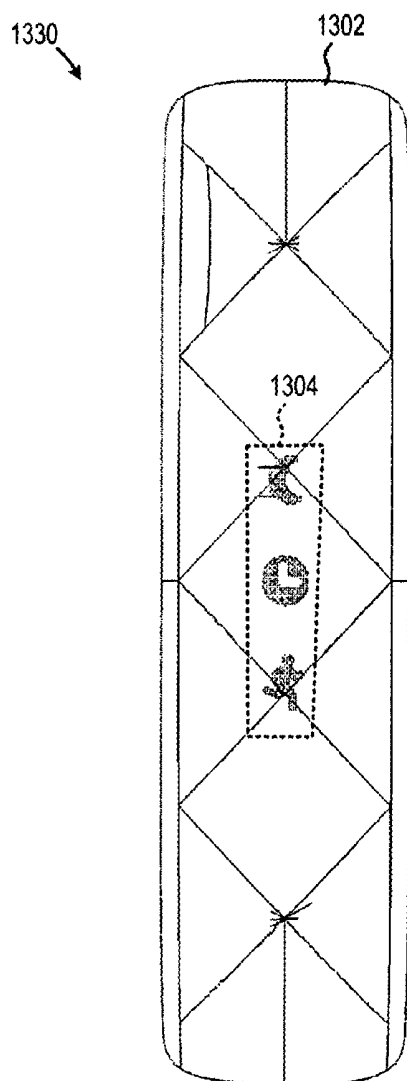


FIG. 13B

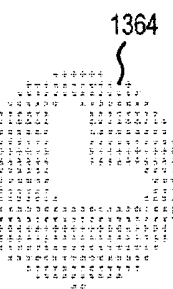
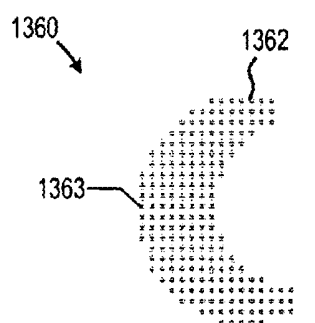


FIG. 13C

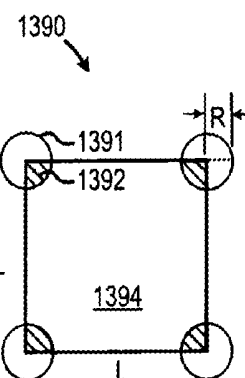
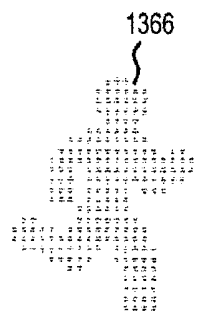
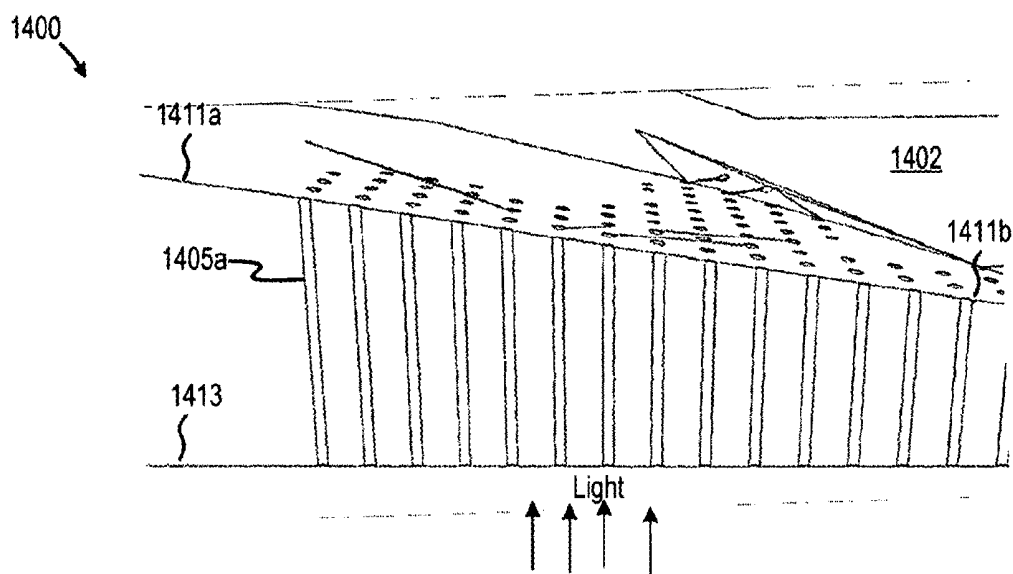
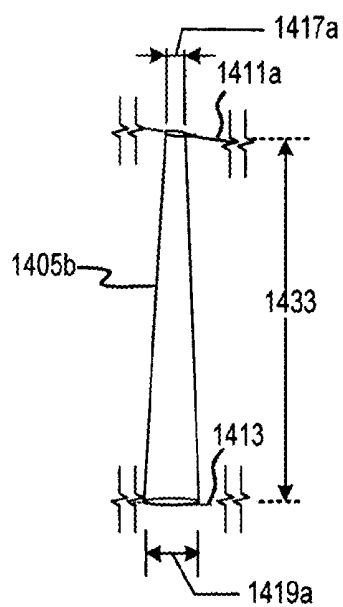


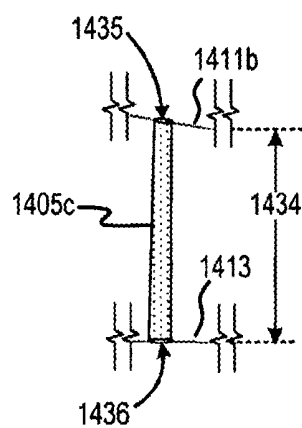
FIG. 13D



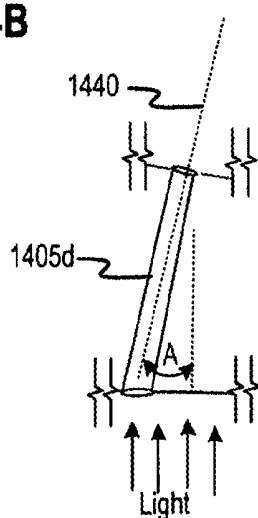
**FIG. 14A**



**FIG. 14B**



**FIG. 14C**



**FIG. 14D**

1500

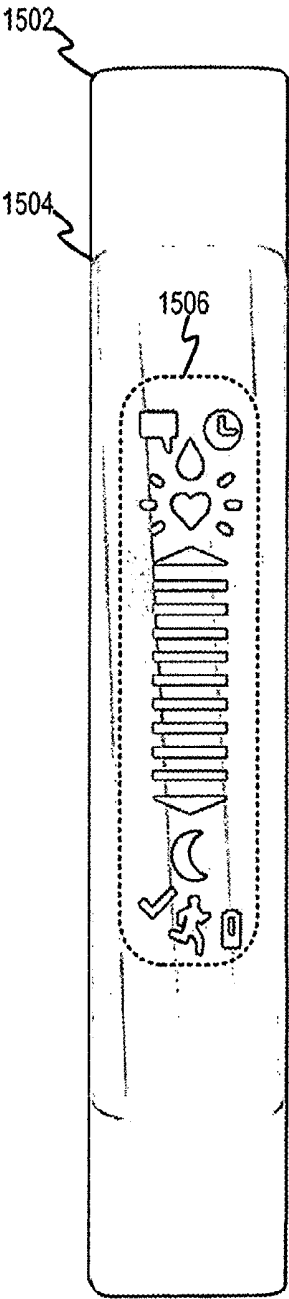


FIG. 15A

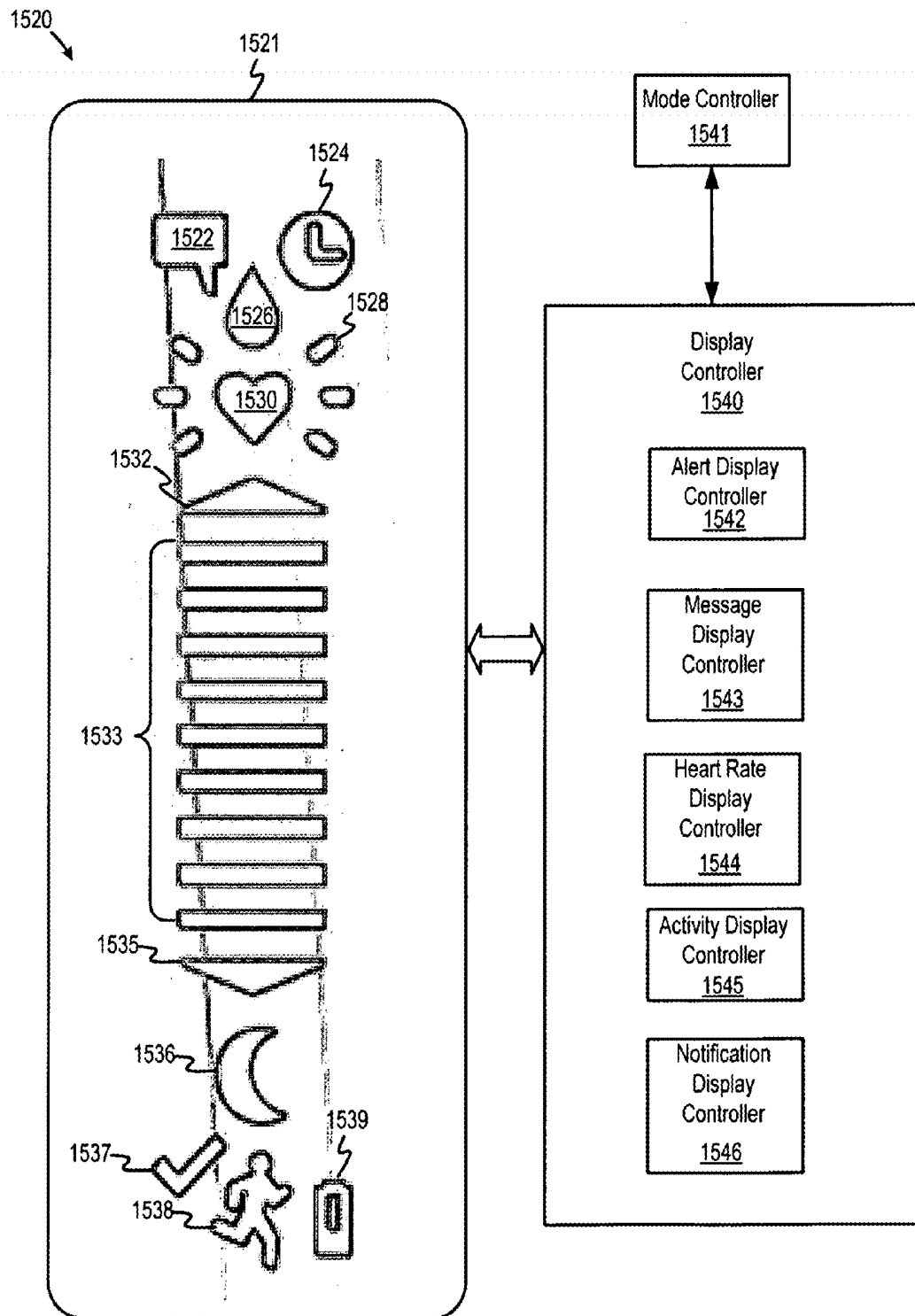


FIG. 15B



1550

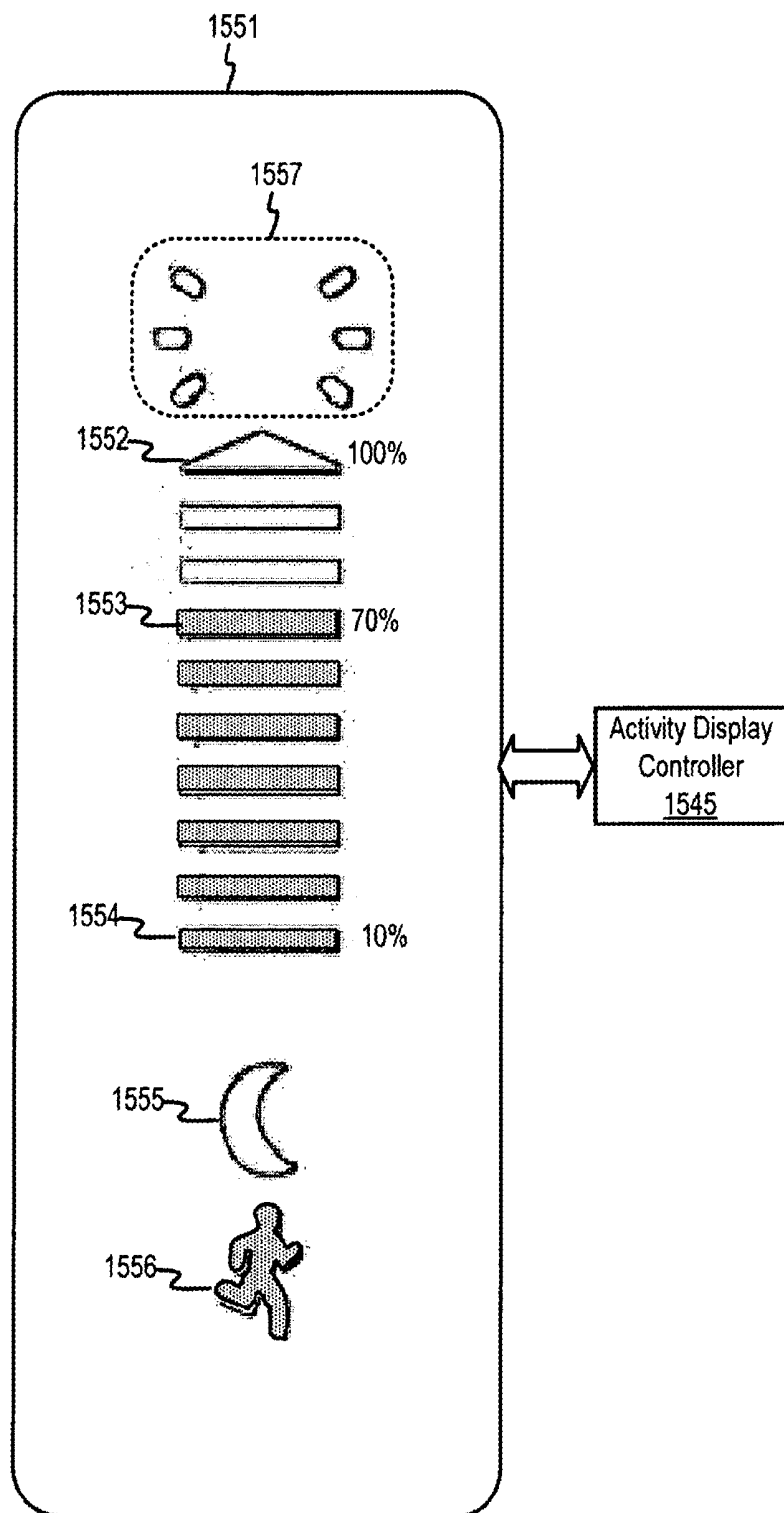


FIG. 15C

1560

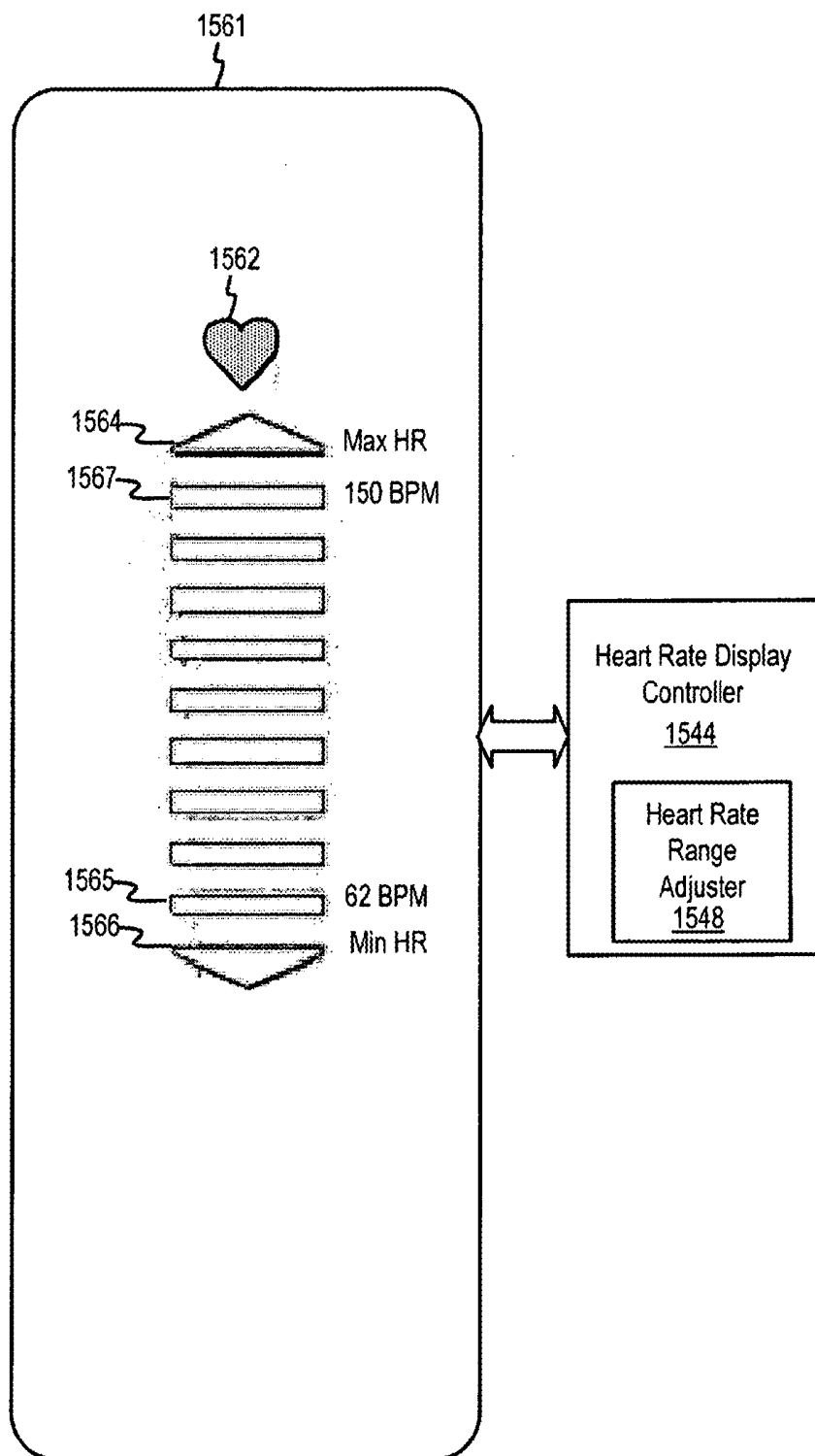


FIG. 15D

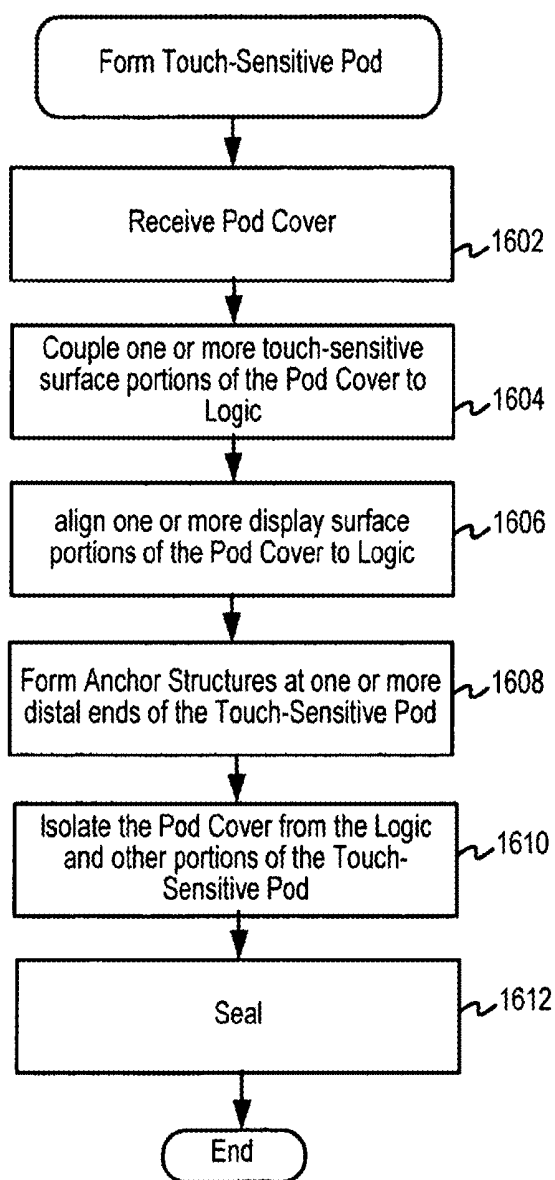
1600  
↓

FIG. 16

1700 ↗

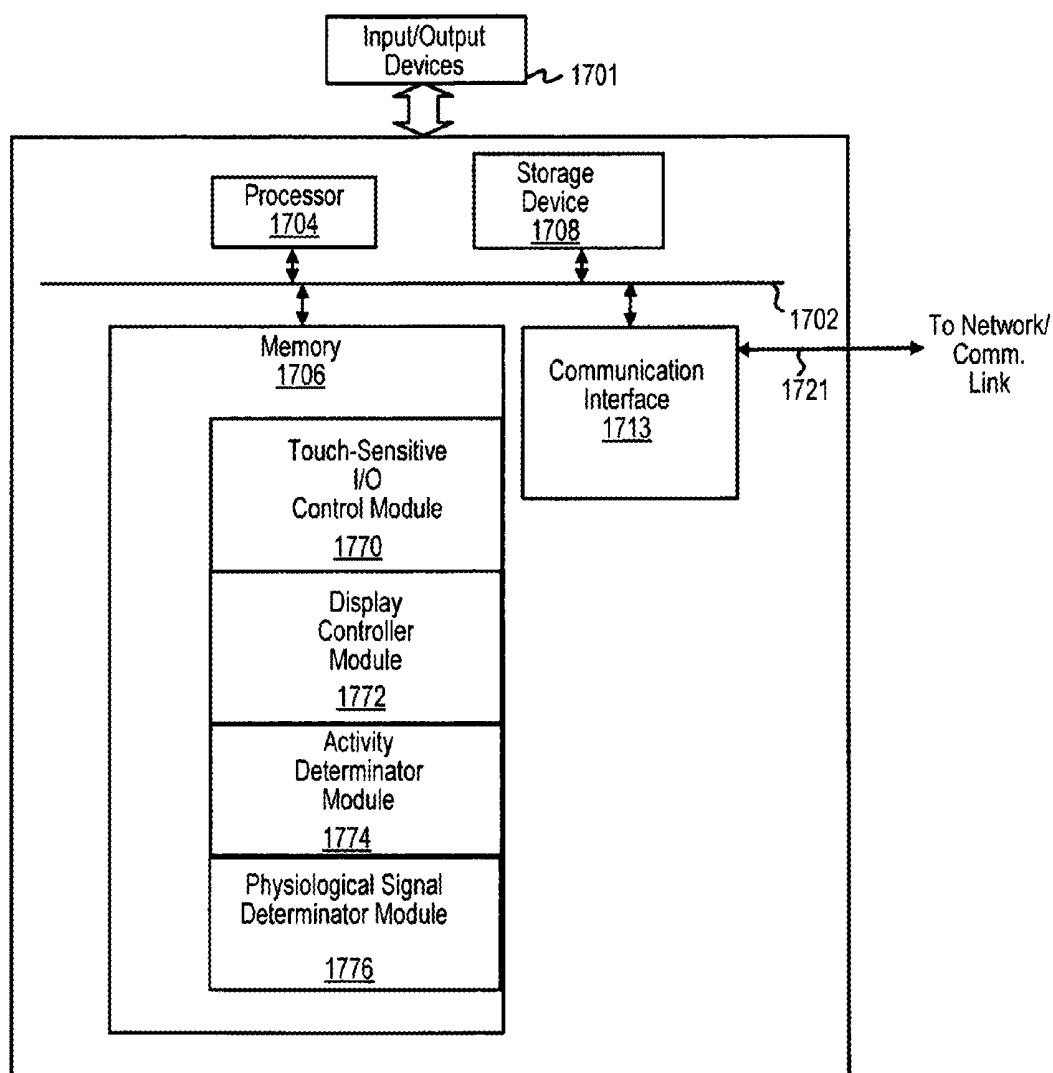


FIG. 17

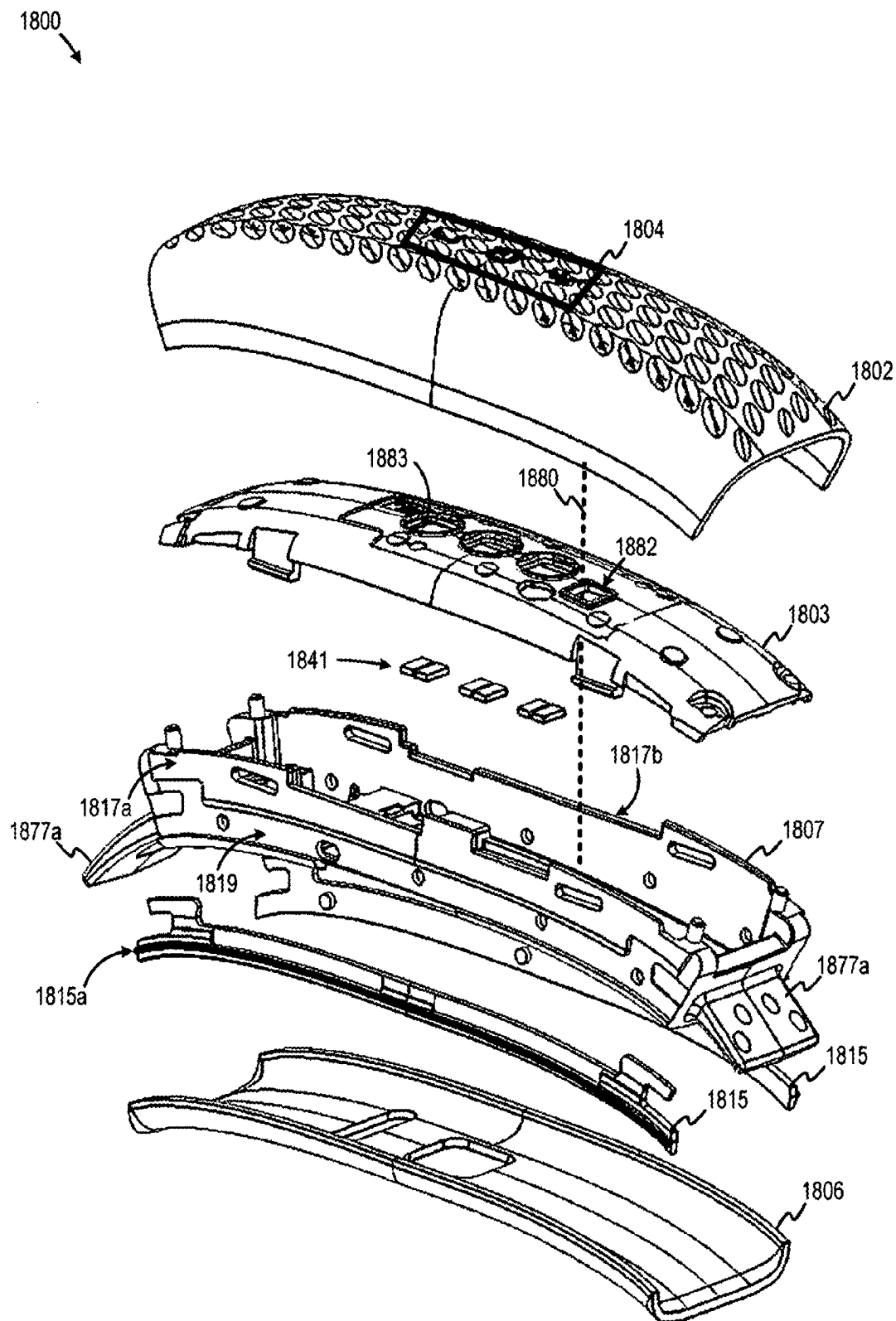


FIG. 18

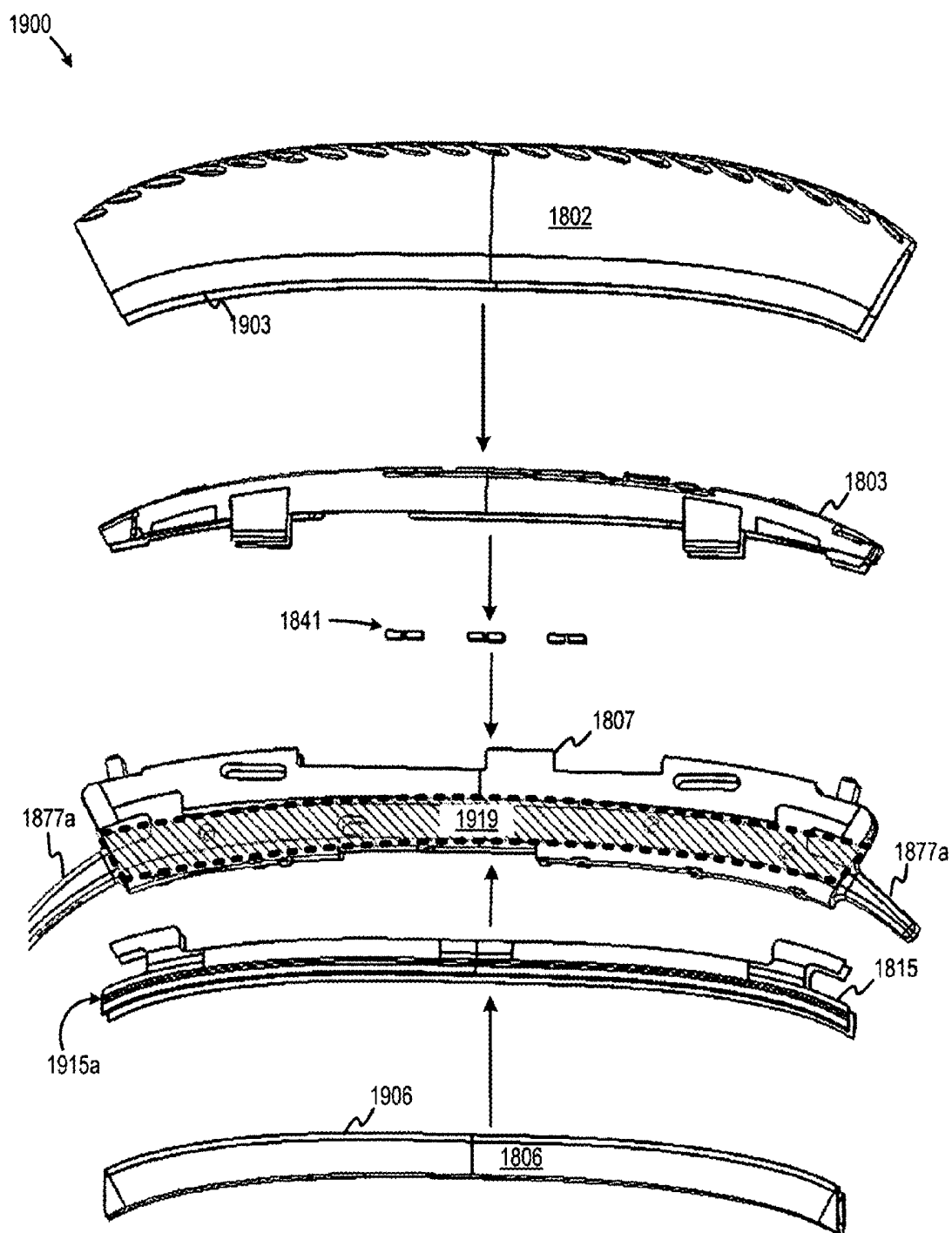


FIG. 19

2000

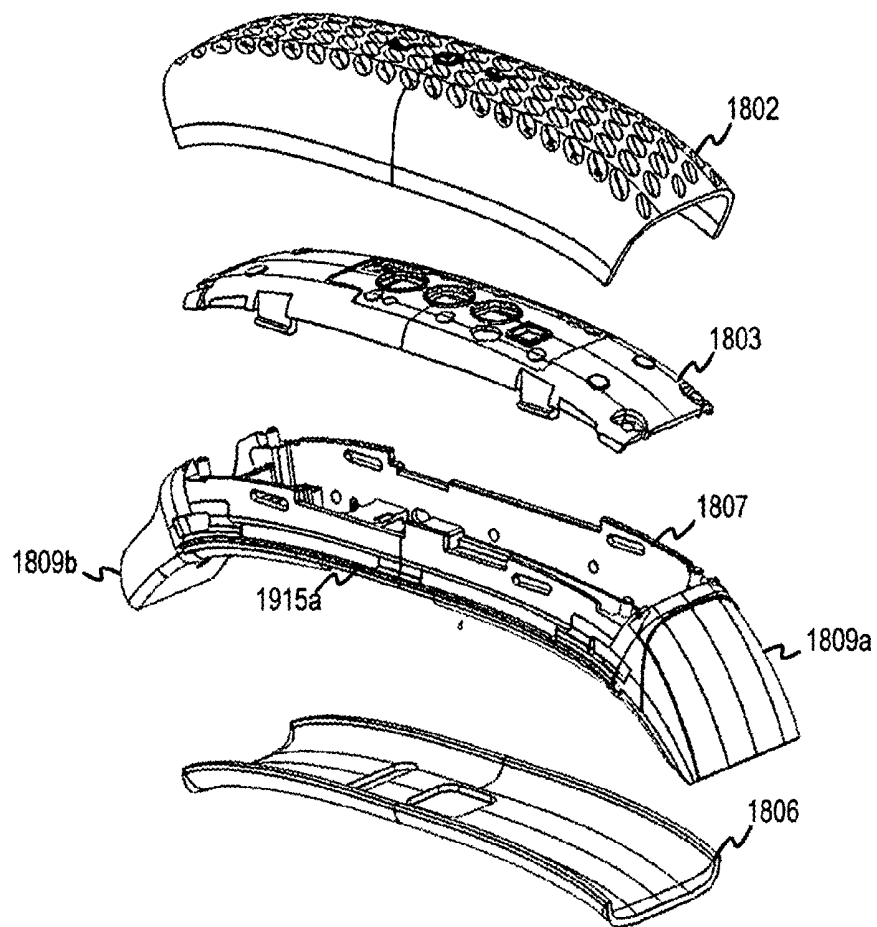


FIG. 20A

2050

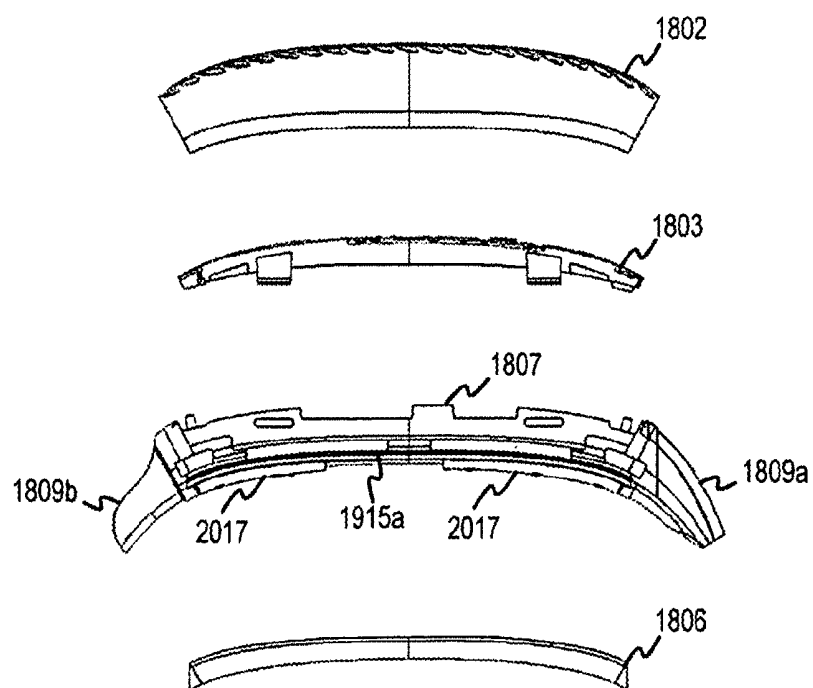


FIG. 20B

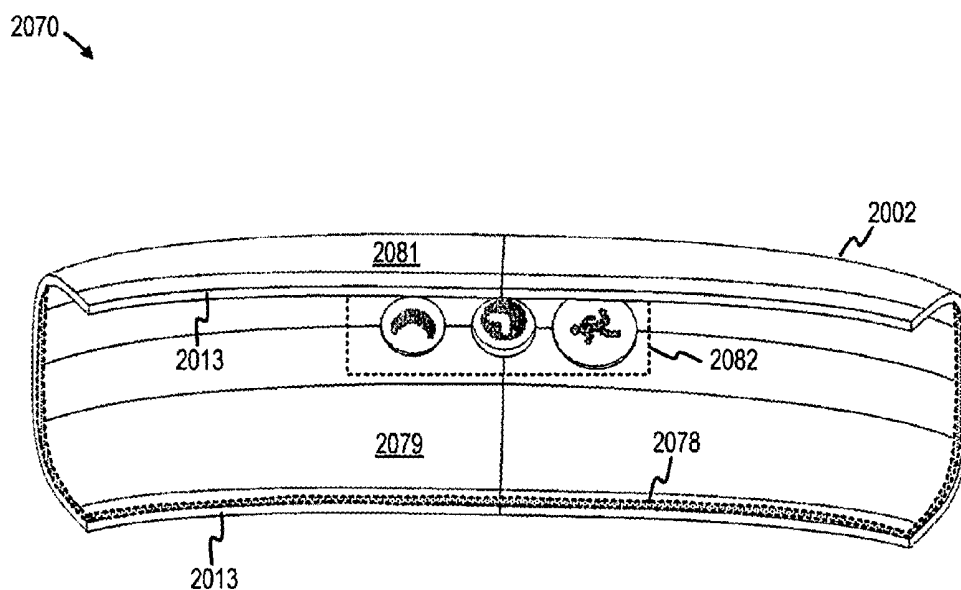


FIG. 20C

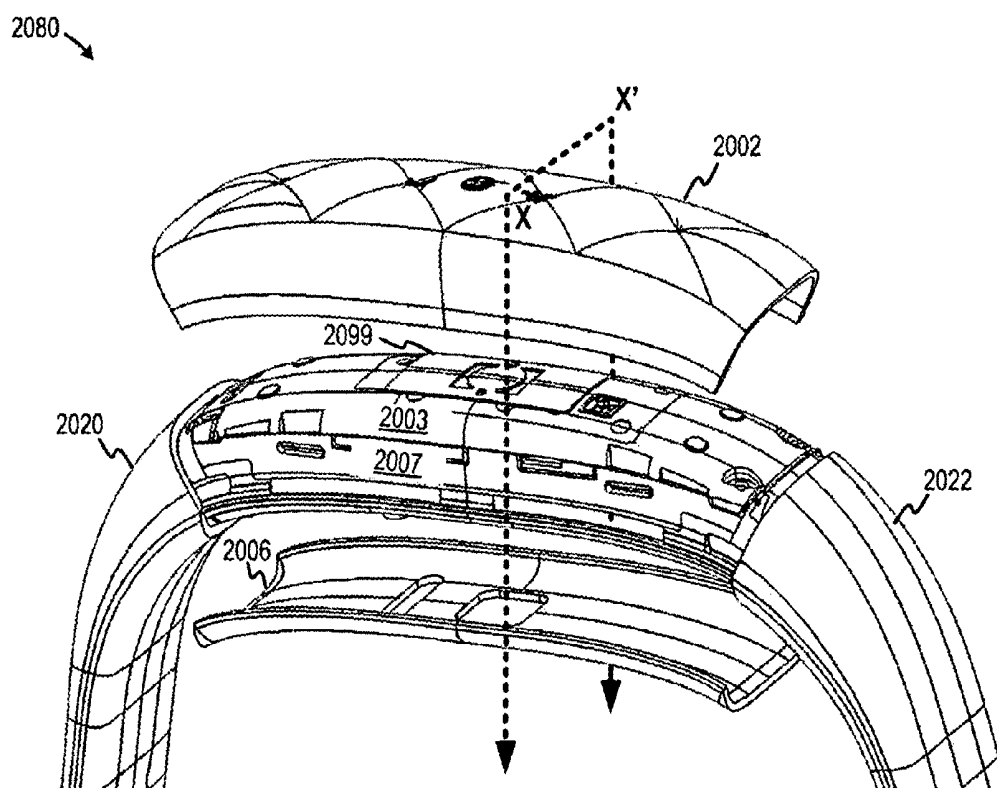


FIG. 20D



2100

X-X' Cross-Section

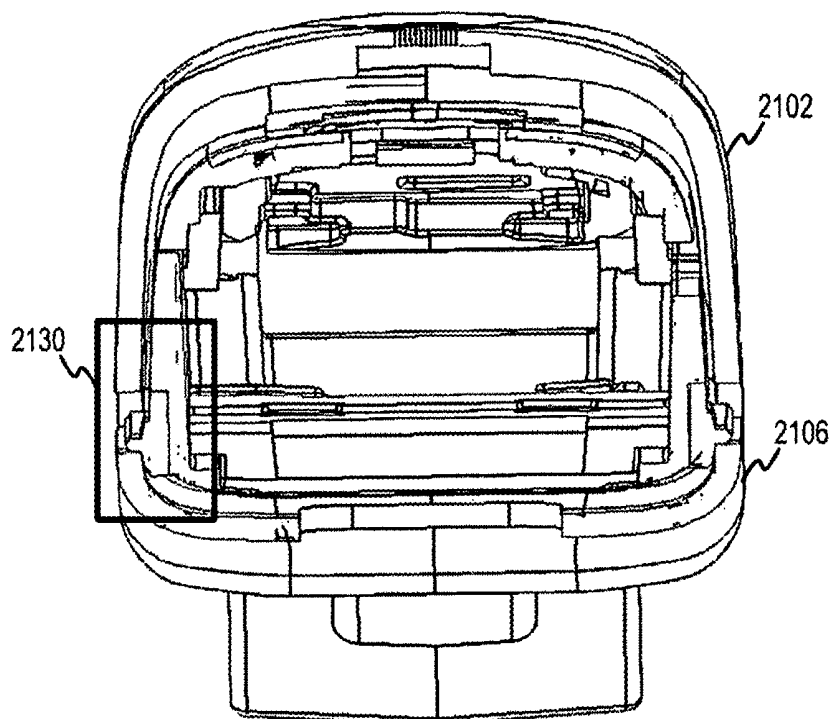


FIG. 21A

2130

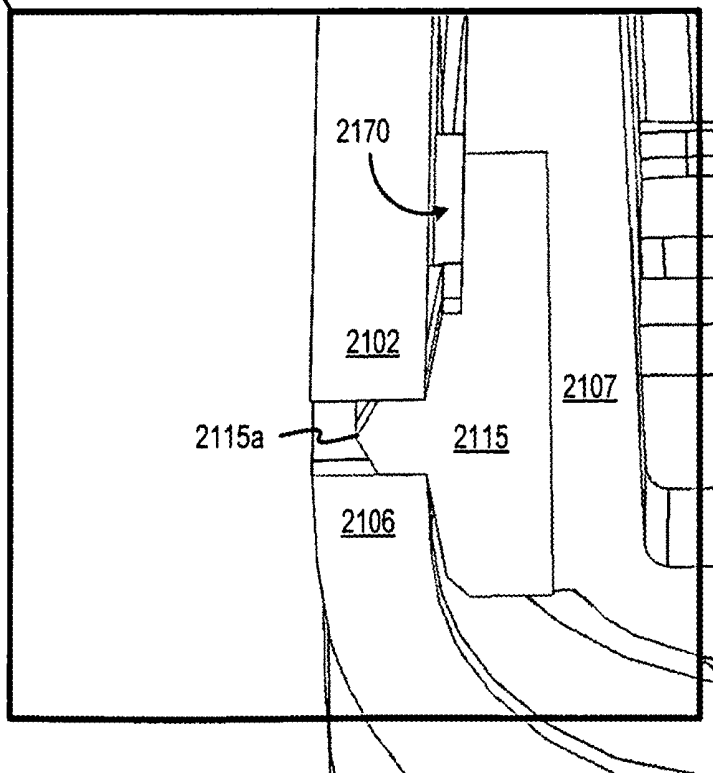


FIG. 21B

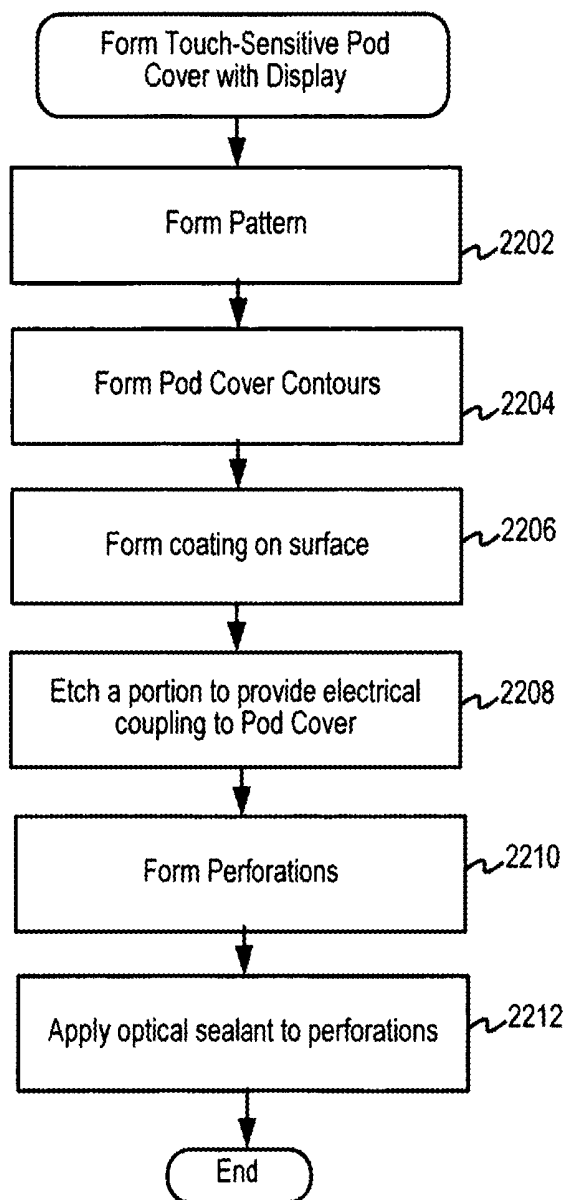
2200  
↓

FIG. 22

2300

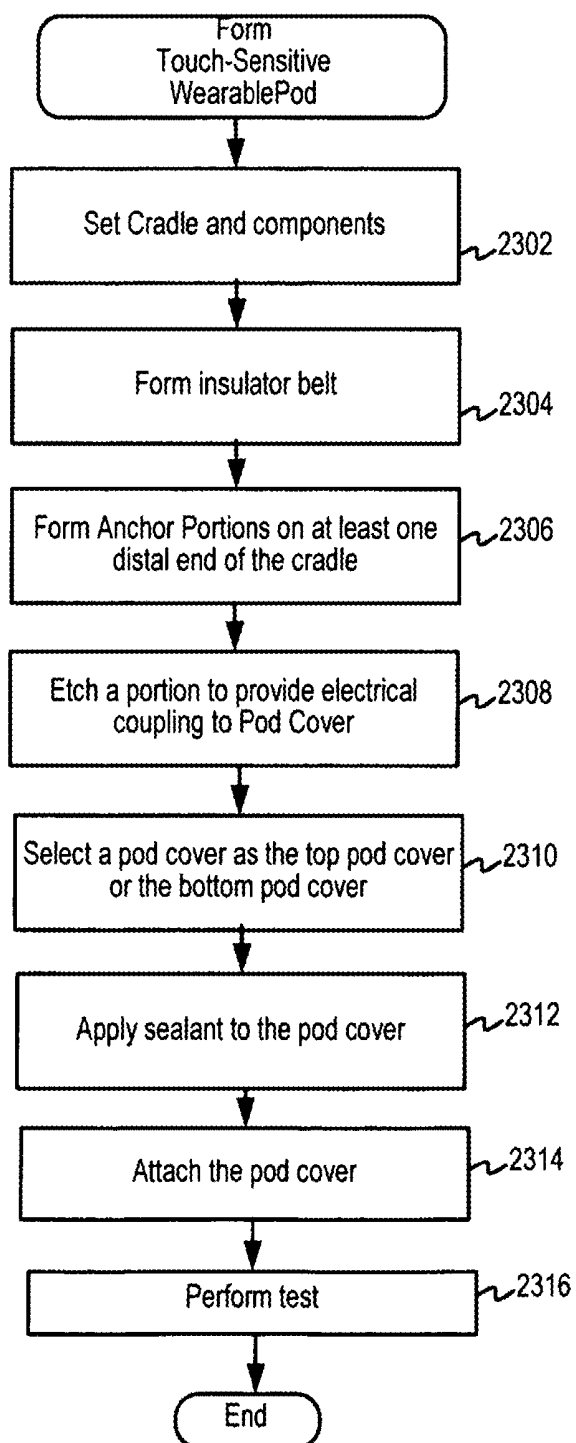


FIG. 23

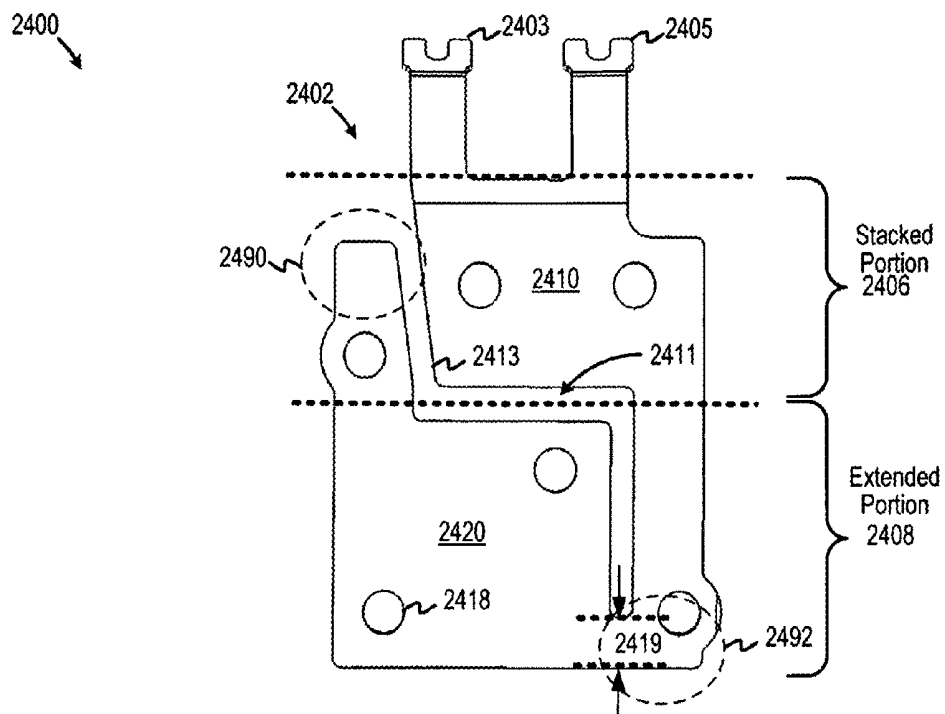


FIG. 24

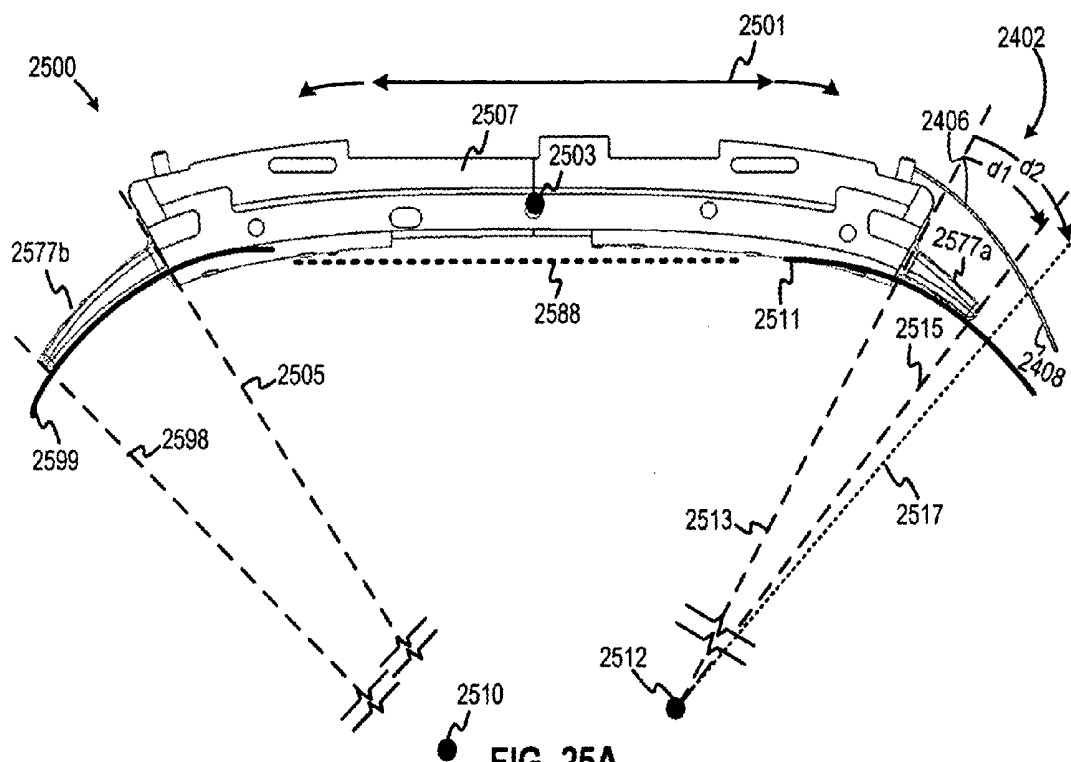
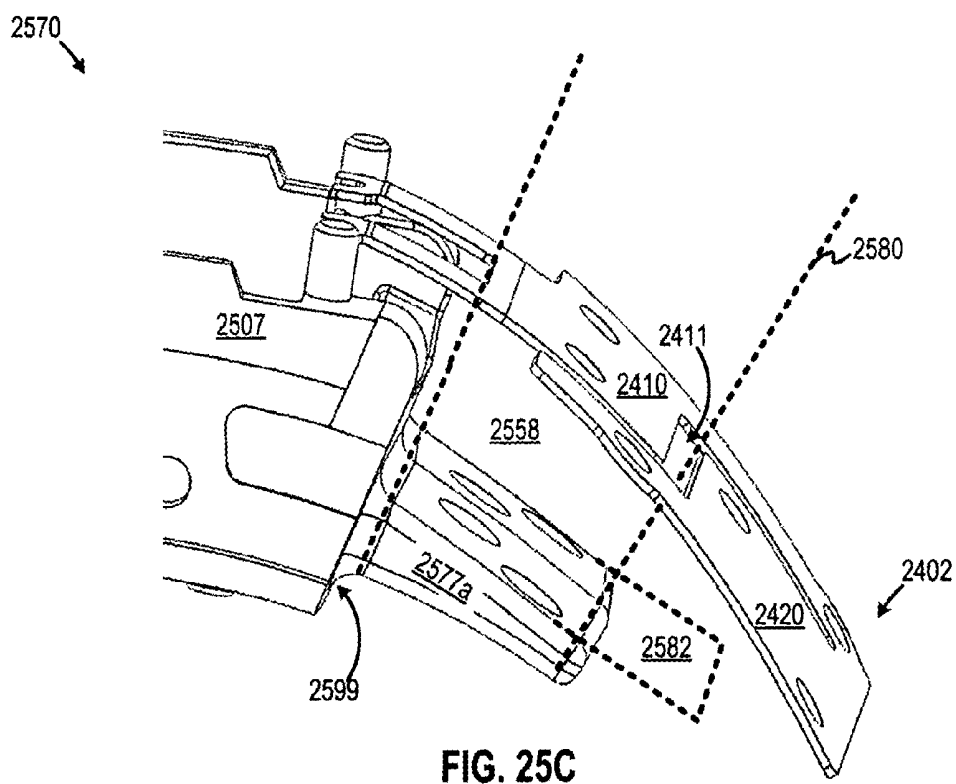
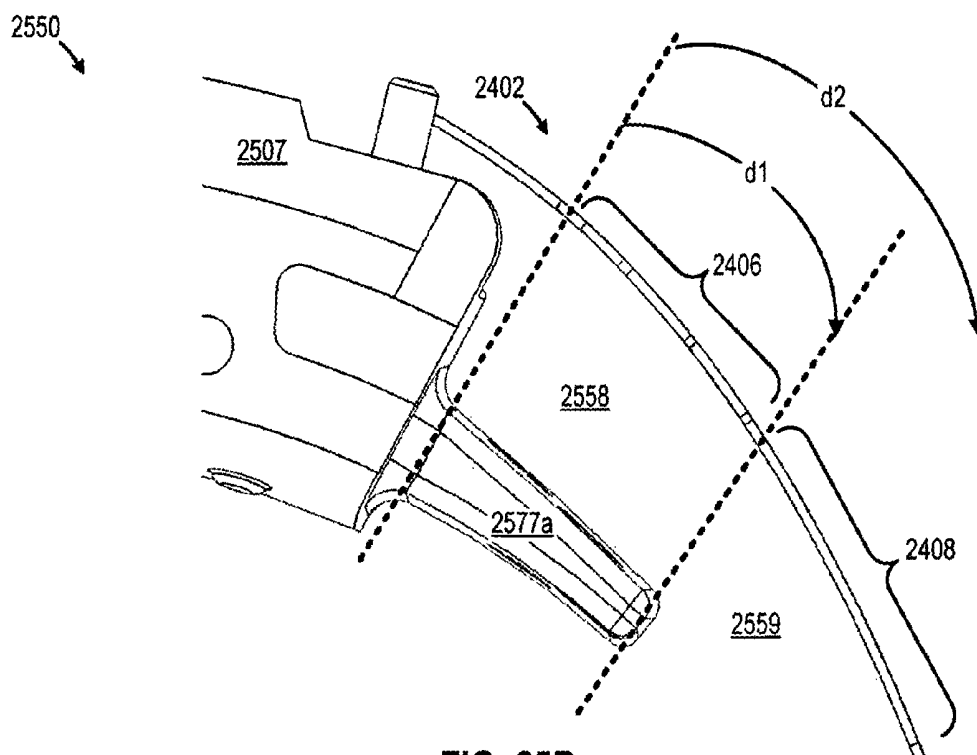
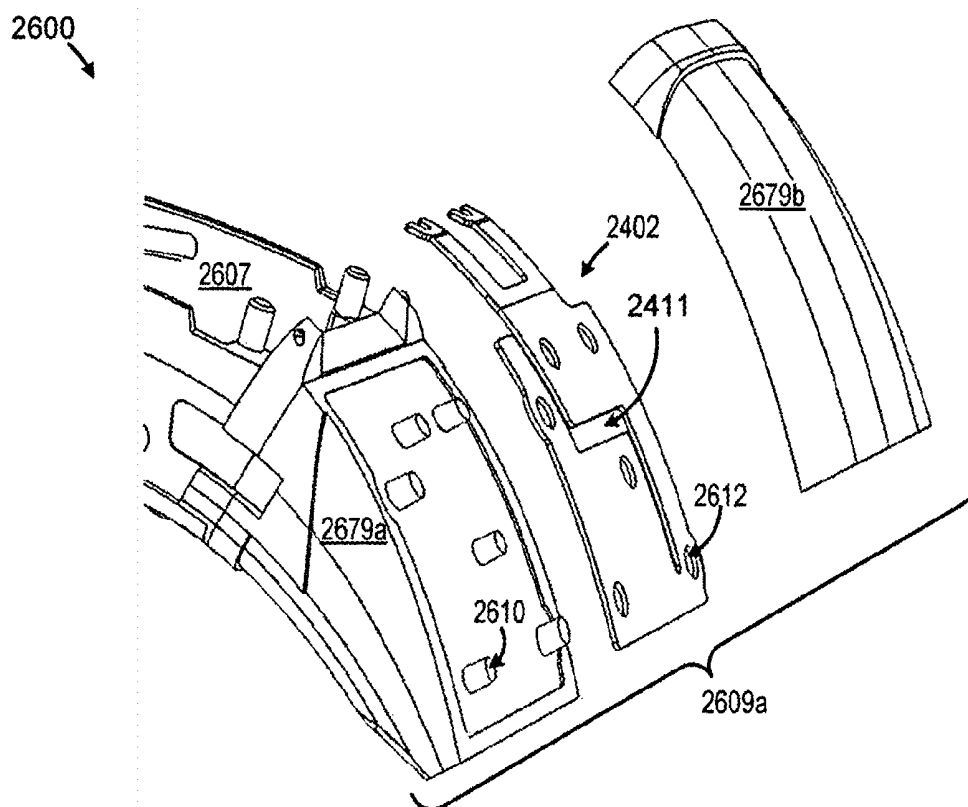
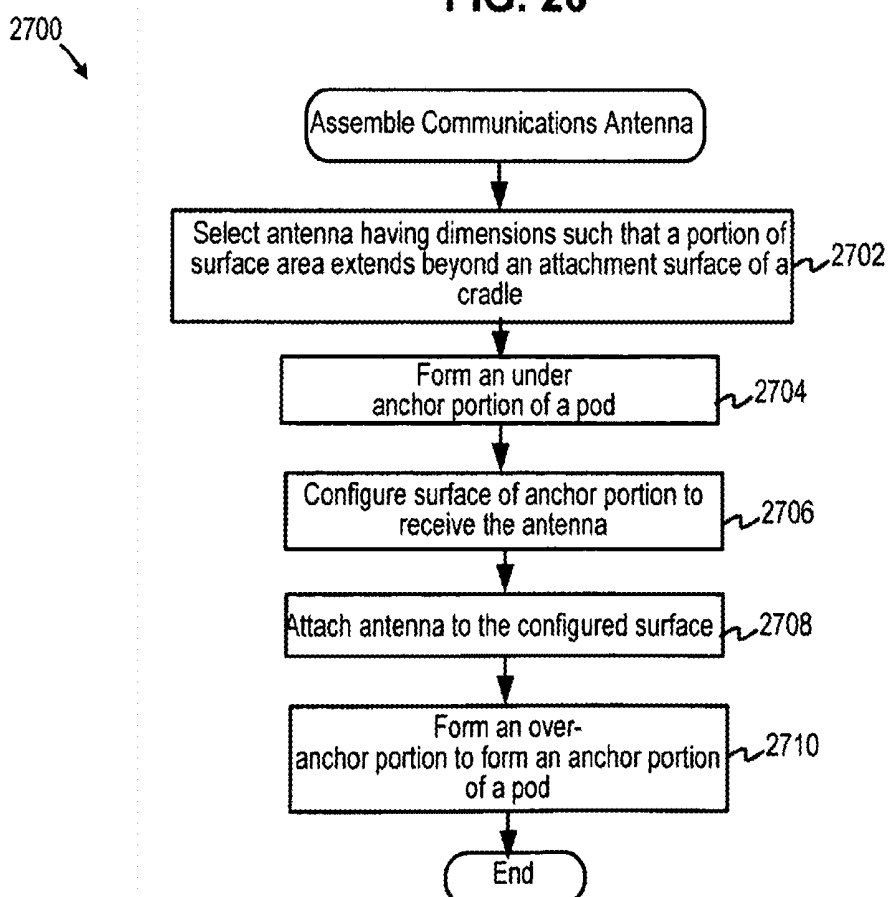


FIG. 25A





**FIG. 26**



**FIG. 27**

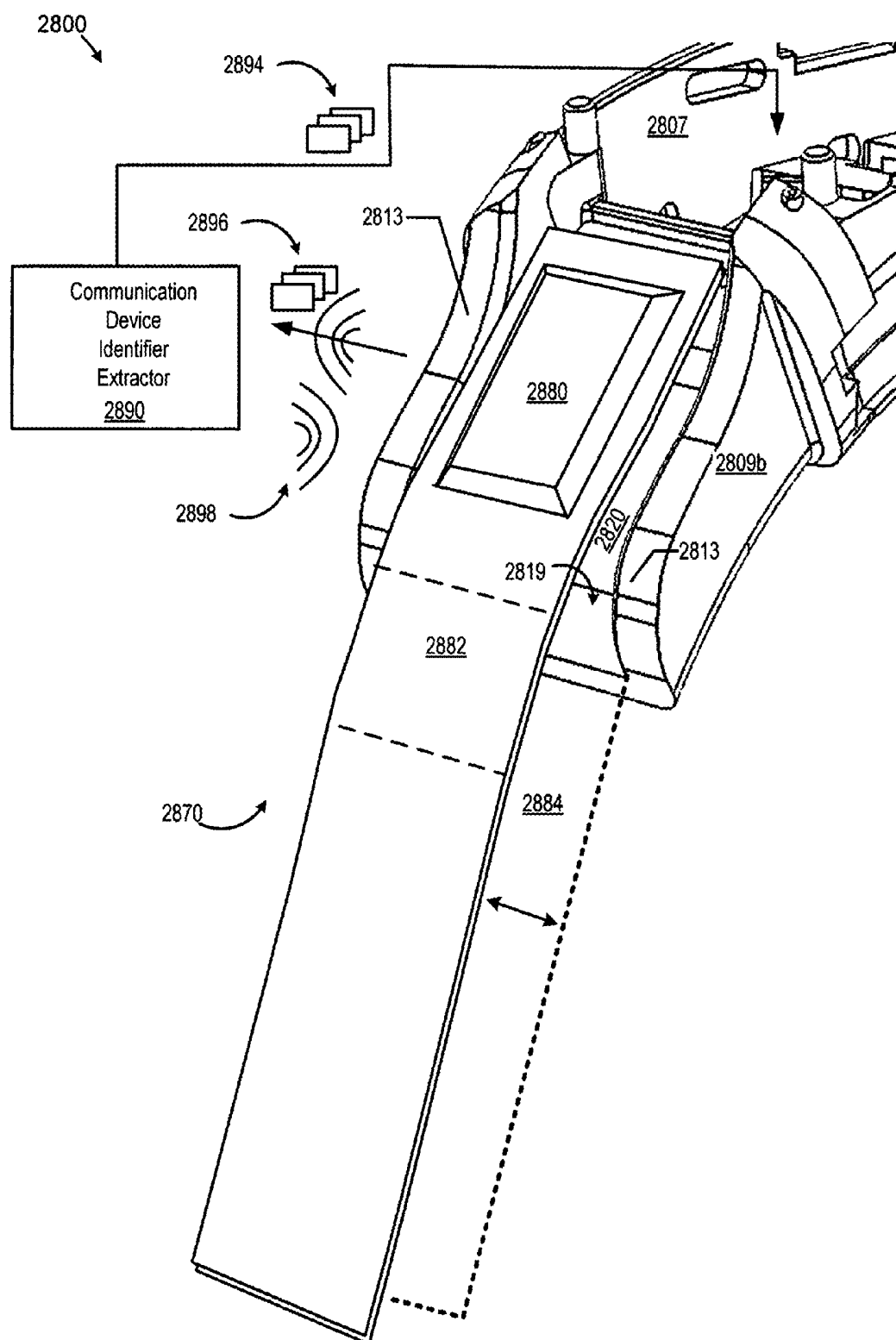
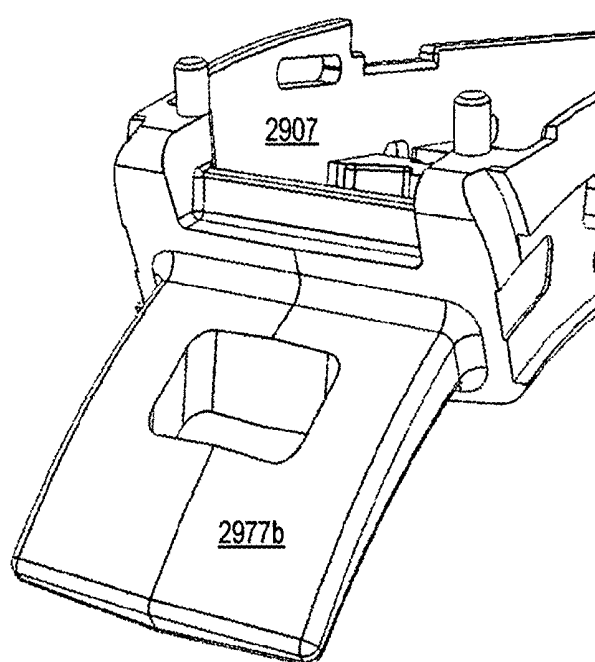


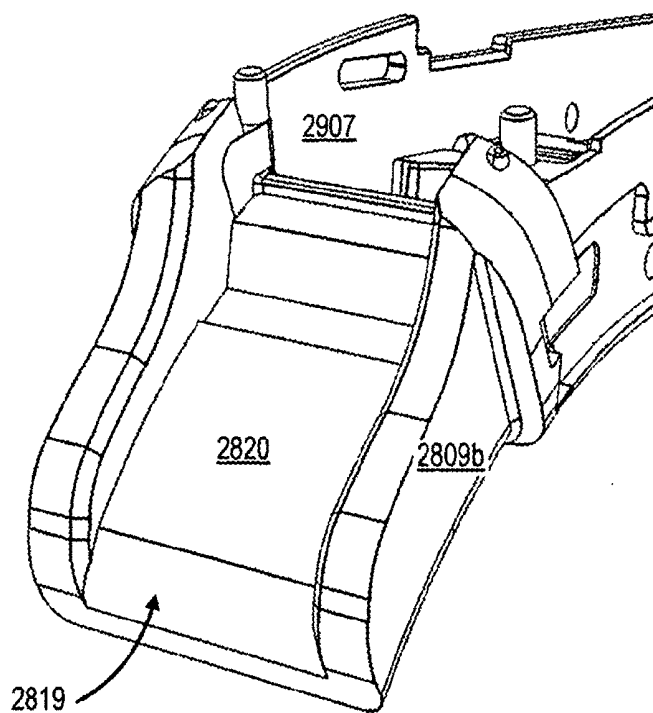
FIG. 28

2900



2950

**FIG. 29A**



**FIG. 29B**



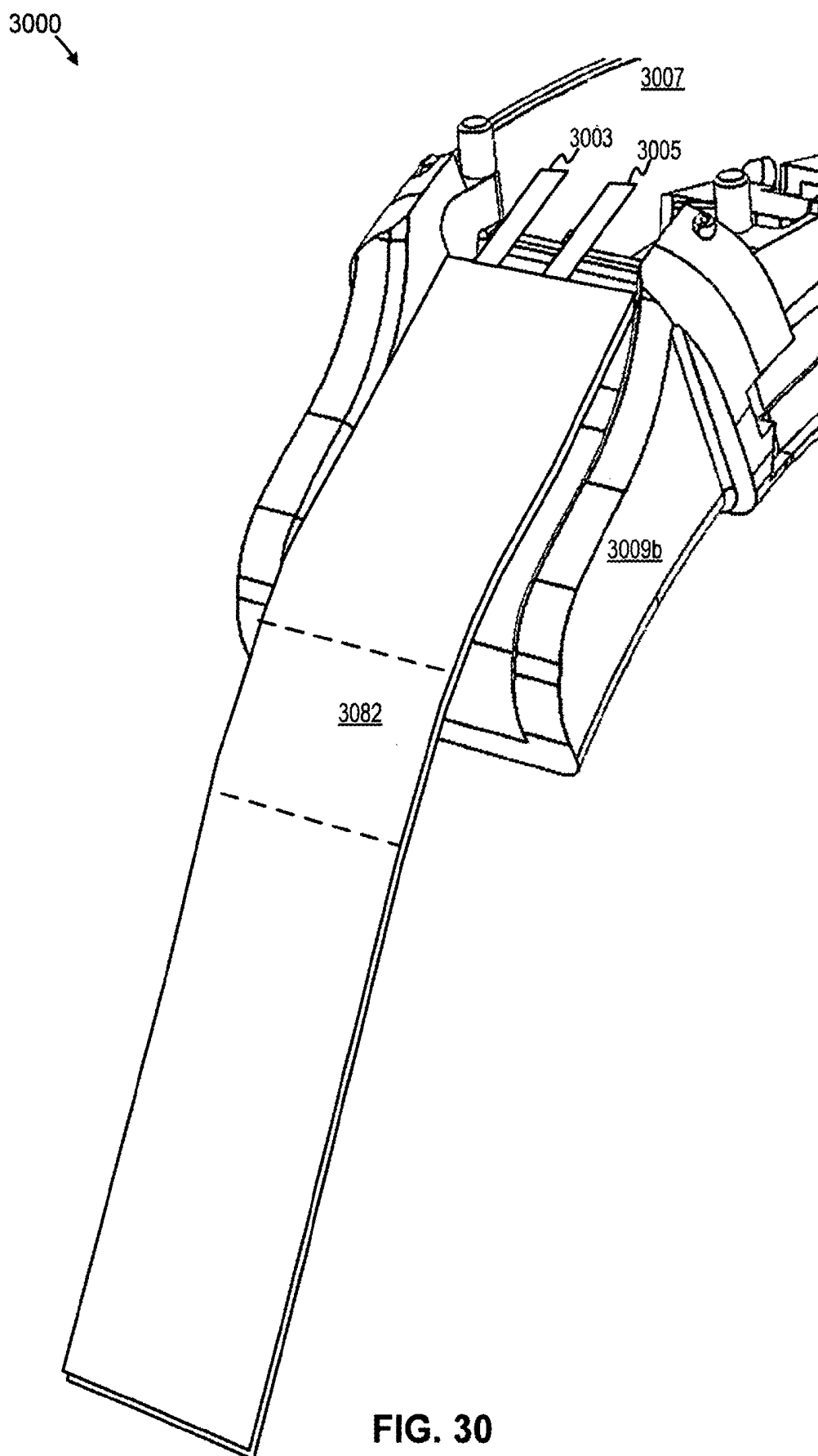


FIG. 30

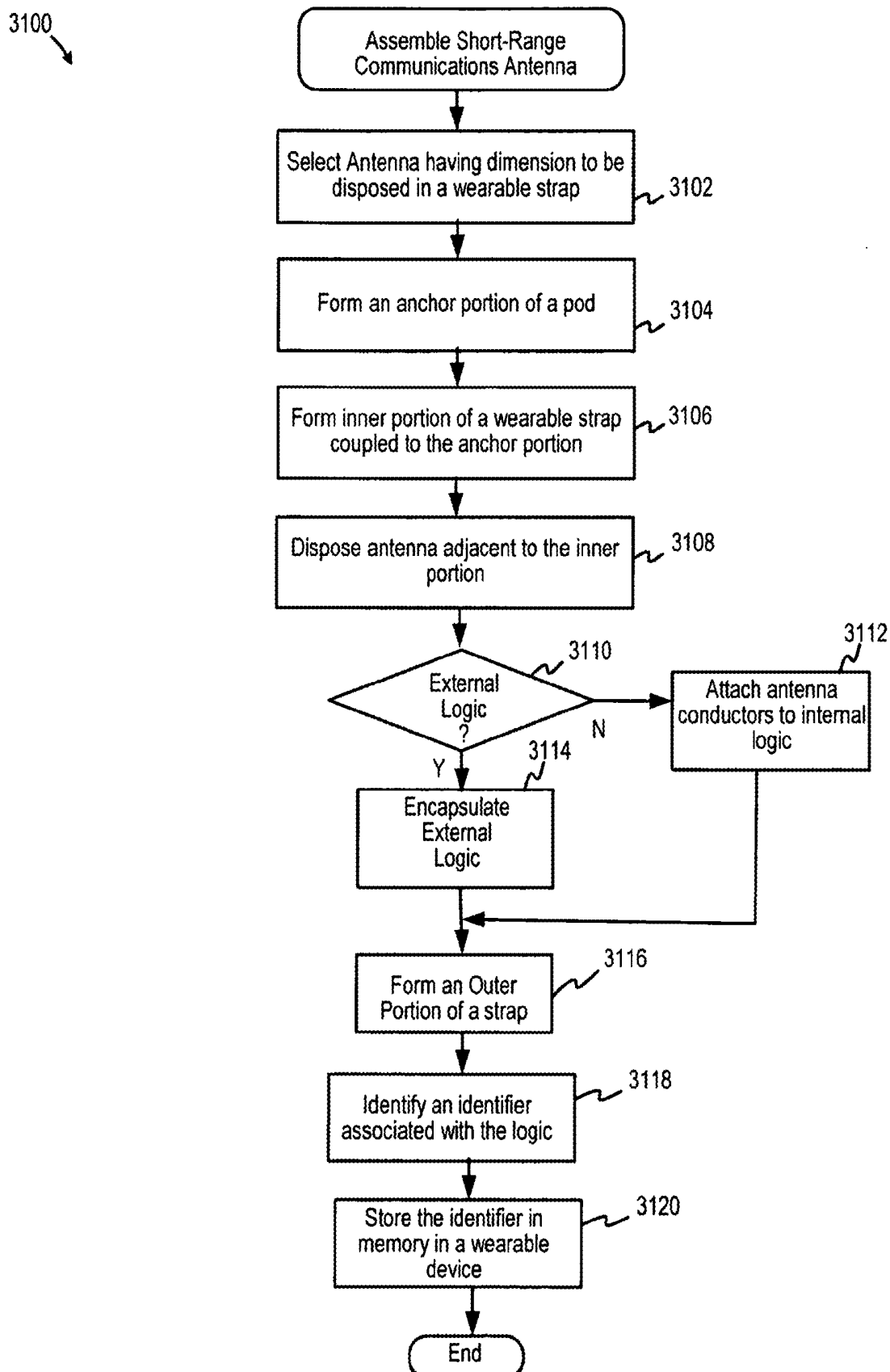


FIG. 31

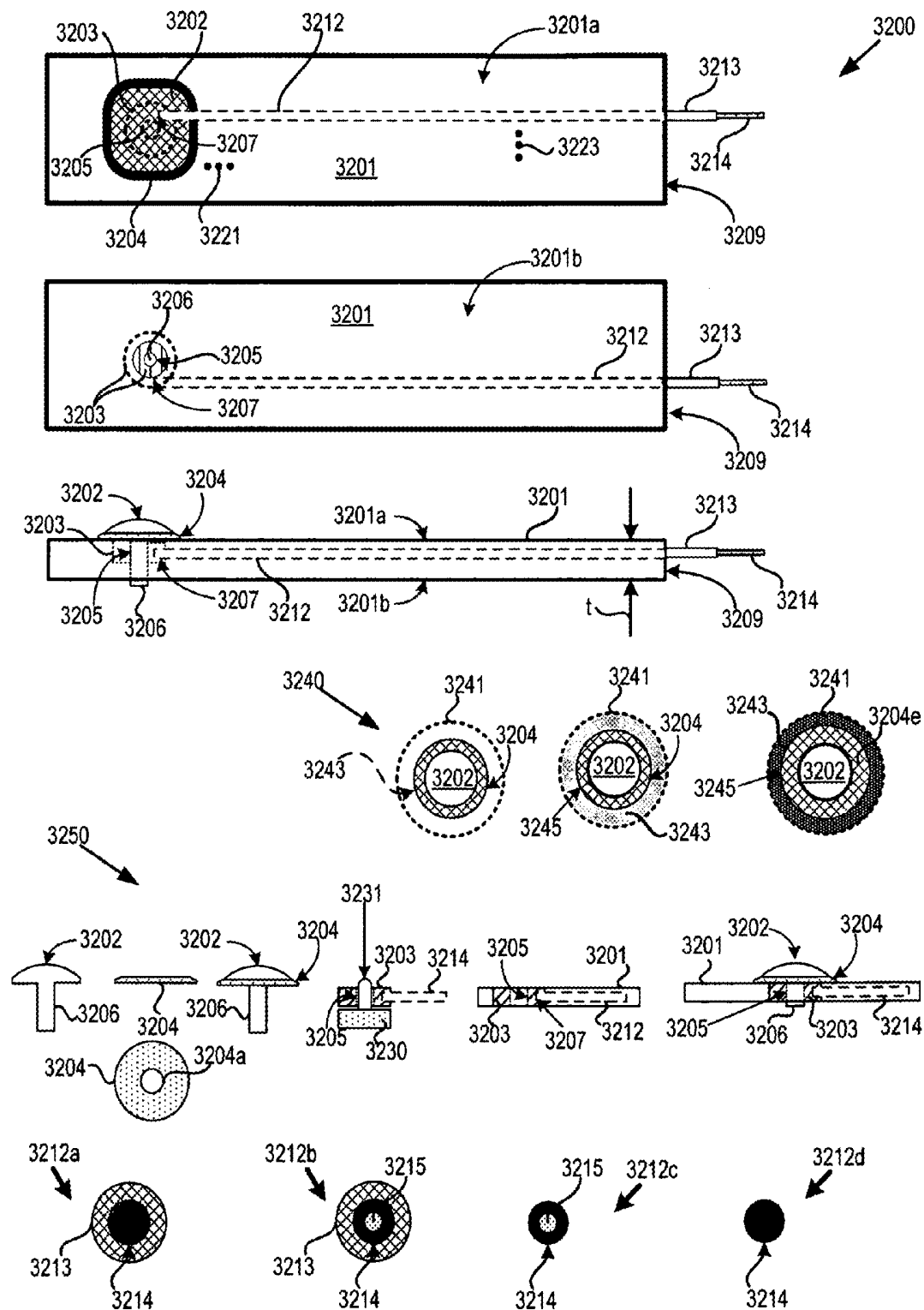
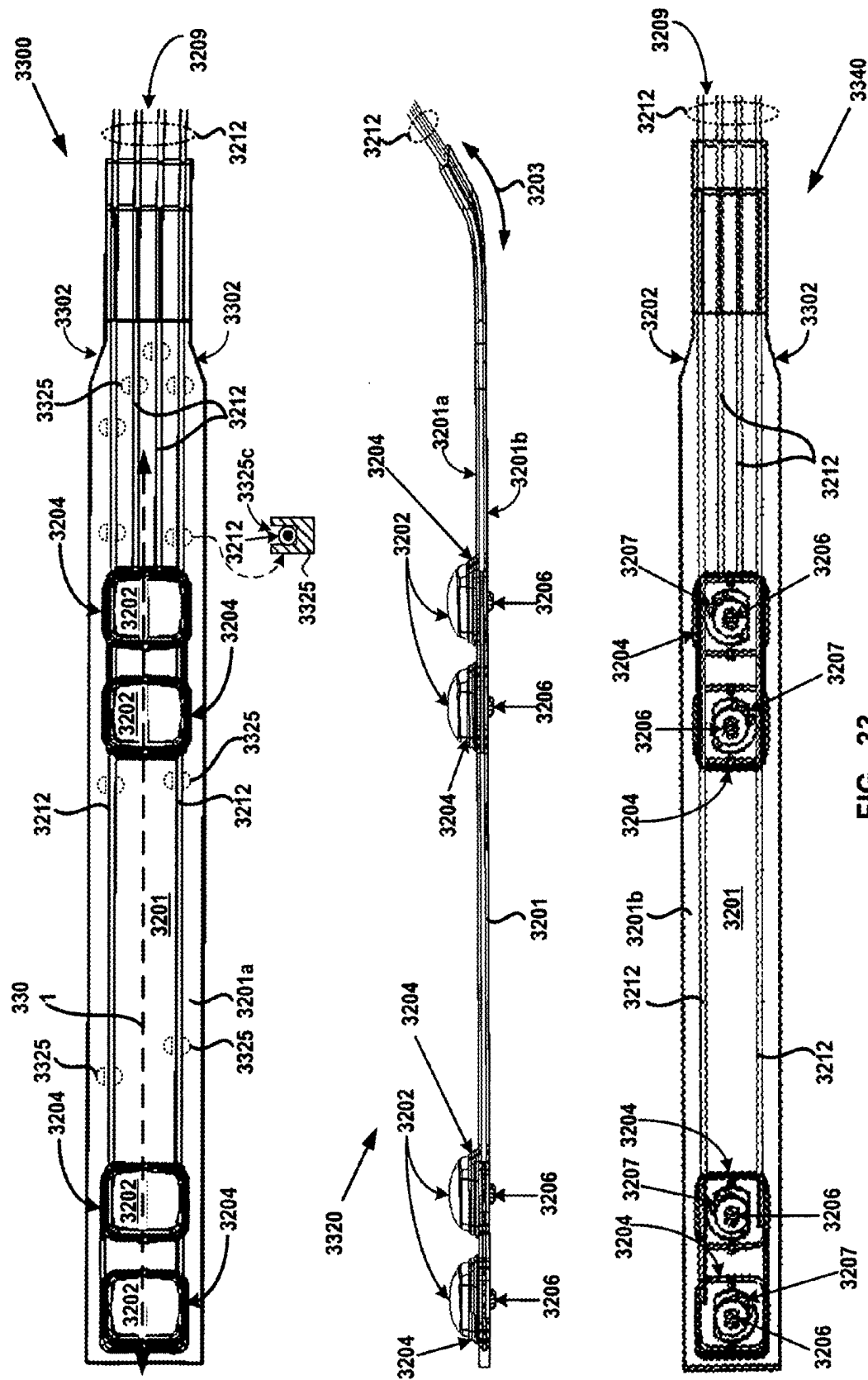
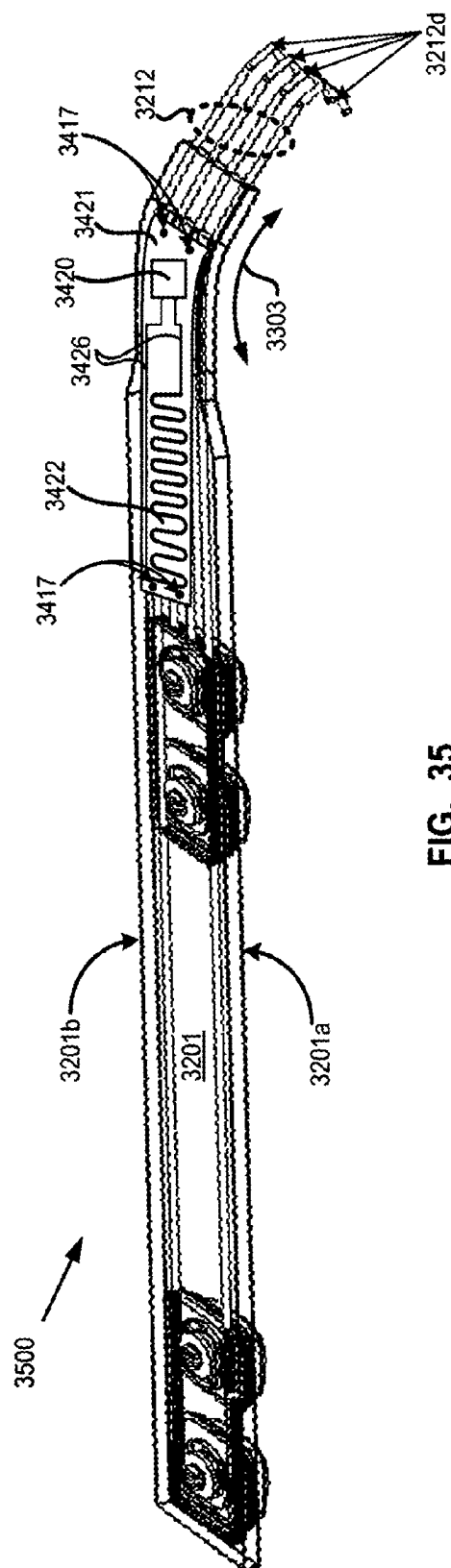
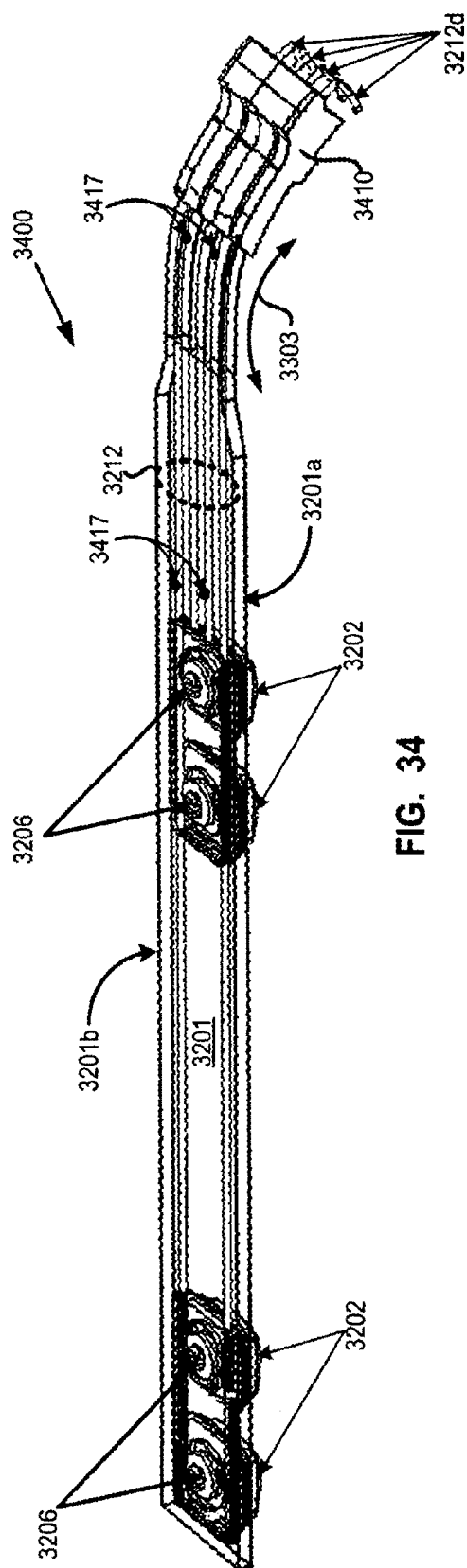


FIG. 32





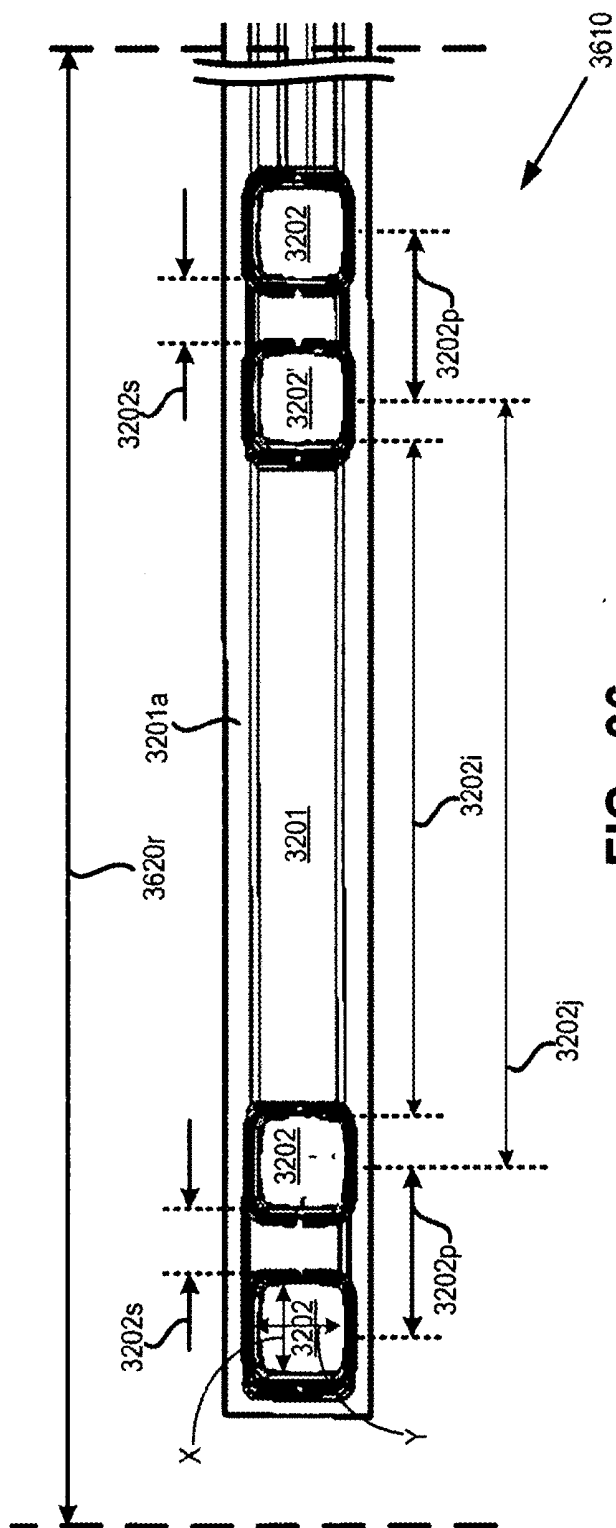
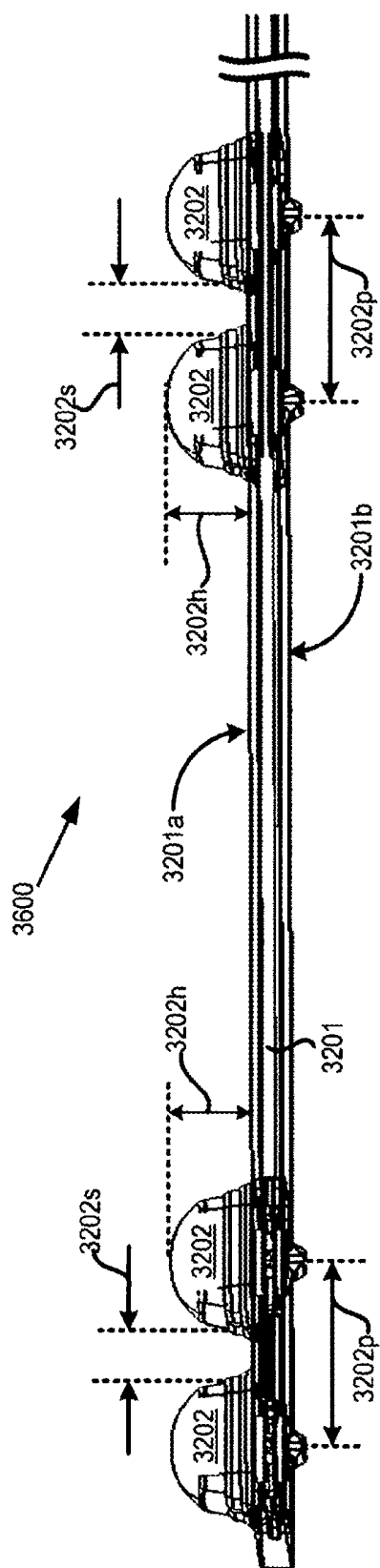


FIG. 36

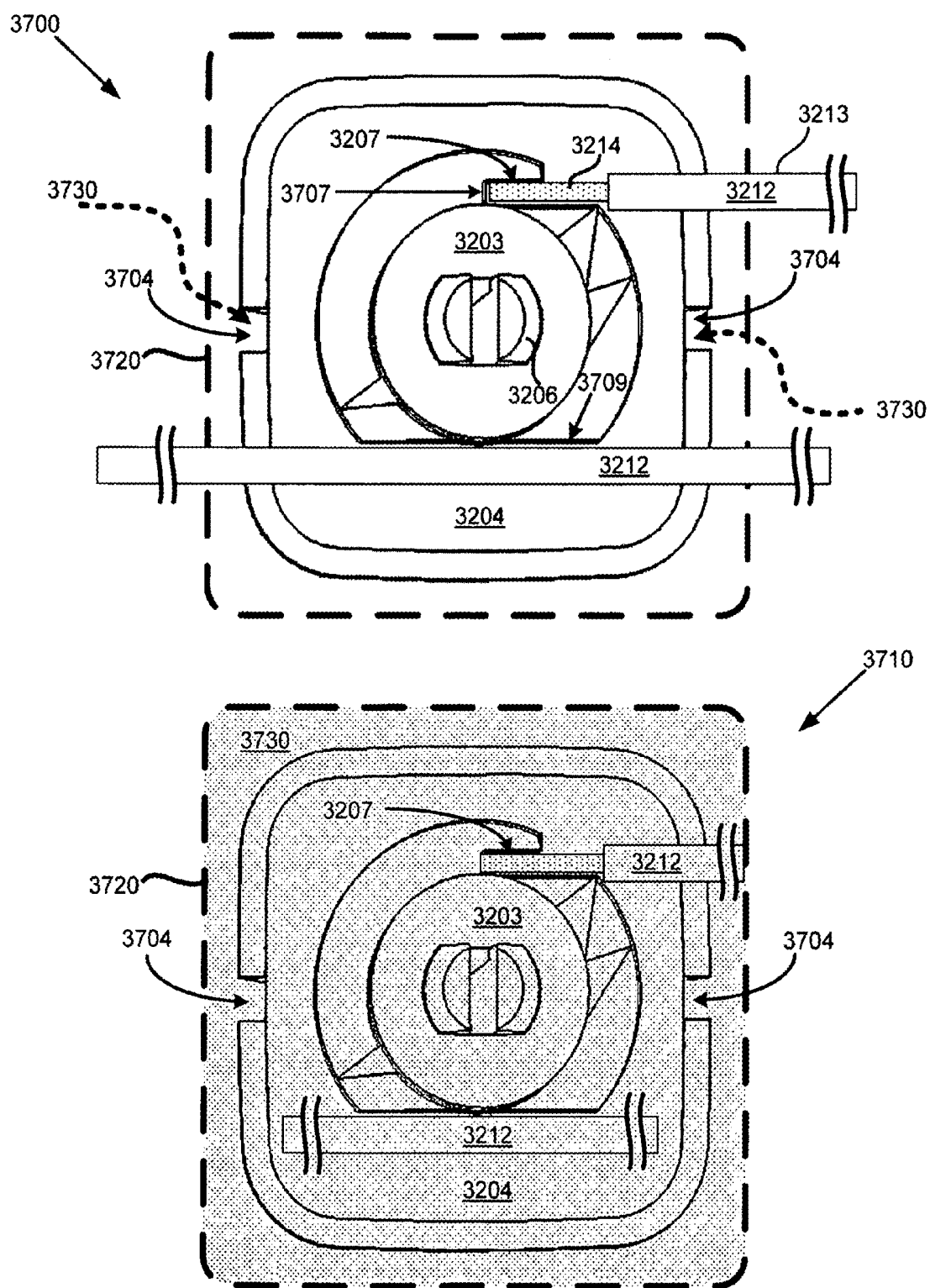
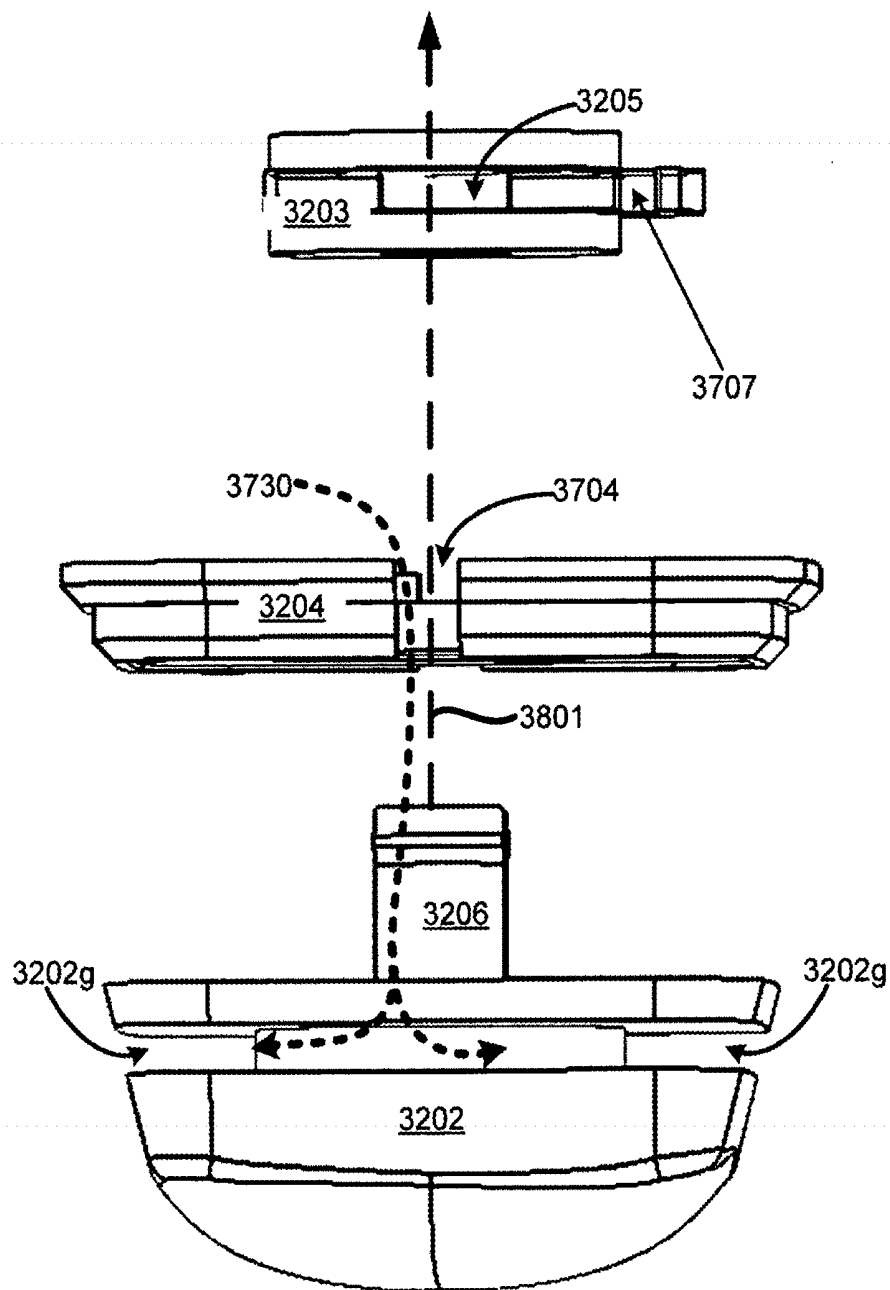


FIG. 37

3800



**FIG. 38**



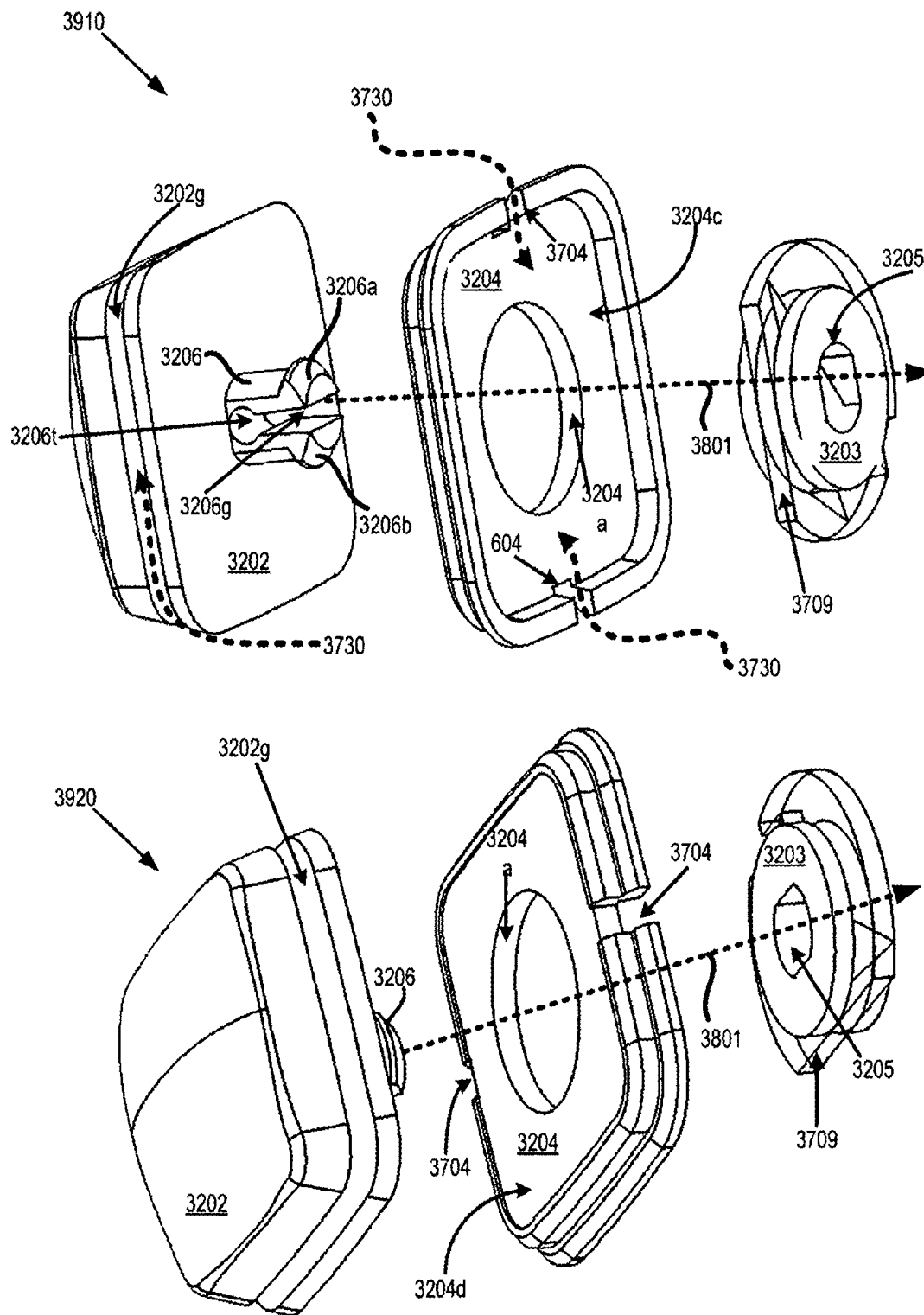


FIG. 39

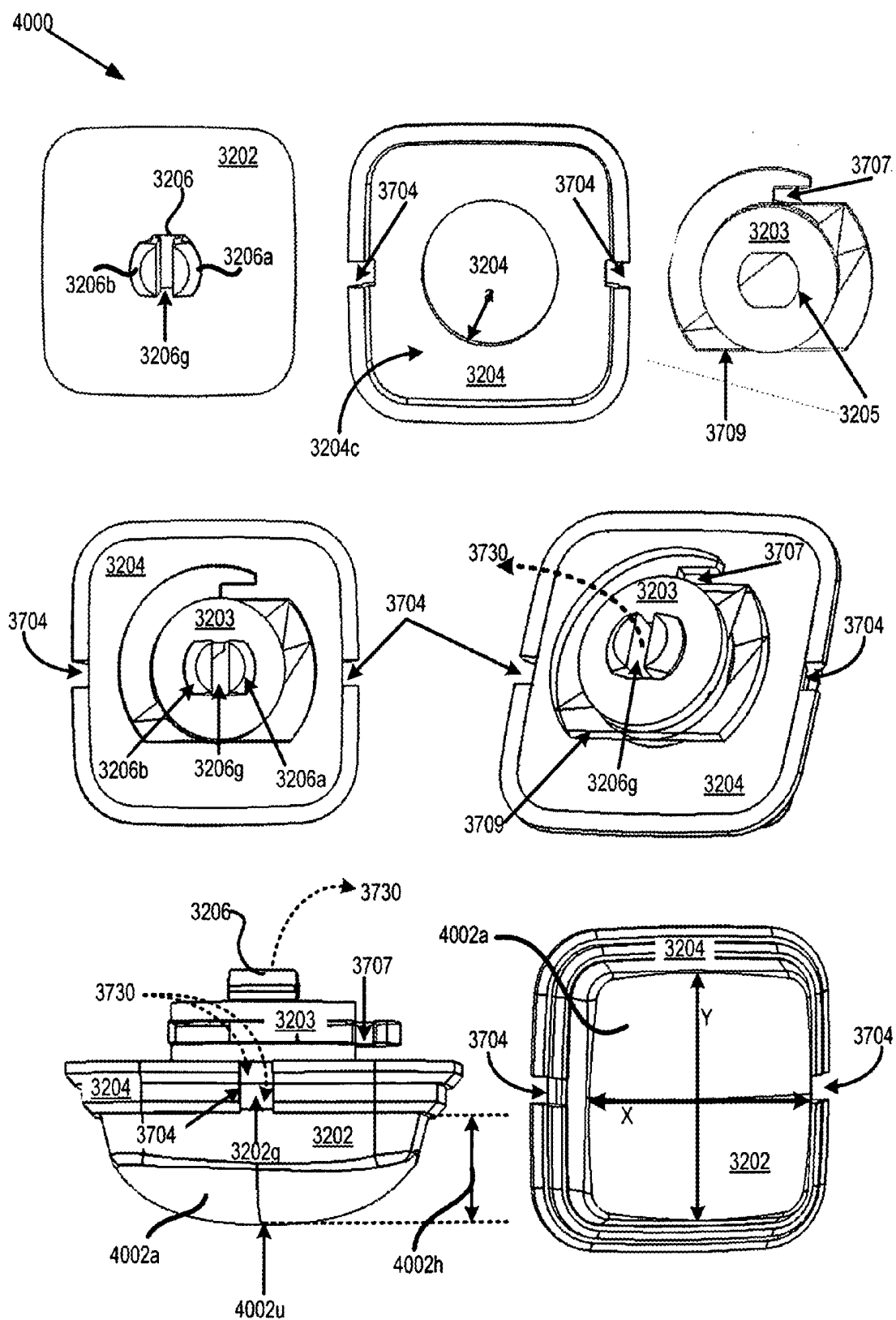
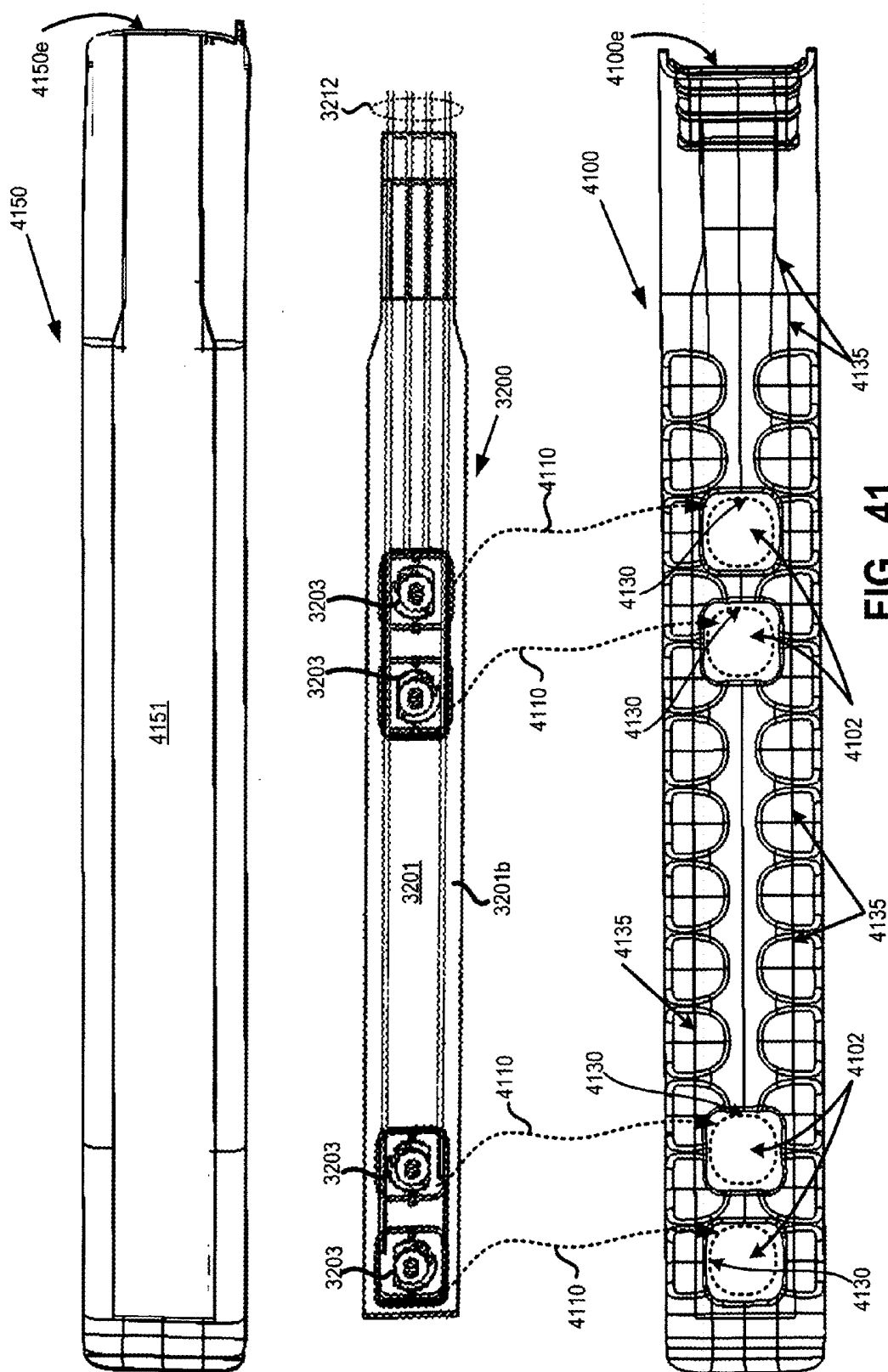
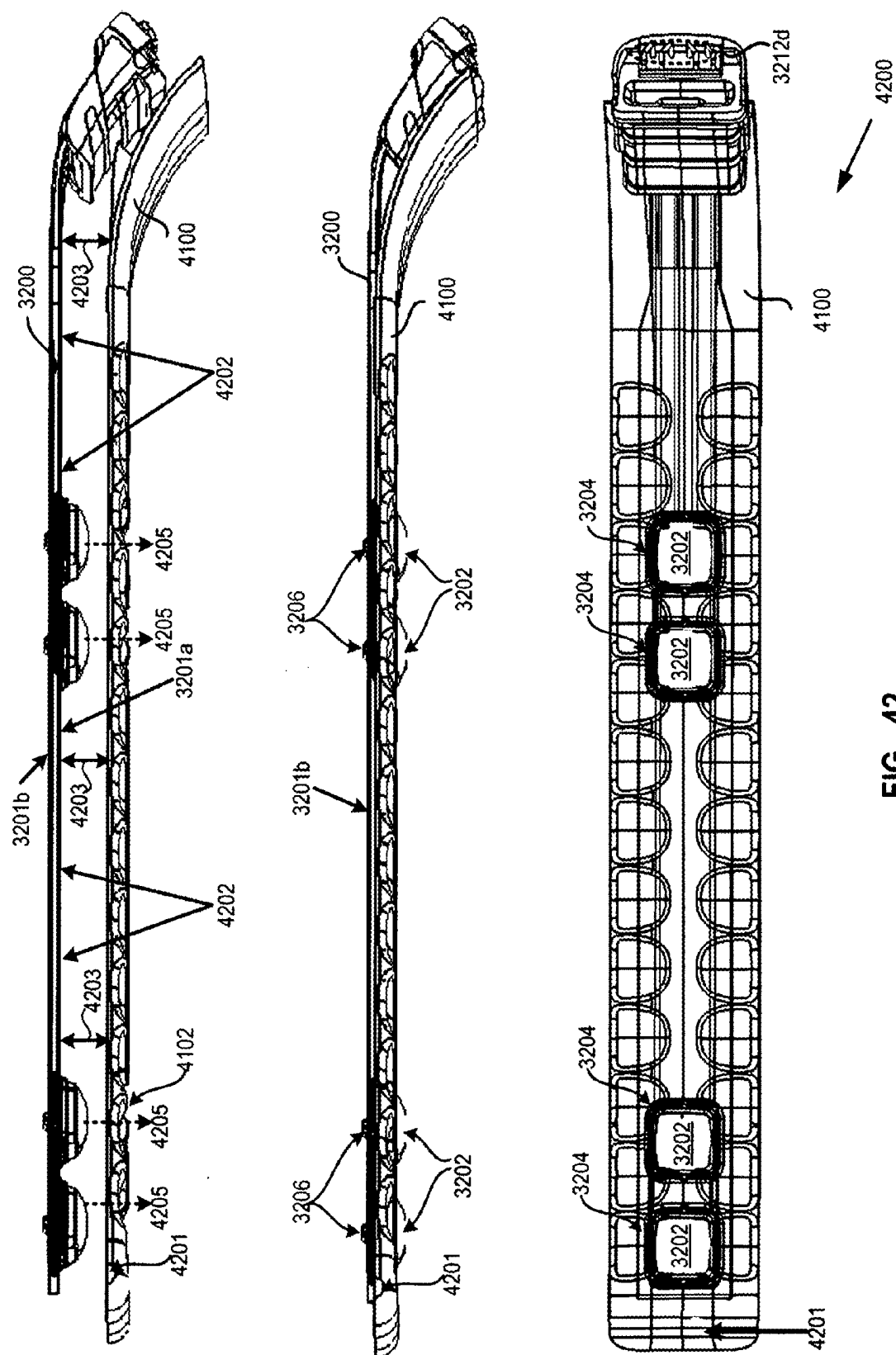
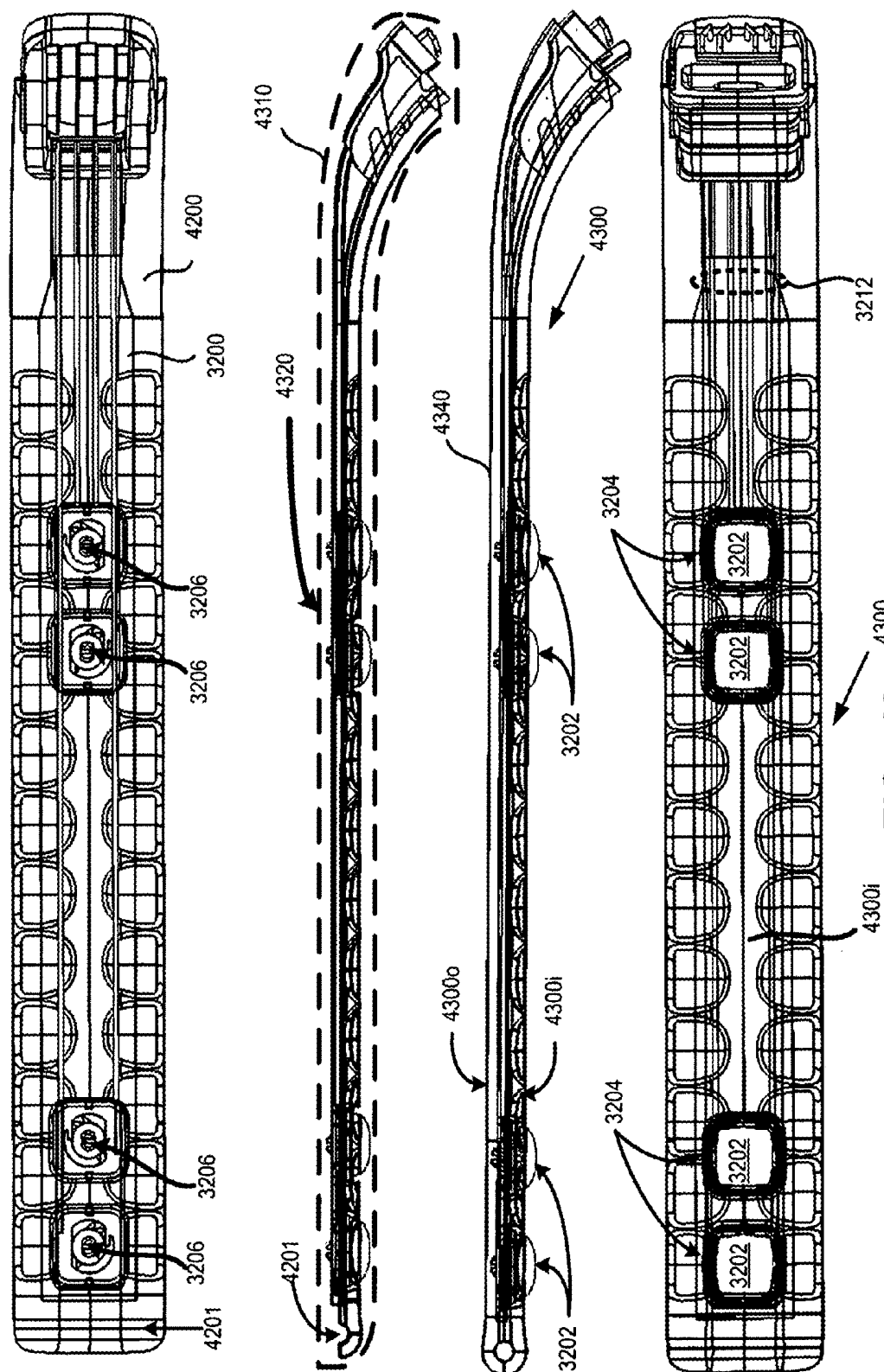


FIG. 40







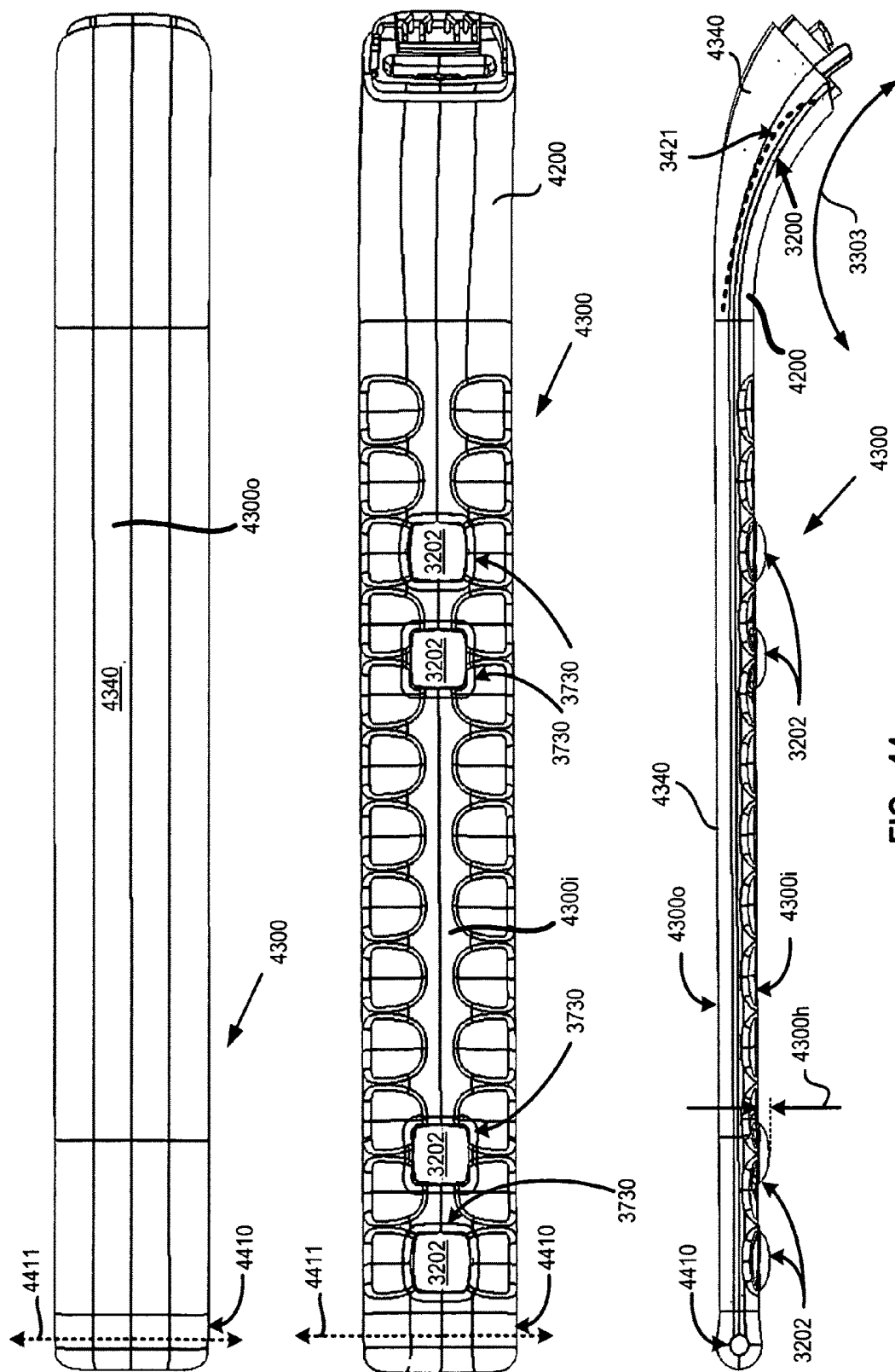


FIG. 44

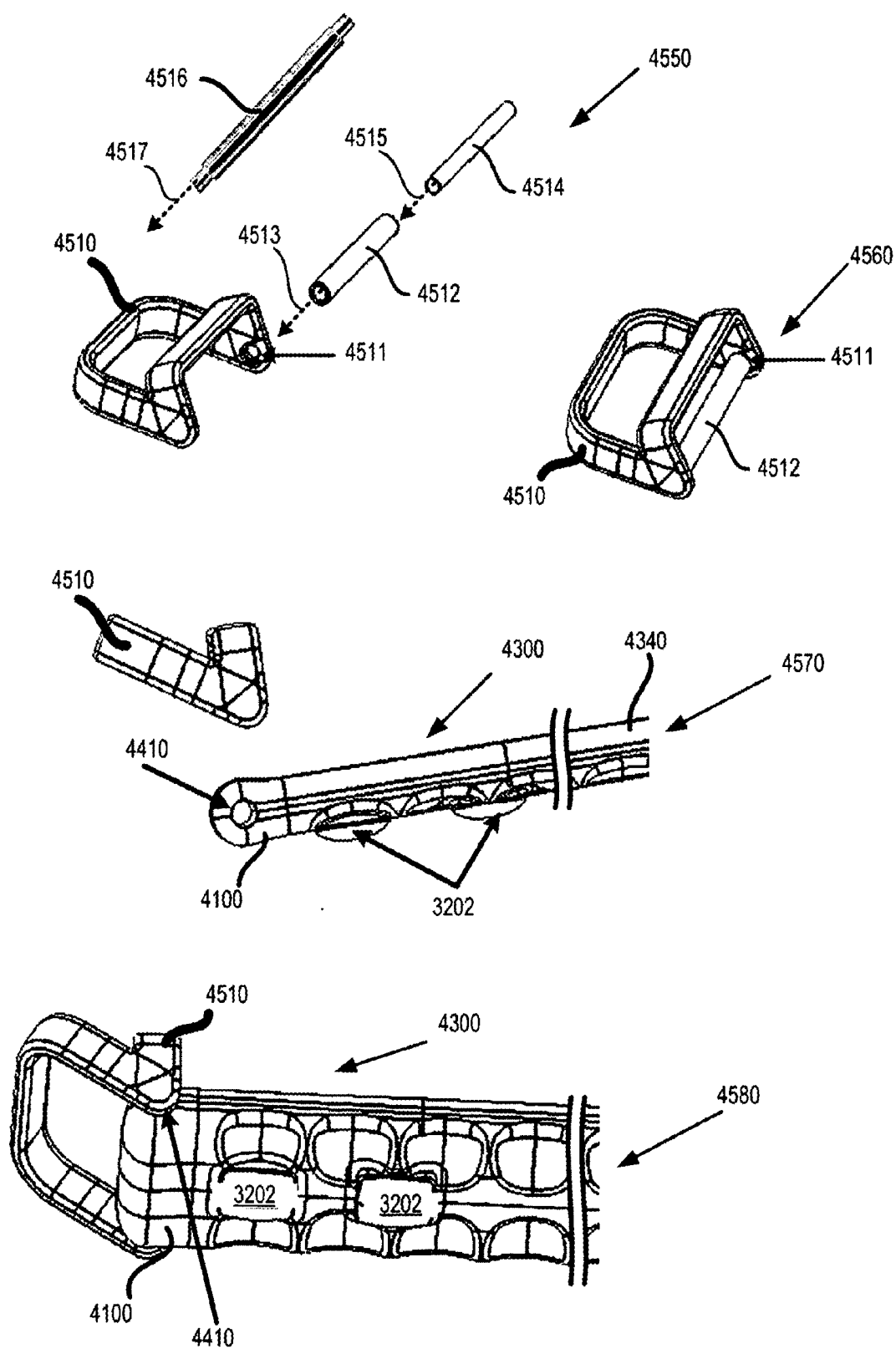


FIG. 45

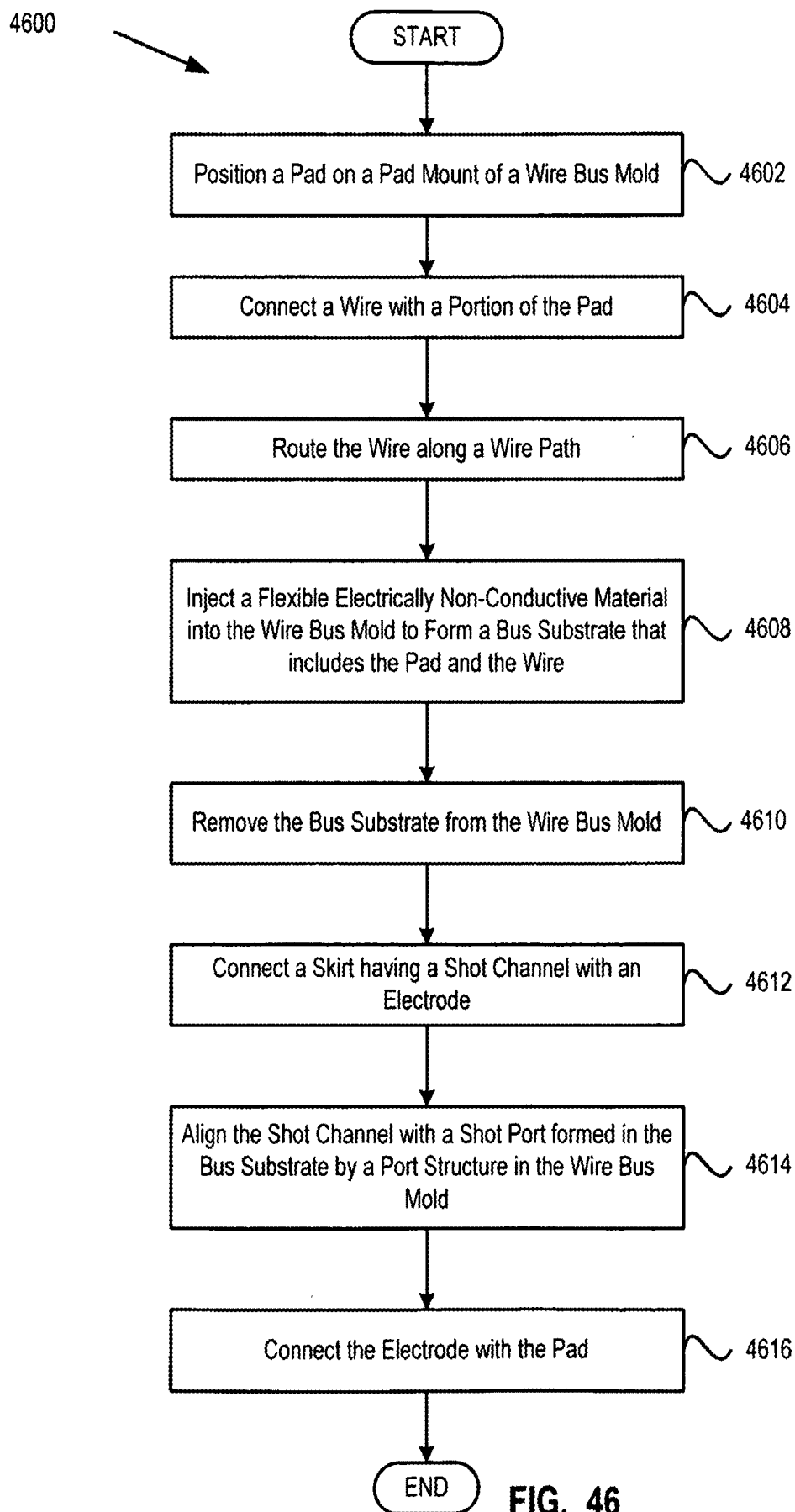


FIG. 46



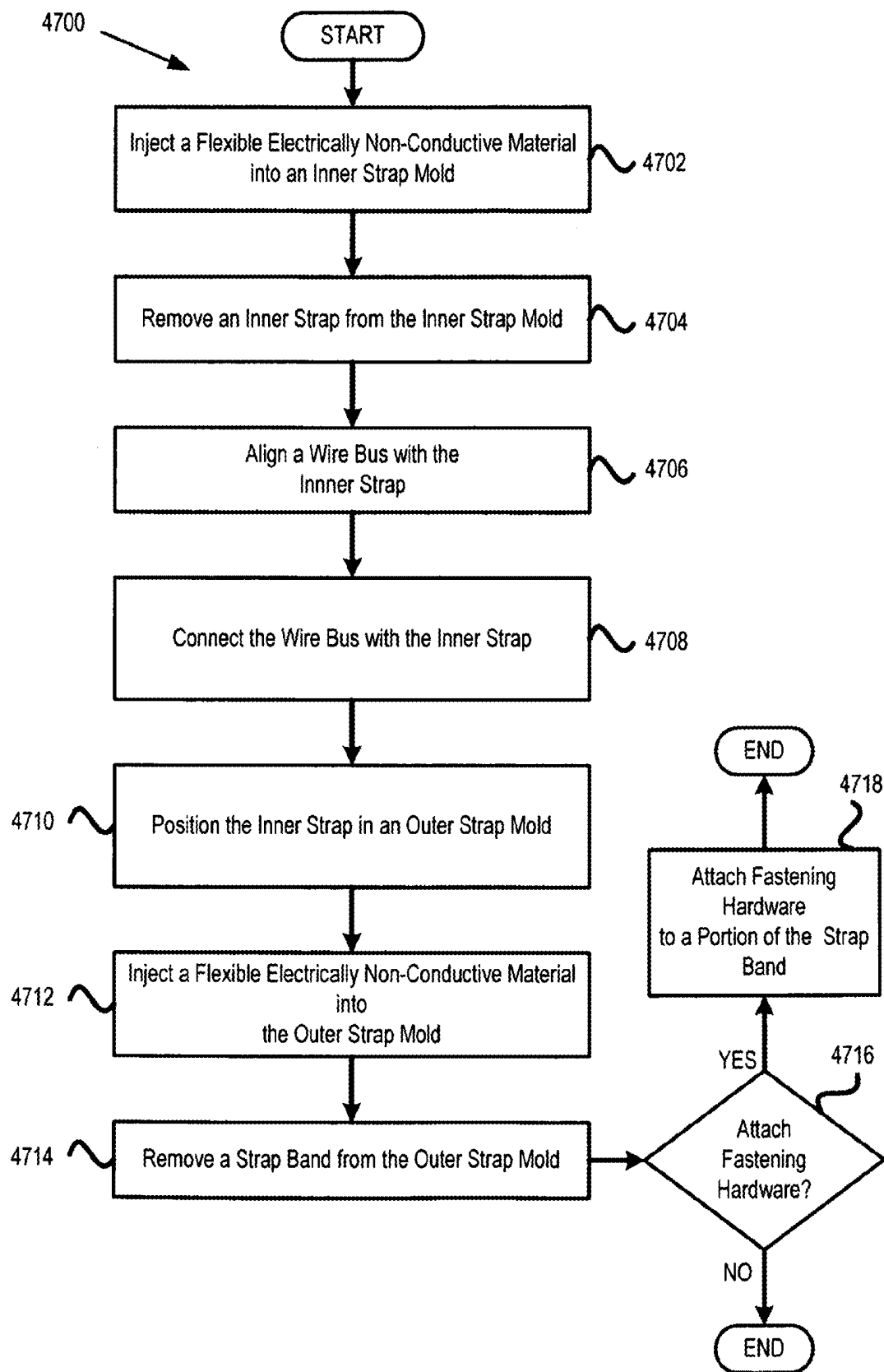


FIG. 47

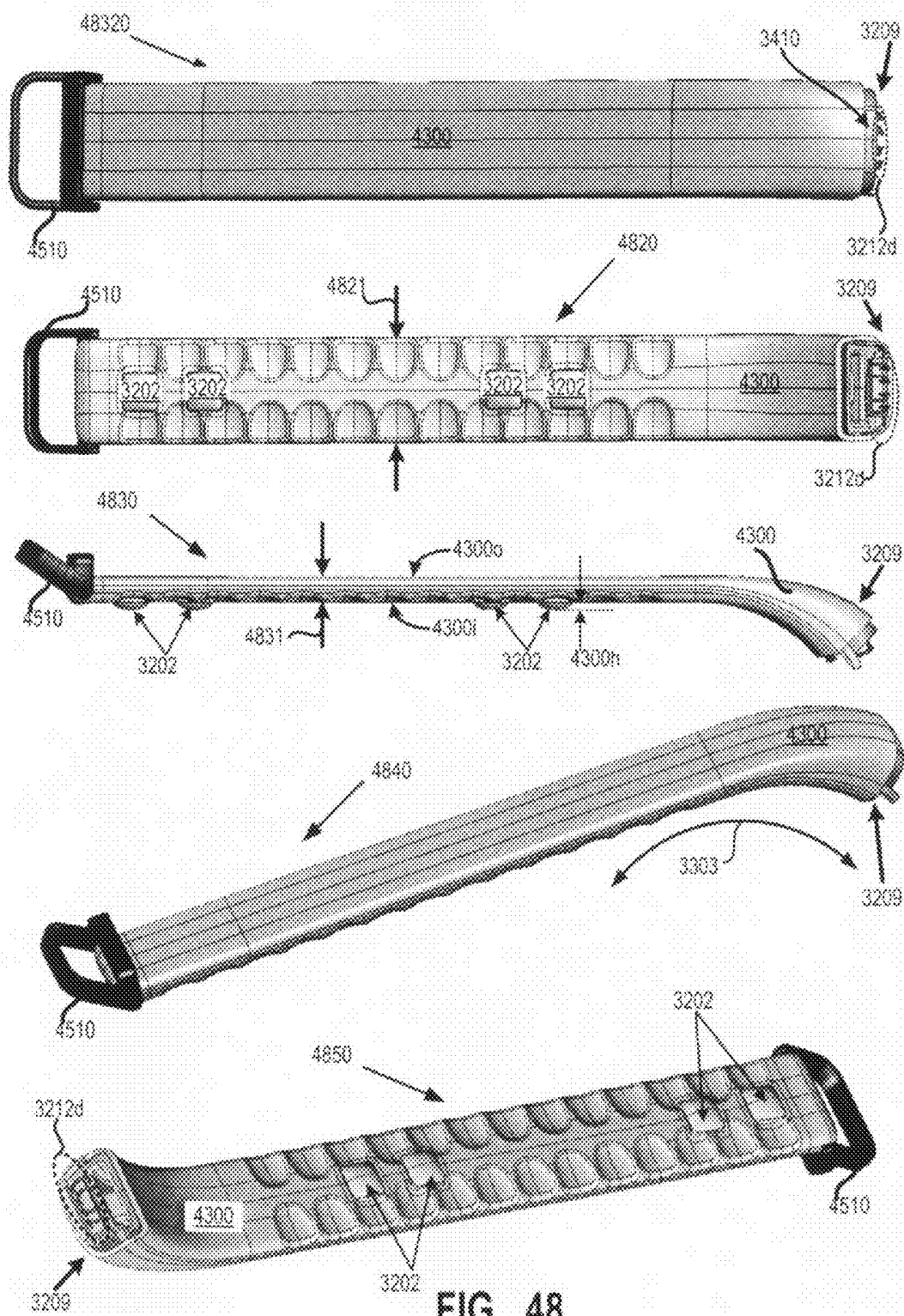


FIG. 48

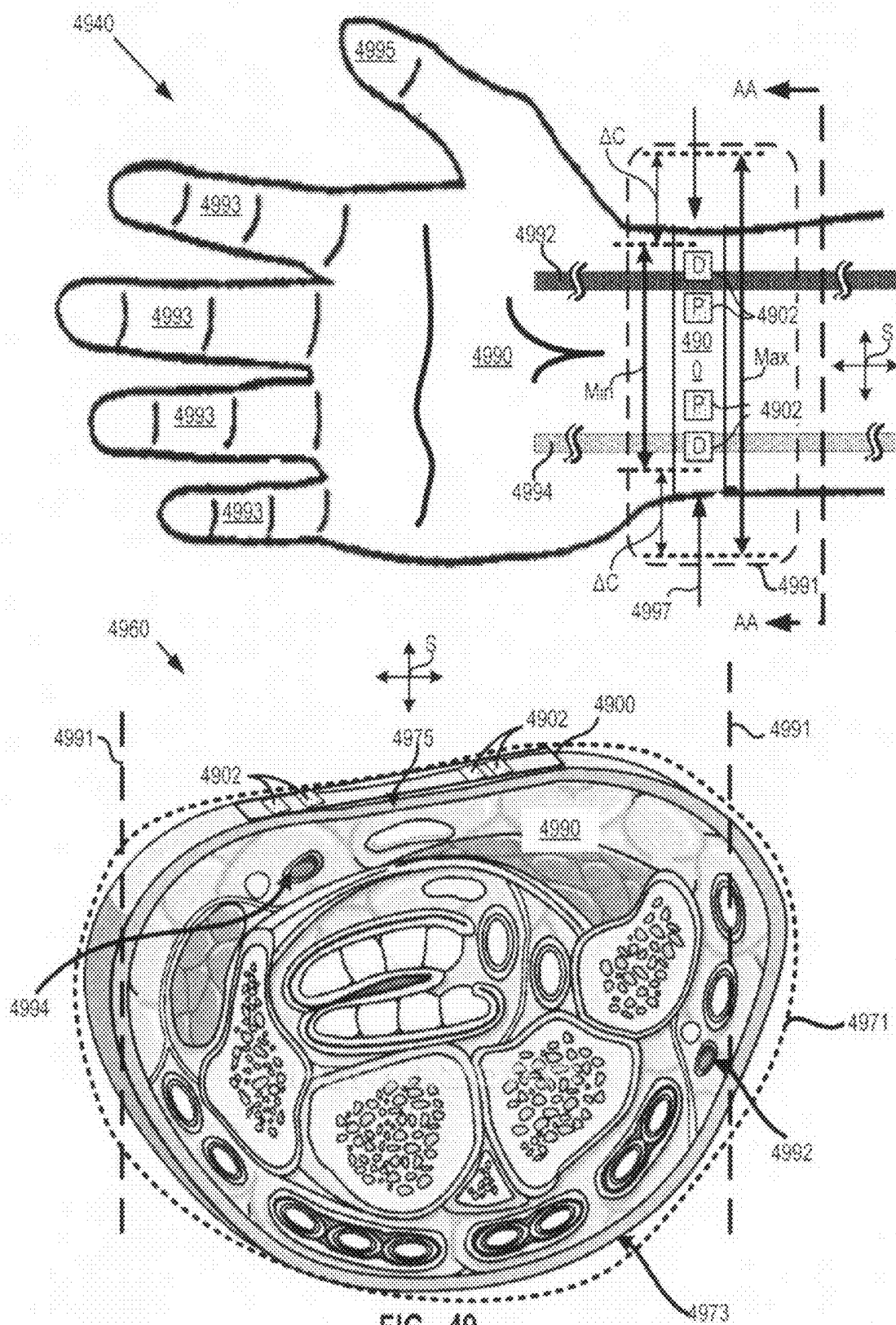


FIG. 49

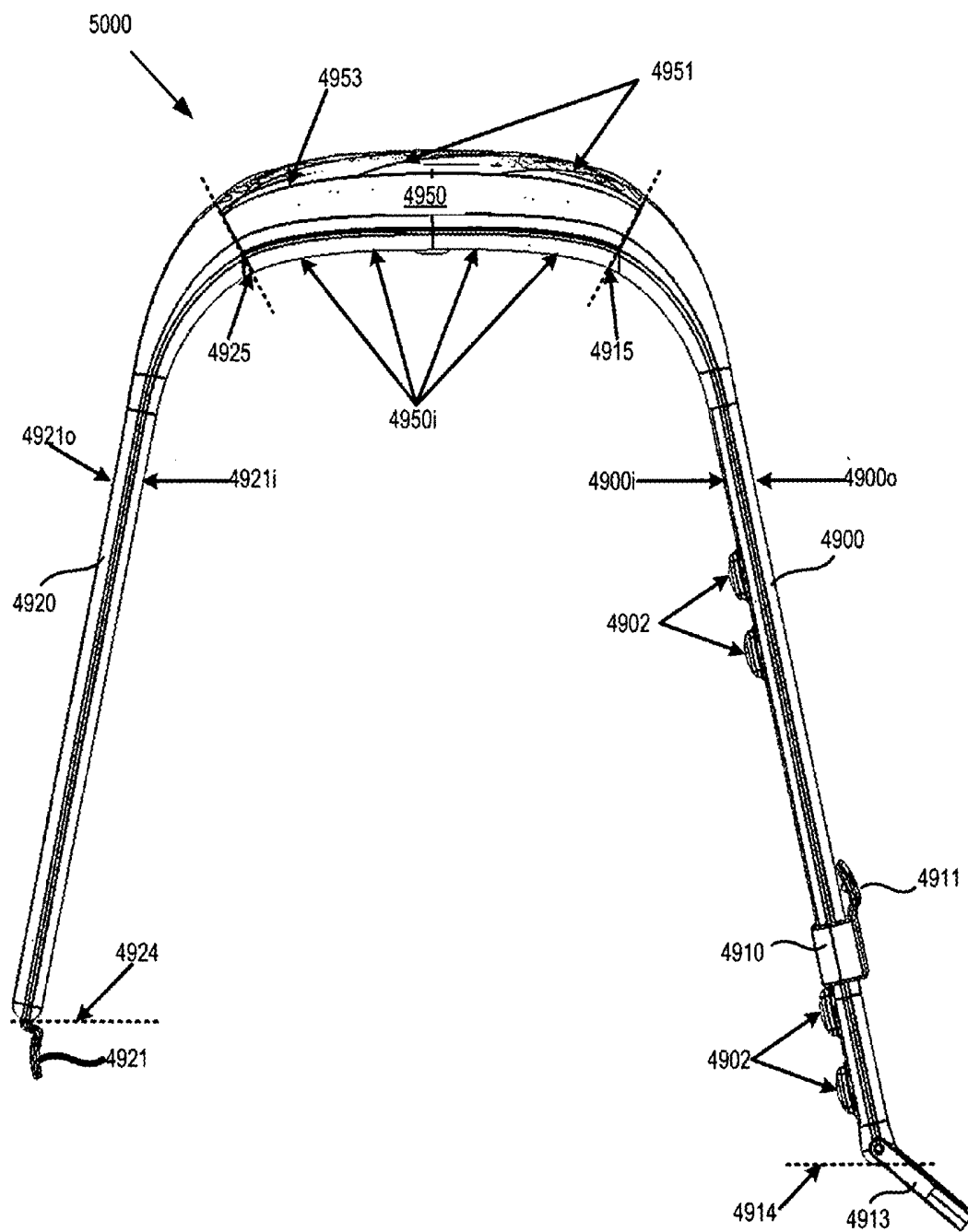
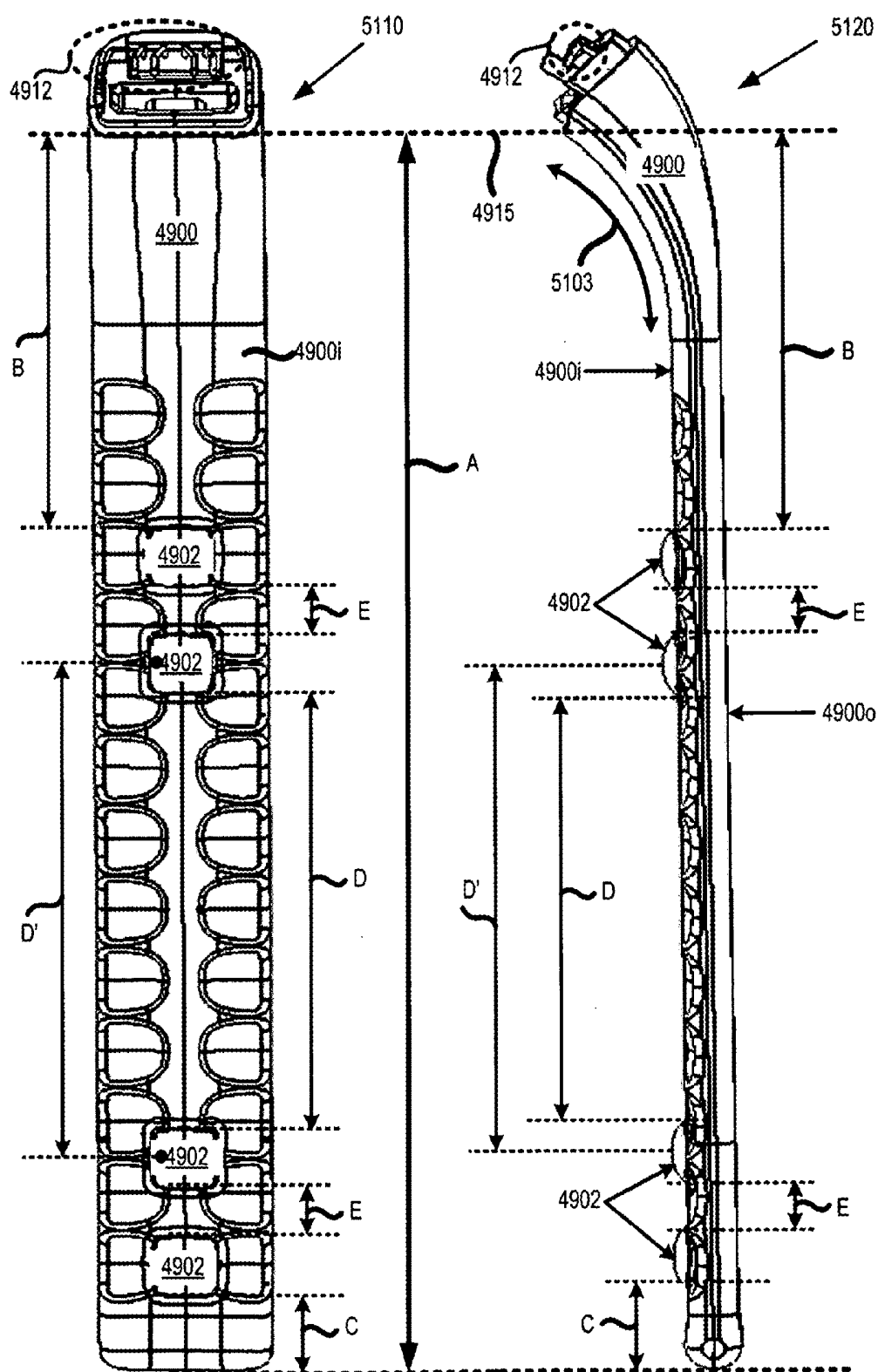


FIG. 50



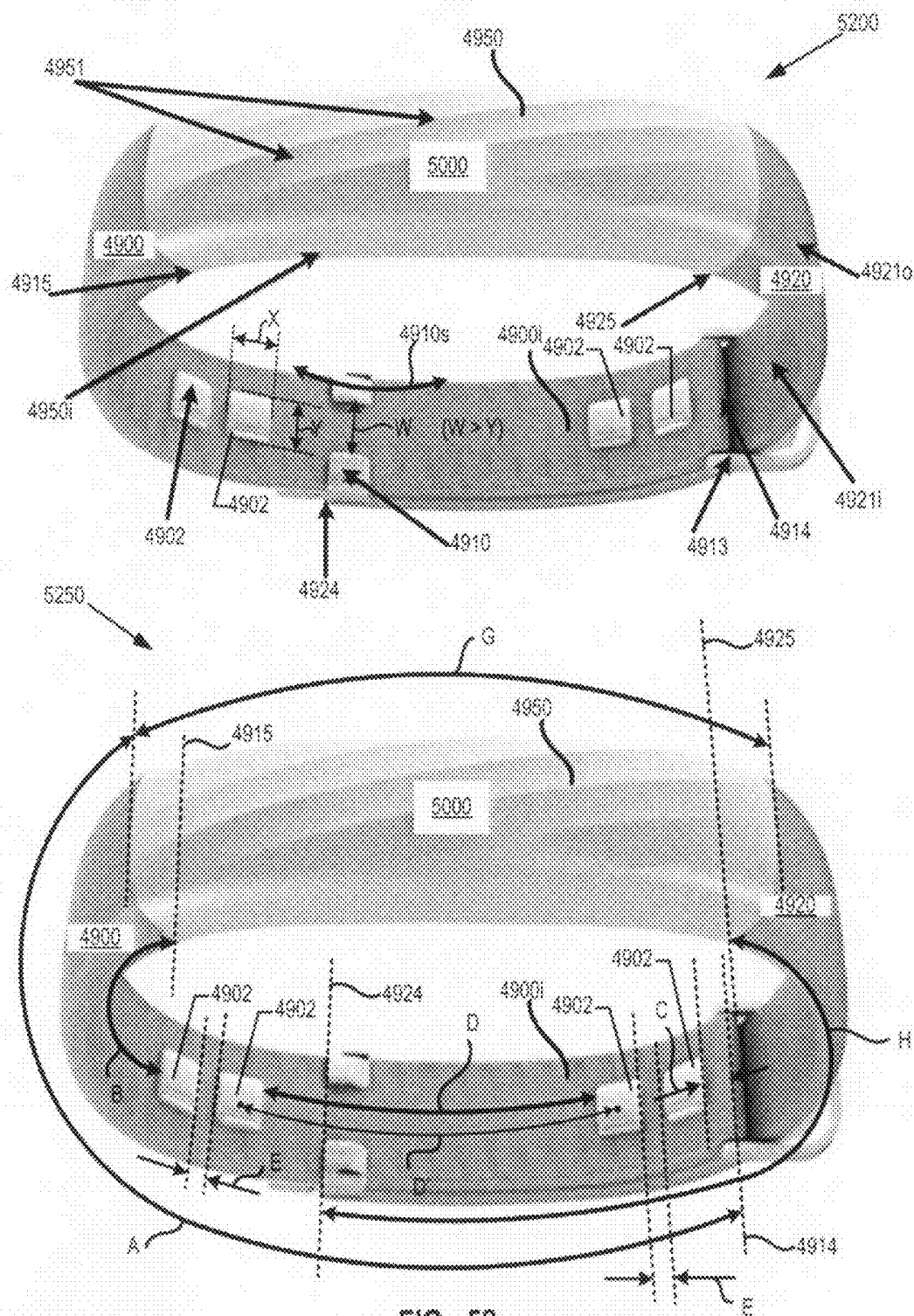


FIG. 52

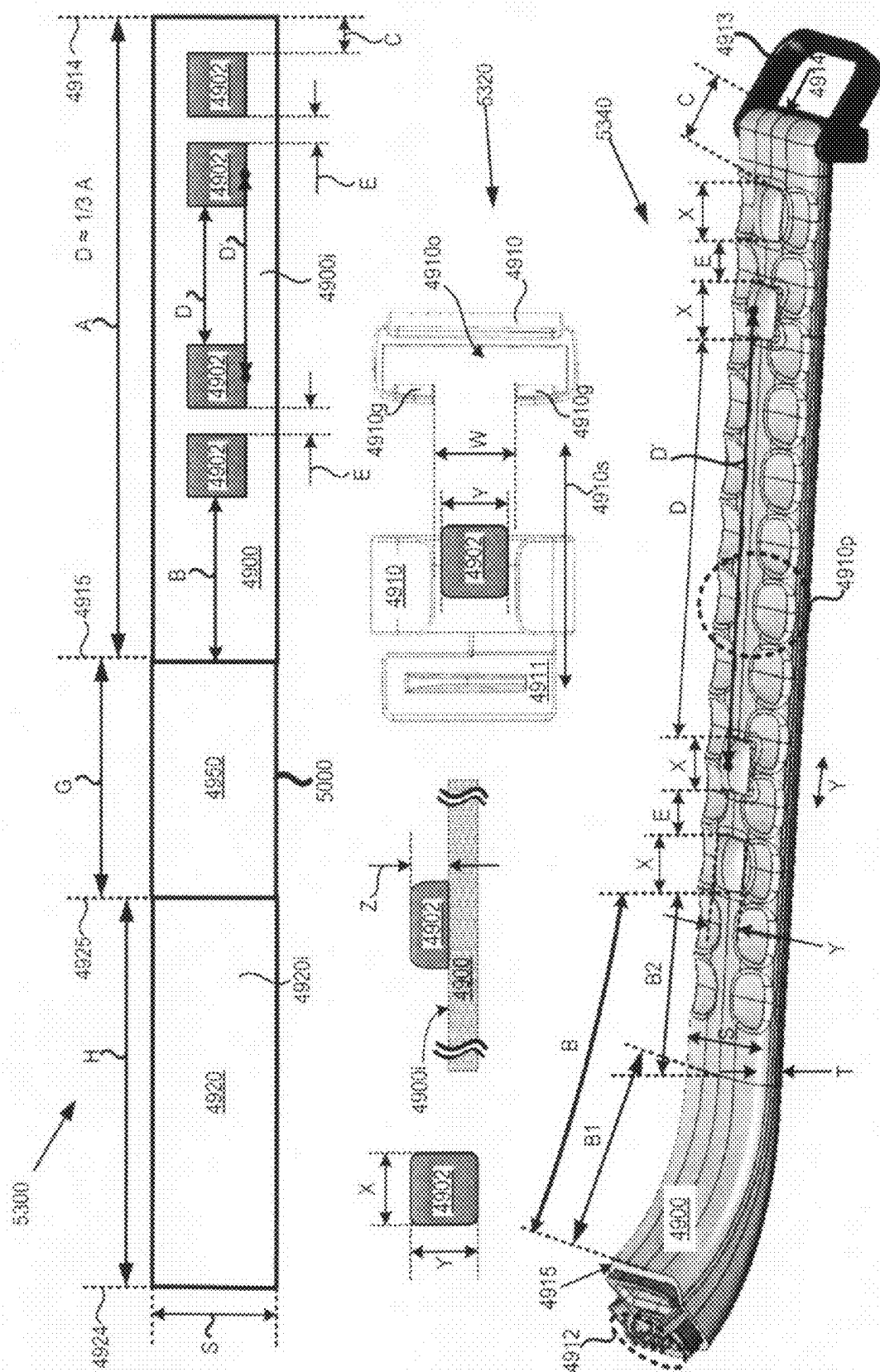


FIG. 53

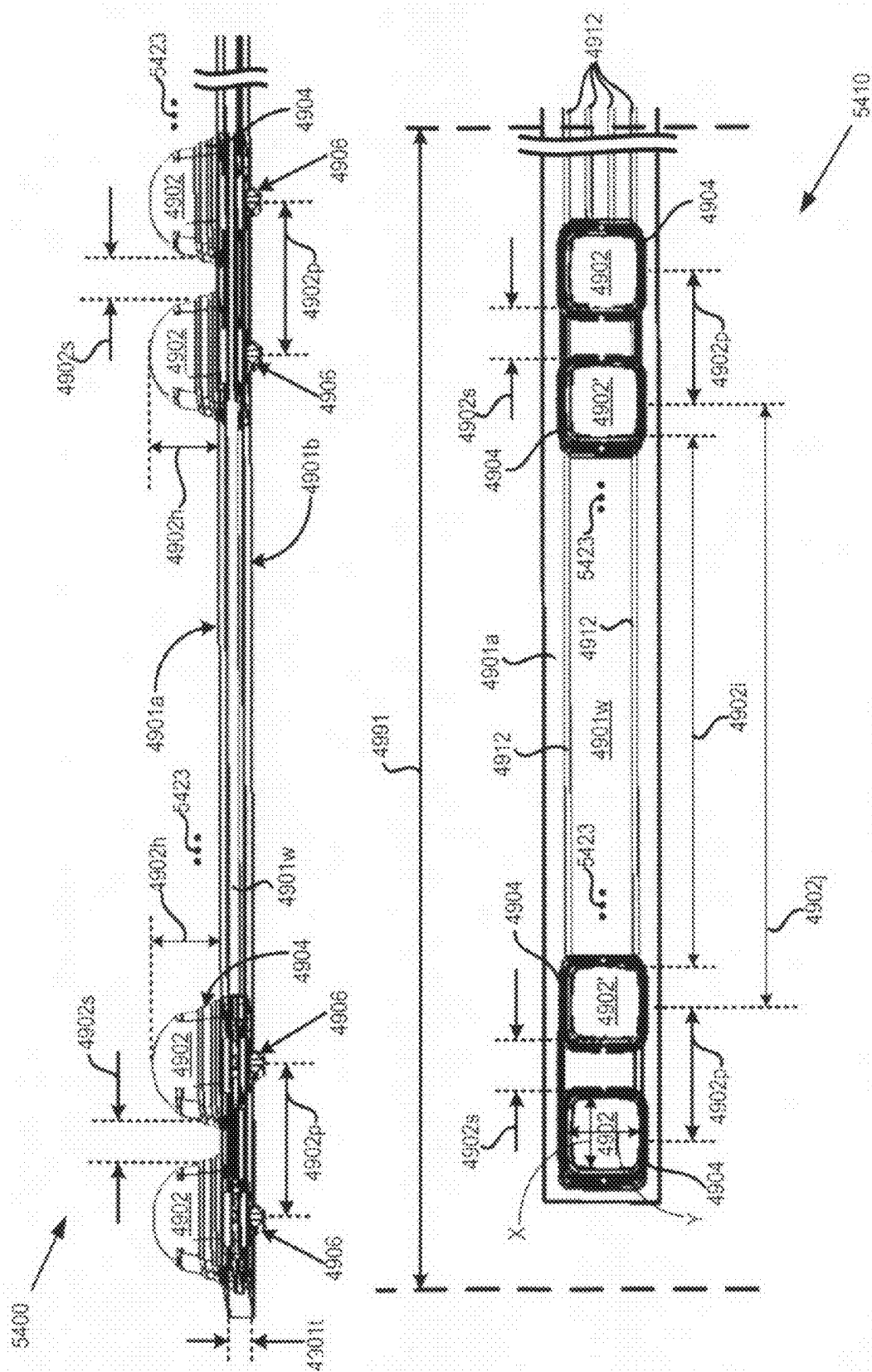
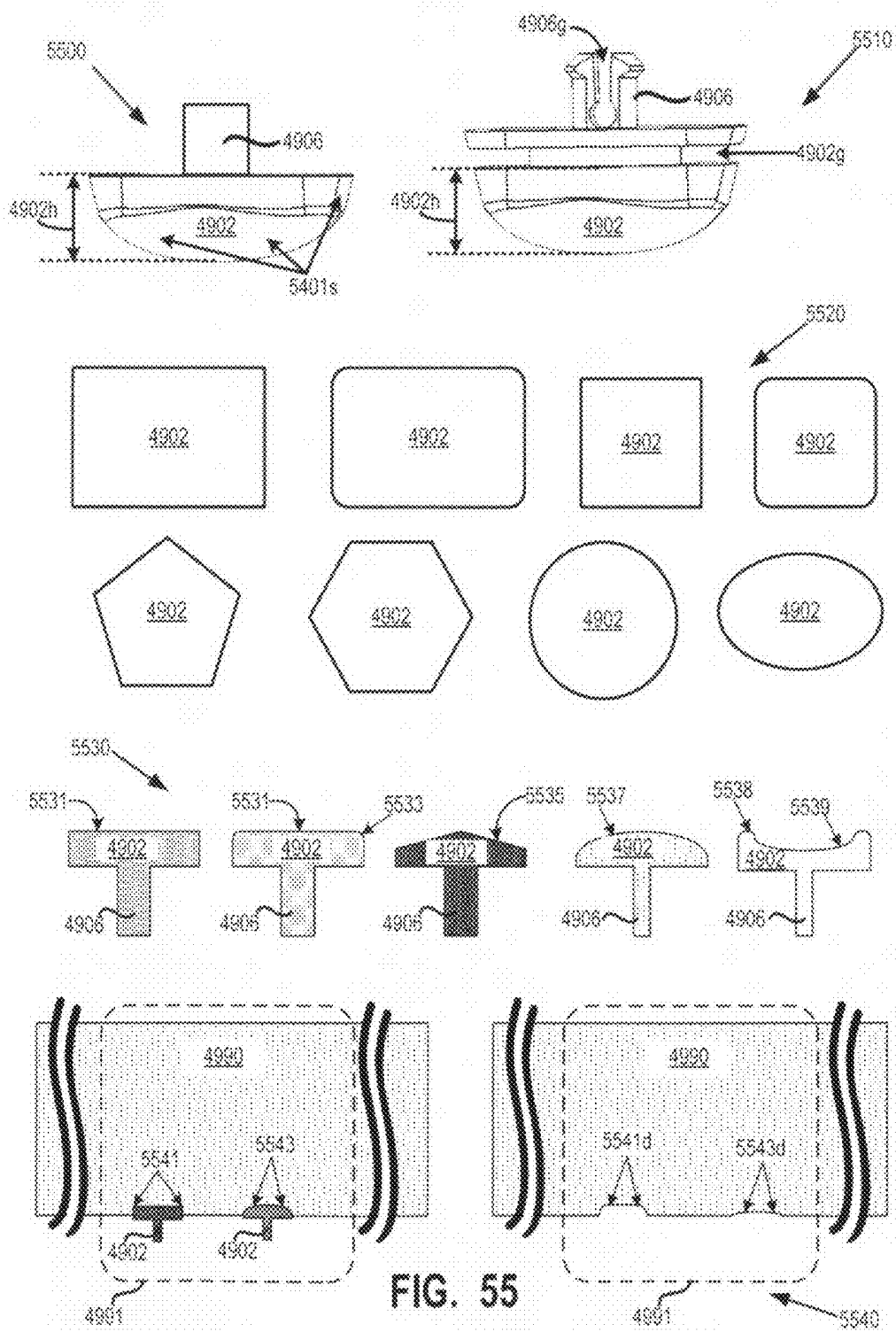
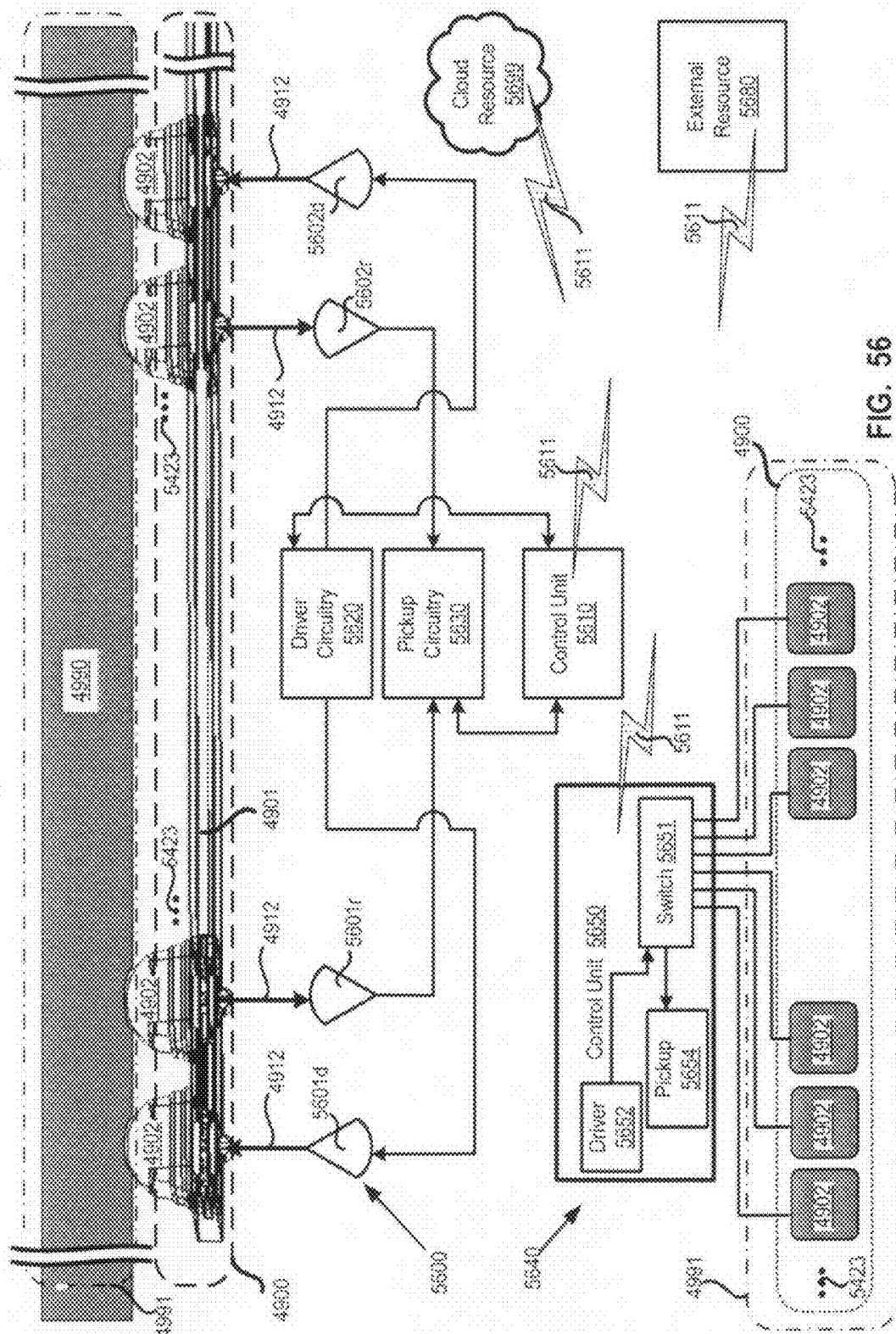


FIG. 54







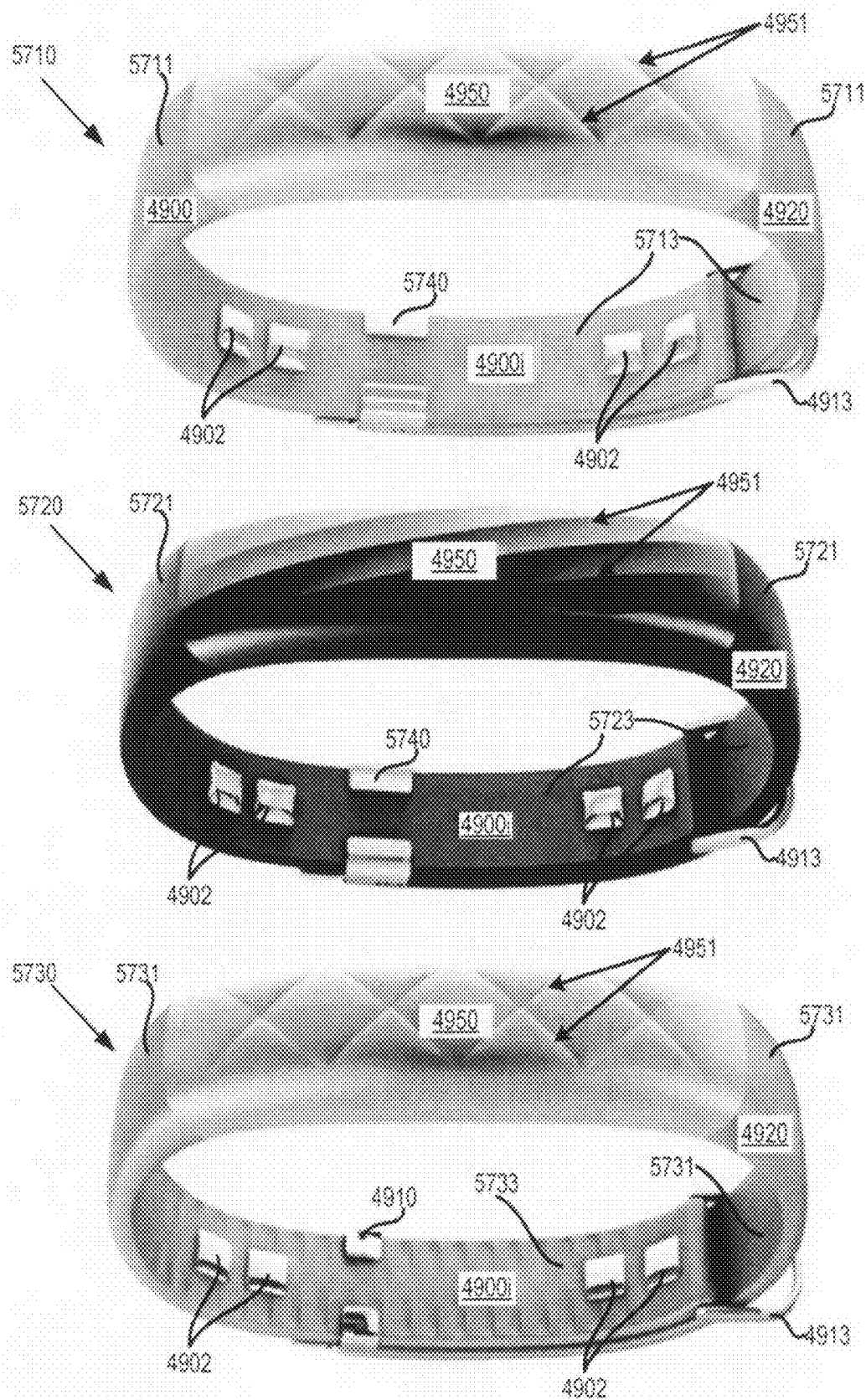


FIG. 57

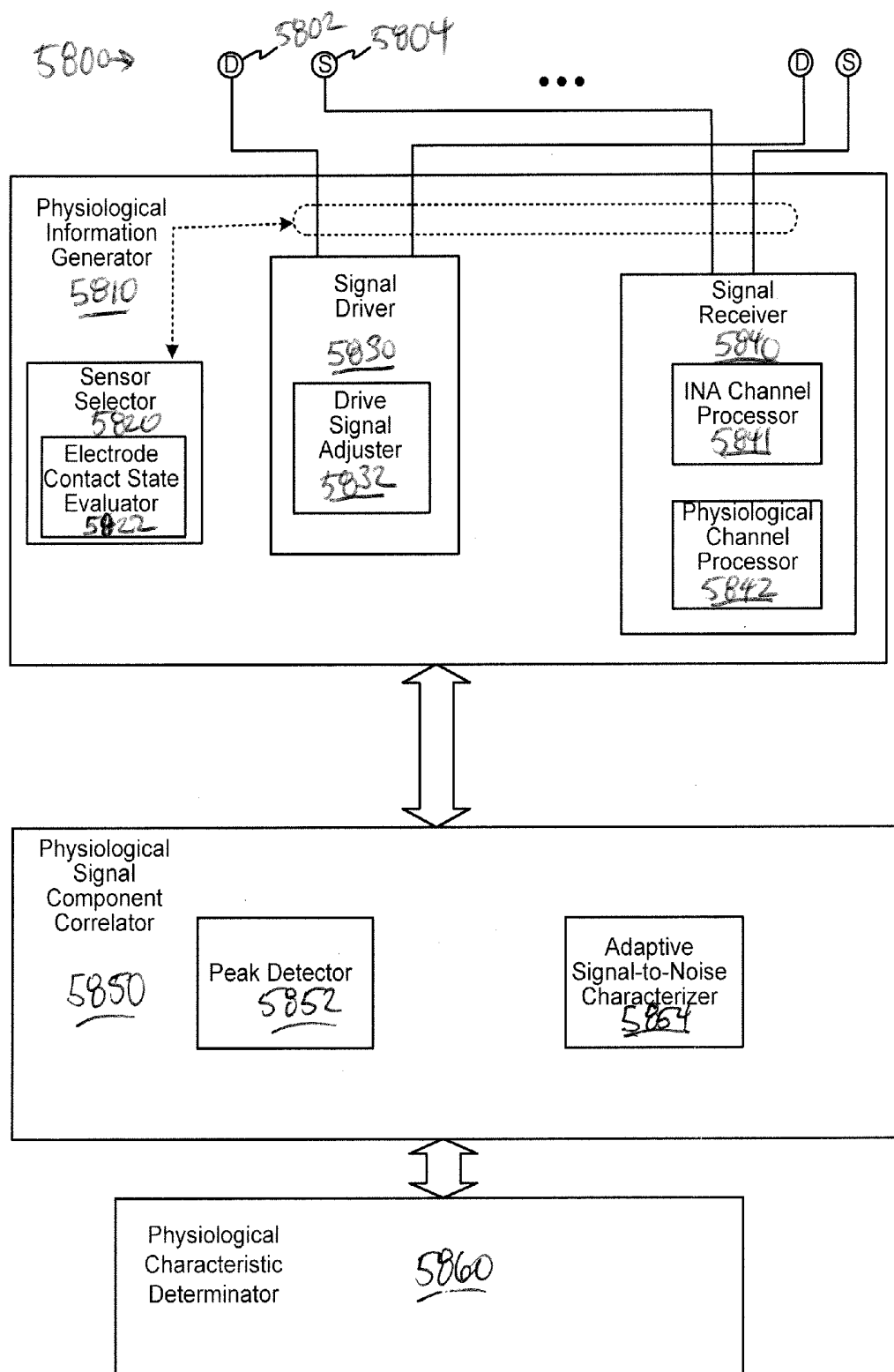


FIG. 58

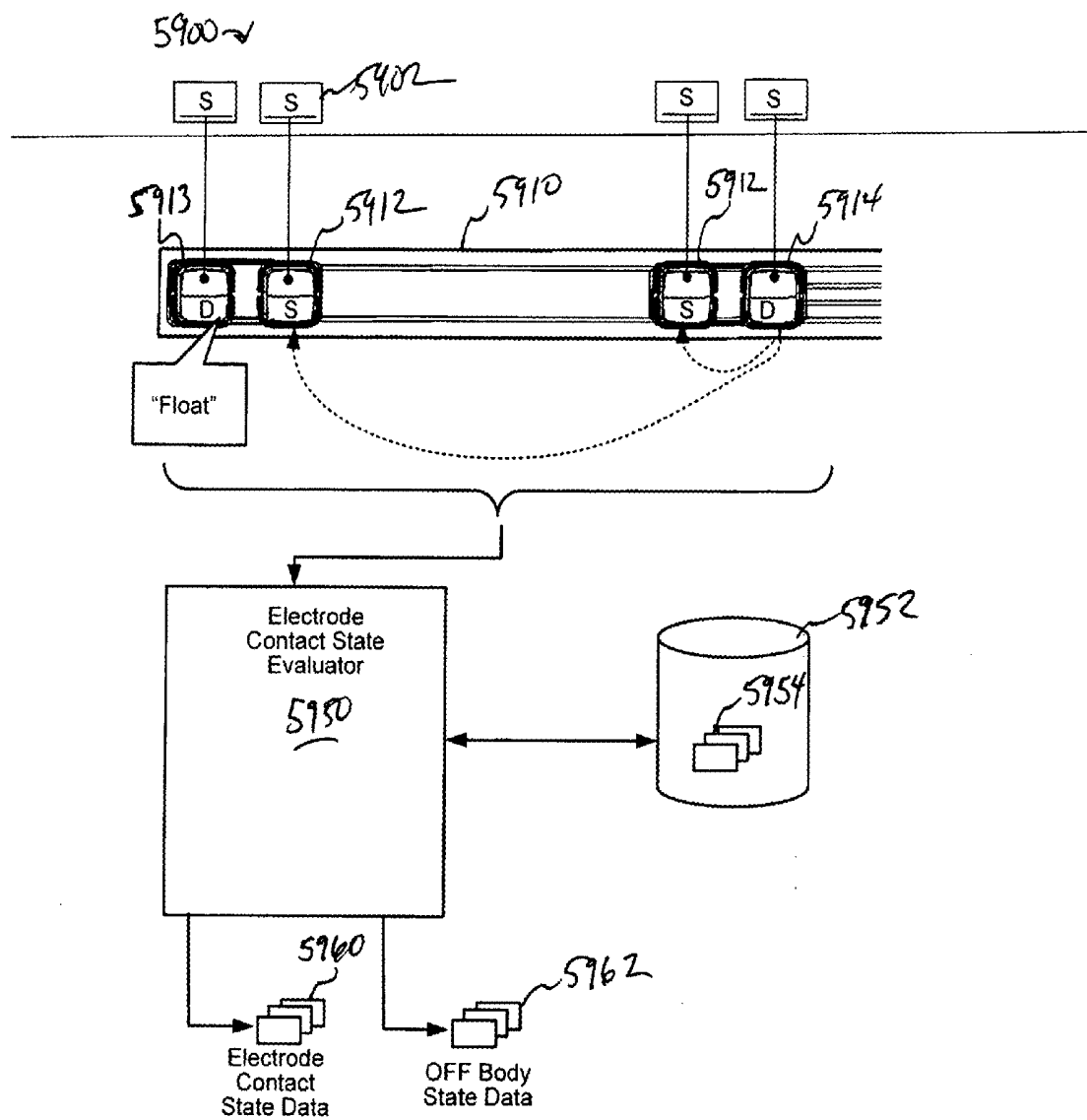


FIG. 59

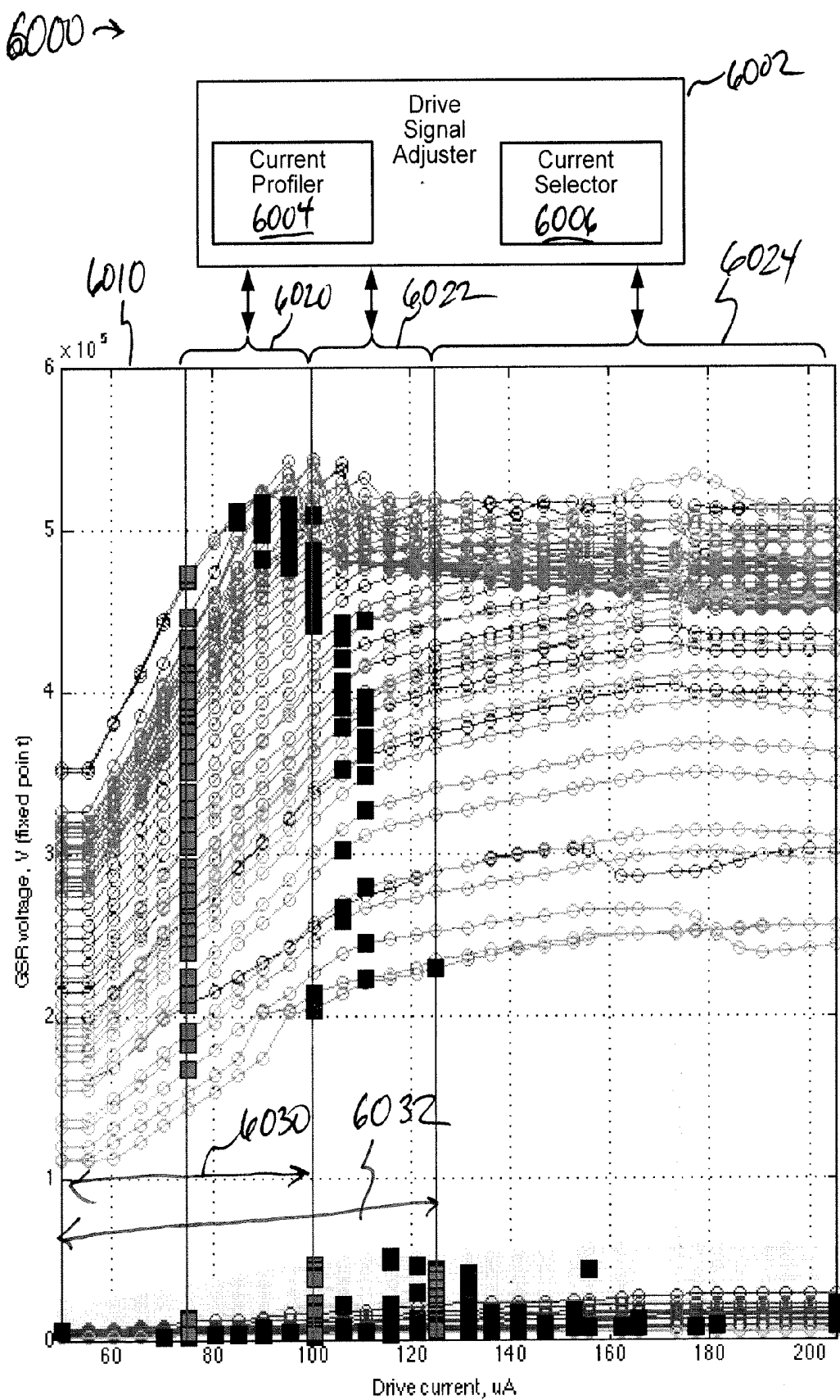


FIG. 60

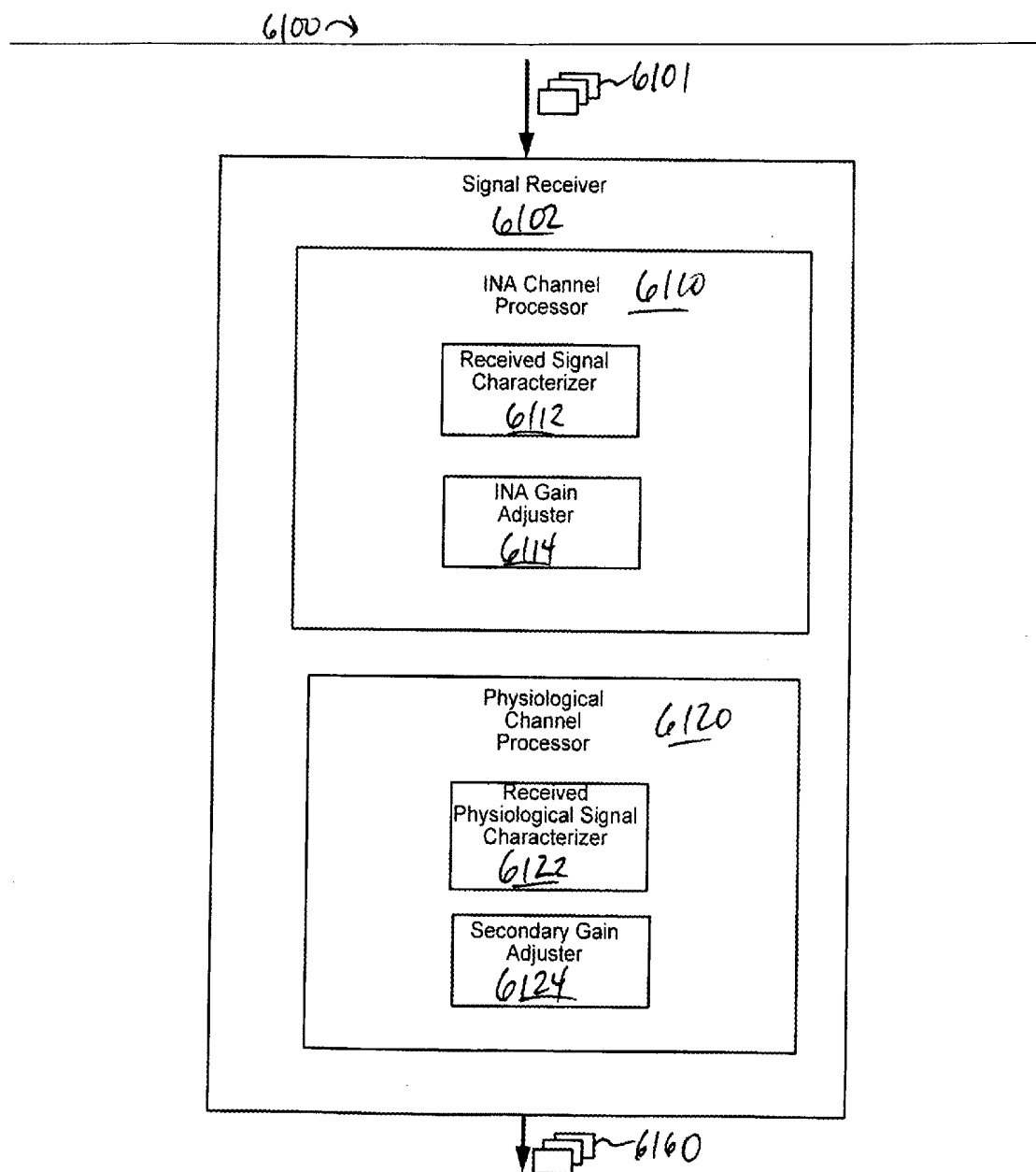


FIG. 61

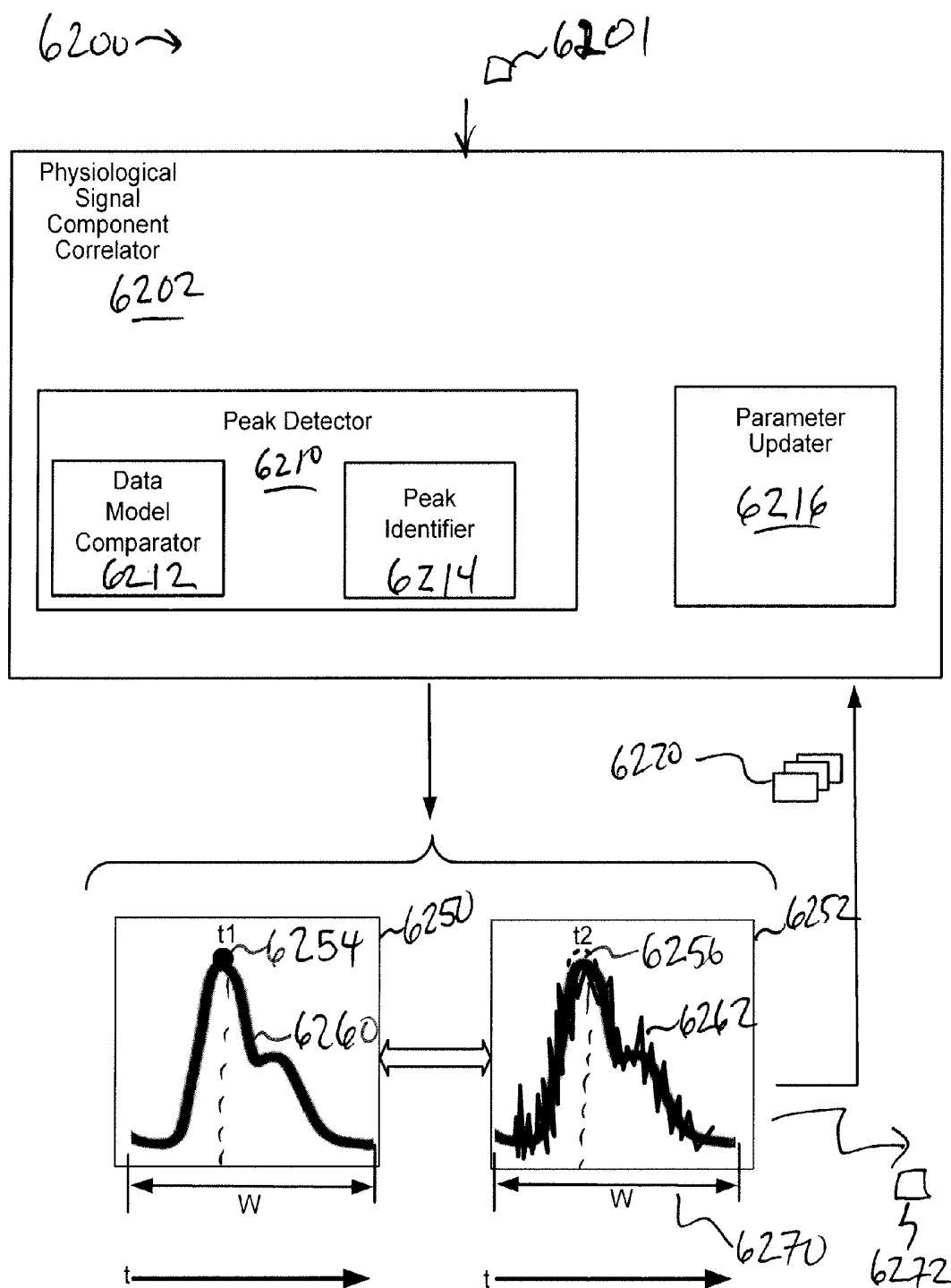


FIG. 62



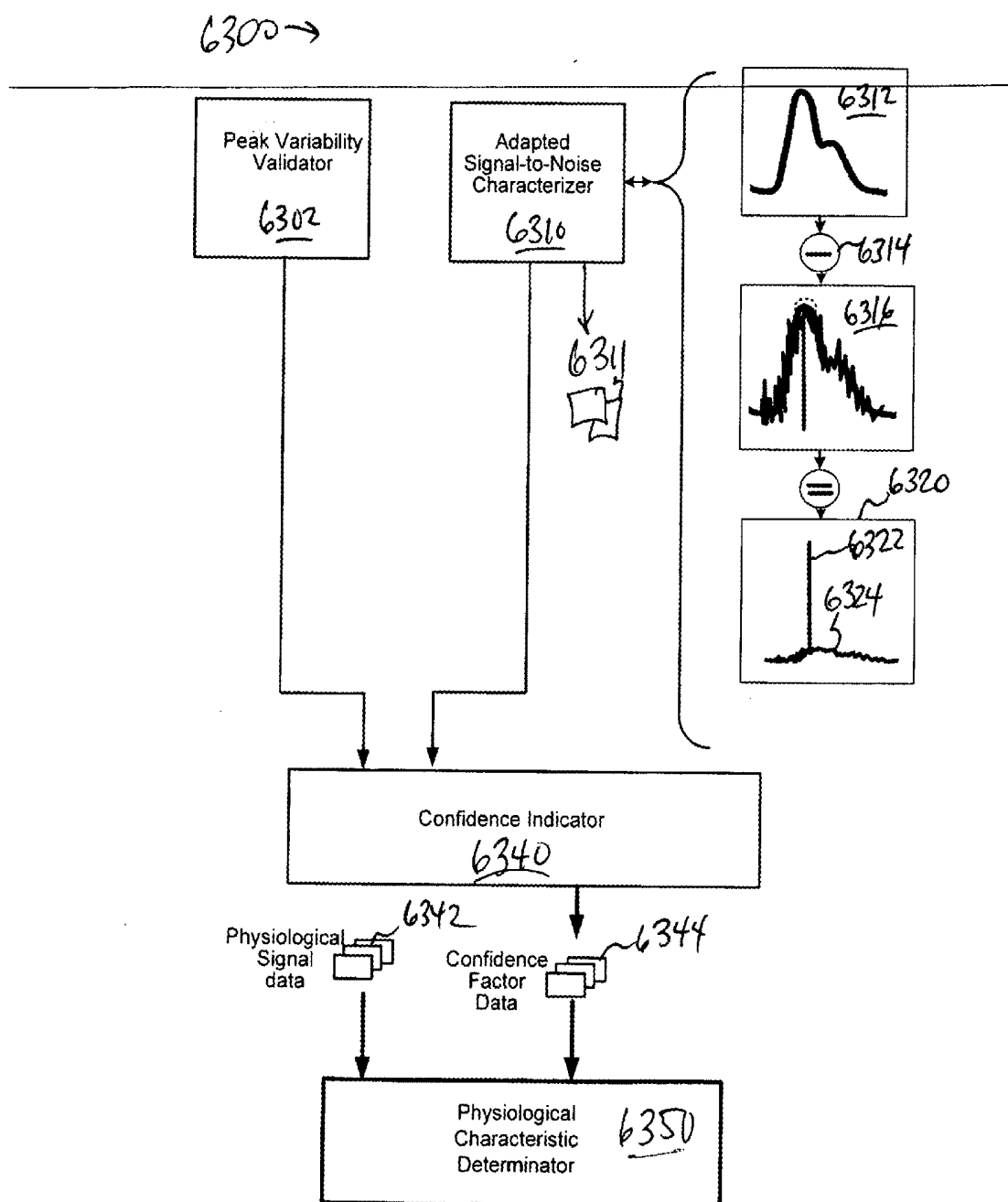


FIG. 63

6400 →

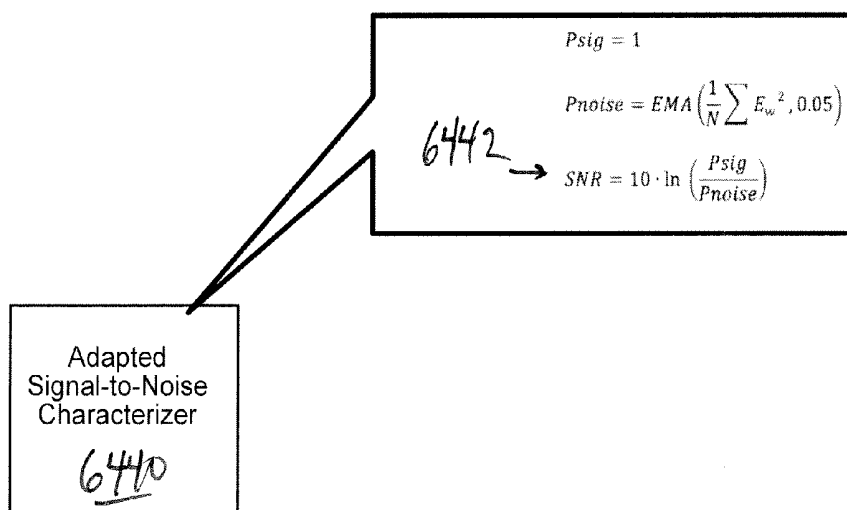
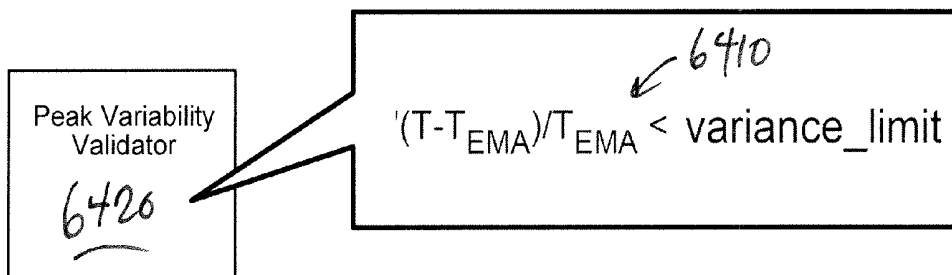
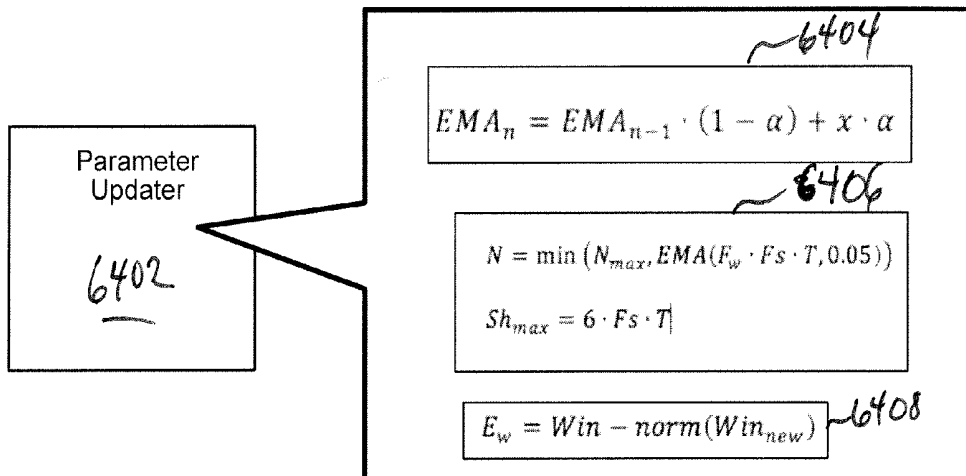
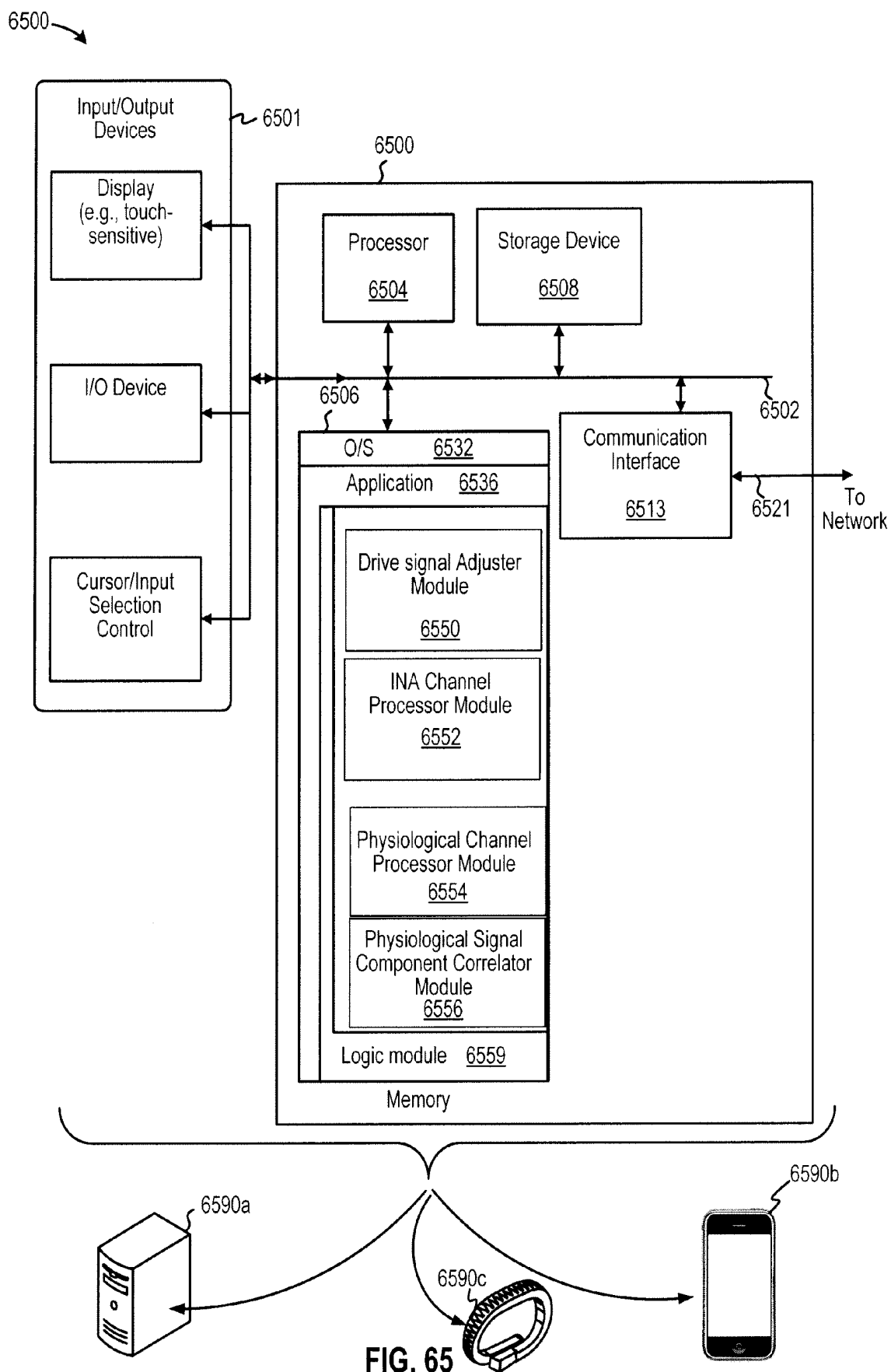


FIG. 64



## PHYSIOLOGICAL CHARACTERISTIC DETERMINATION BASED ON SIGNAL CORRELATION

### CROSS-RELATED APPLICATIONS

**[0001]** This application is a continuation-in-part application of U.S. patent application Ser. No. 14/480,628 (ALI-516) filed on Sep. 8, 2014; THIS APPLICATION is a continuation-in-part application of U.S. patent application Ser. No. 13/831,260 (ALI-147) filed on Mar. 14, 2013, which claims priority to Chinese Utility Model Patent Application Number 201220513278.5 filed on Sep. 29, 2012; THIS APPLICATION is a continuation-in-part application of U.S. patent application Ser. No. 13/802,305 (ALI-267) filed on Mar. 13, 2013, which is a continuation-in-part application of U.S. patent application Ser. No. 13/831,260 (ALI-147) filed on Mar. 14, 2013, which claims priority to Chinese Utility Model Patent Application Number 201220513278.5 filed on Sep. 29, 2012; THIS APPLICATION is a continuation-in-part application of U.S. patent application Ser. No. 13/802,319 (ALI-268) filed on Mar. 13, 2013, which is a continuation-in-part application of U.S. patent application Ser. No. 13/831,260 (ALI-147) filed on Mar. 14, 2013, which claims priority to Chinese Utility Model Patent Application Number 201220513278.5 filed on Sep. 29, 2012, all of which are incorporated by reference herein for all purposes.

### FIELD

**[0002]** Embodiments relate generally to electrical and electronic hardware, computer software, wired and wireless network communications, and computing devices, and, in particular, to a wearable device implementing a touch-sensitive interface in a metal pod cover and/or bioimpedance sensing to determine physiological characteristics, such as heart rate.

### BACKGROUND

**[0003]** Wearable devices have leveraged increased sensor and computing capabilities that can be provided in reduced personal and/or portable form factors, and an increasing number of applications (i.e., computer and Internet software or programs) for different uses, consumers (i.e., users) have given rise to large amounts of personal data that can be analyzed on an individual basis or an aggregated basis (e.g., anonymized groupings of samples describing user activity, state, and condition).

**[0004]** Presently, development and design of many wearable devices, such as so-called “smart watches,” are including glass-based touchscreens to enable users to interact with glass (or transparent plastic) to provide user input or receive visual information. An example of a glass-based touch screen includes CORNING® GORILLA® GLASS, or those formed using OLED or other like technology. Developers of wearable devices using such touchscreens continue to face challenges, not only technically but in user experience design. For example, relatively large glass-based touchscreens may be perceived to be to “bulky” or “unwieldy” for some consumers, whereas miniaturized glass-based screens may fail to provide sufficient information to a user. Moreover, some conventional touchscreens are susceptible to the environments in which users typically expect reliable operation.

**[0005]** Further, some conventional smart watches implement short range communication systems (e.g., transceivers and antennas) adjacent glass portions and/or plastic portions

of a housing to interference from metal structures. While conventional wearable devices typically are functional, such devices have sub-optimal properties that consumers view less favorably.

**[0006]** Thus, what is needed is a solution for facilitating the use and manufacture of wearable devices without the limitations of conventional devices or techniques.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** Various embodiments or examples (“examples”) of the invention are disclosed in the following detailed description and the accompanying drawings:

**[0008]** FIG. 1 is a perspective view of a wearable device, according to some embodiments;

**[0009]** FIGS. 2A and 2B are diagrams depicting an exploded front view and an exploded perspective view, respectively, of a wearable device, according to some embodiments;

**[0010]** FIGS. 3 and 4 are flow diagrams depicting examples of flows for forming a cradle and forming an anchored cradle, respectively, according to some embodiments;

**[0011]** FIGS. 5A and 5B are diagrams depicting a front view and a perspective view, respectively, of an anchored cradle, according to some embodiments;

**[0012]** FIGS. 6A to 6C are diagrams depicting formation of an intermediate assembly structure formed in molding process, according to some examples;

**[0013]** FIGS. 7A to 7B are diagrams depicting formation of another intermediate assembly structure formed in molding process, according to some examples;

**[0014]** FIGS. 8A to 8C are diagrams depicting exploded views of logic, circuitry, and components disposed within the interior of a cradle anchored to two straps, according to some embodiments;

**[0015]** FIGS. 9A and 9B are diagrams depicting an assembly step in which one or more pod covers of a wearable pod are integrated into a wearable device, according to some embodiments;

**[0016]** FIG. 10 is an example of a flow to form wearable device, according to some embodiments;

**[0017]** FIG. 11 is an exploded view of an example of a wearable pod having, for example, an opaque surface, according to some embodiments;

**[0018]** FIG. 12 is a diagram depicting a touch-sensitive I/O controller, according to some embodiments;

**[0019]** FIGS. 13A to 13D are diagrams depicting various aspects of an interface of a wearable pod, according to some examples;

**[0020]** FIGS. 14A to 14D depict examples of micro-perforations, according to some examples;

**[0021]** FIGS. 15A to 15D are diagrams depicting another example of a display portion for a wearable pod, according to some embodiments;

**[0022]** FIG. 16 is an example of a flow to form a wearable pod, according to some embodiments;

**[0023]** FIG. 17 illustrates an exemplary computing platform disposed in a wearable pod configured to facilitate a touch-sensitive interface in an opaque or predominately opaque surface in accordance with various embodiments;

**[0024]** FIG. 18 is an exploded perspective view of an example of a wearable pod having, for example, a metal surface, according to some embodiments;

[0025] FIG. 19 is an exploded front view of an example of a wearable pod having, for example, a metal surface, according to some embodiments;

[0026] FIGS. 20A to 20B are respective exploded perspective and exploded front views of a wearable pod including anchor portions, according to some embodiments;

[0027] FIG. 20C is a bottom perspective view of a pod cover implementing a sealant during assembly, according to some embodiments;

[0028] FIG. 20D is a diagram depicting a perspective front view of a wearable pod being assembled as part of a wearable device, according to some embodiments;

[0029] FIGS. 21A and 21B are diagrams depicting a cross-section of a portion of an isolation belt, according to some examples;

[0030] FIG. 22 depicts an example of a flow to form a touch-sensitive pod cover for a wearable pod, according to some examples; and

[0031] FIG. 23 depicts an example of a flow for a touch-sensitive wearable pod, according to some embodiments

[0032] FIG. 24 is a diagram depicting an antenna configured for implementation in a wearable pod having a metalized interface, according to some embodiments;

[0033] FIGS. 25A to 25C depict examples of an antenna oriented relative to an attachment portion of a cradle, according to some embodiments;

[0034] FIG. 26 is an exploded perspective view of an anchor portion, according to some embodiments;

[0035] FIG. 27 is an example of a flow to manufacture a communications antenna in a wearable pod and/or device, according to some embodiments;

[0036] FIG. 28 is a diagram depicting an antenna configured for implementation in a wearable pod having a metalized interface, according to some embodiments;

[0037] FIGS. 29A and 29B are perspective views of an attachment portion and an anchor portion, respectively, according to some embodiments;

[0038] FIG. 30 is a diagram depicting another example of a near field communication antenna implemented in a wearable device;

[0039] FIG. 31 is an example of a flow to manufacture a short-range communications antenna in a wearable pod and/or device, according to some embodiments.

[0040] FIG. 32 depicts various examples of a wire bus and components coupled with the wire bus, according to some embodiments;+

[0041] FIG. 33 depicts top, side, and bottom plan views of a wire bus, according to some embodiments;

[0042] FIG. 34 depicts one example of a wire bus including a wire bridge, according to some embodiments;

[0043] FIG. 35 depicts one example of a wire bus including a substrate having an antenna coupled with a near field communication chip, according to some embodiments;

[0044] FIG. 36 depicts examples of relative spacing and dimensions of electrodes included in a wire bus, according to some embodiments;

[0045] FIG. 37 depicts examples of wire routing and connection with pads included in a wire bus, according to some embodiments;

[0046] FIG. 38 depicts a side view of one example of an electrode, a skirt, and a pad that may be included in a wire bus, according to some embodiments;

[0047] FIG. 39 depicts profile views of other examples of an electrode, a skirt, and a pad that may be included in a wire bus, according to some embodiments;

[0048] FIG. 40 depicts various views of yet other examples of an electrode, a skirt, and a pad that may be included in a wire bus, according to some embodiments;

[0049] FIG. 41 depicts one example of an assembly order of a strap band that includes a wire bus, an inner strap and an outer strap, according to some embodiments;

[0050] FIG. 42 depicts one example of a wire bus being coupled with an inner strap, according to some embodiments;

[0051] FIG. 43 depicts one example of an outer strap being formed on wire bus coupled with an inner strap, according to some embodiments;

[0052] FIG. 44 depicts top, side and bottom views of one example of a strap band that includes an encapsulated wire bus and sealed electrodes, according to some embodiments;

[0053] FIG. 45 depicts examples of fastening hardware that may be coupled with a strap band, according to some embodiments;

[0054] FIG. 46 depicts one example of a flow diagram for a method of fabricating a wire bus, according to some embodiments;

[0055] FIG. 47 depicts one example of a flow diagram for a method of fabricating a strap band that includes a wire bus, according to some embodiments;

[0056] FIG. 48 depicts various views of a strap band, according to some embodiments;

[0057] FIG. 49 depicts examples of a strap band positioned on a body portion, according to some embodiments;

[0058] FIG. 50 depicts a side view of a strap band coupled with a device, according to some embodiments;

[0059] FIG. 51 depicts a top plan view and a side view of a strap band, according to some embodiments;

[0060] FIG. 52 depicts profile views of a system including a strap band, according to some embodiments;

[0061] FIG. 53 depicts views of a strap band and relative dimensions and positions of components of the strap band, according to some embodiments;

[0062] FIG. 54 depicts a side view and top plan view of a wire bus, according to some embodiments;

[0063] FIG. 55 depicts various examples of electrodes, according to some embodiments;

[0064] FIG. 56 depicts examples of circuitry coupled with electrodes of a strap band, according to some embodiments;

[0065] FIG. 57 depicts profile views of systems that include a strap band, according to some embodiments;

[0066] FIG. 58 is a diagram depicting examples of various components configured to determine one or more physiological characteristics, according to some examples;

[0067] FIG. 59 is a diagram of an example of an electrode contact state evaluator, according to some examples;

[0068] FIG. 60 is an example of a number of current profiles with which a drive signal adjuster may adjust current, according to some examples;

[0069] FIG. 61 is a diagram depicting a signal receiver, according to some examples;

[0070] FIG. 62 is a diagram depicting a physiological signal component correlator, according to some examples;

[0071] FIG. 63 is a diagram depicting an example of components of a physiological signal component correlator, according to some embodiments;

[0072] FIG. 64 is a diagram depicting exemplary operation of a parameter updater, peak variability validator, and an adapted signal-to-noise ratio characterizer, according to various examples; and

[0073] FIG. 65 illustrates an exemplary computing platform disposed in a device configured to facilitate physiological signal determination in accordance with various embodiments.

#### DETAILED DESCRIPTION

[0074] Various embodiments or examples may be implemented in numerous ways, including as a system, a process, an apparatus, a user interface, or a series of program instructions on a computer readable medium such as a computer readable storage medium or a computer network where the program instructions are sent over optical, electronic, or wireless communication links. In general, operations of disclosed processes may be performed in an arbitrary order, unless otherwise provided in the claims.

[0075] A detailed description of one or more examples is provided below along with accompanying figures. The detailed description is provided in connection with such examples, but is not limited to any particular example. The scope is limited only by the claims and numerous alternatives, modifications, and equivalents are encompassed. Numerous specific details are set forth in the following description in order to provide a thorough understanding. These details are provided for the purpose of example and the described techniques may be practiced according to the claims without some or all of these specific details. For clarity, technical material that is known in the technical fields related to the examples has not been described in detail to avoid unnecessarily obscuring the description.

[0076] FIG. 1 is a perspective view of a wearable device, according to some embodiments. Diagram 100 depicts a wearable device including a wearable pod 101 including logic, whether in hardware, software or combination thereof, a strap band 120 and band 122. Among other things, strap band 120 and band 122 are composed of material designed to provide comfort while being worn by a user. In the example shown, the logic is disposed between a top pod cover 102 and a bottom pod cover 106. Top pod cover 102 may be formed in a substrate of an opaque material, such as metal. According to some embodiments, one or more portions of pod cover 102 are configured to accept user input by way of detected capacitance values (or changes in capacitance values), thereby effectuating capacitive touch sensing (e.g., “cap touch”) as a means receiving commands or inputs from a user.

[0077] A display portion 104 is disposed at the predominately opaque portion of top pod cover 102, and is configured to emit light of various shapes (e.g., any type of symbol) and colors to convey information to a user. In one example, display portion 104, or portions thereof, is selectively opaque in that some portions selectable do not emit light while and other arrangements of light to transmit through the surface. As such, display portion 104 may be configured to provide or output information to a user, the information describing aspects of the activity in which users engaged, progress toward a goal of completing the activity, physiological information, such as heart rate, among other things. Further, wearable pod 101 includes any number of sensors and related circuitry, such as bioimpedance circuitry and sensors, galvanic skin response circuitry and sensors, temperature-related circuitry and sensors, and the like.

[0078] Strap band 120 includes any number of groups of electrodes. As shown, a group 130 of electrodes is disposed at an approximate distance 152 from wearable pod 101, whereby a first electrode is separated by an approximate distance 154 from the second electrode in group 130. Group 132 of electrodes is shown to be disposed at an approximate distance 156 from group 130, with a first electrode in group 132 being separated at an approximate distance 158 from a second electrode. The approximate distances are configured to dispose one of either group 130 of electrodes or group 132 of electrodes adjacent to a first blood vessel (e.g., an ulnar artery) and to dispose the other group of either group 130 of electrodes or group 132 of electrodes adjacent to a second blood vessel (e.g., a radial artery). Logic in a wearable pod 101 can be coupled to electrodes in groups 130 and 132 to employ bioimpedance sensing for extracting heart-related information, as well as other physiological information, including but not limited to respiration rates. According to some examples, distances 154 and 158 may be about 4.0 mm+/-50%, and distance 156 may range from about 31.5 mm to about 36.0 mm+/-30%, depending on technologies used to pick-up and monitor bioimpedance signals. Distance 152 may be about 32.0 mm+/-30%.

[0079] According to some embodiments, one or more electrodes of groups 130 and 132 of electrodes may be configured for multi-mode use. For example, an electrode may be implemented to effect bioimpedance sensing in one mode, and electrode may be used to implement galvanic skin conductance sensing in another mode. In some instances, electrode from group 130 may operate cooperatively with an electrode in group 132. Note that while strap 120 may be described as a “strap band” and strap 122 may be described as a “band,” the terms strap and band may be used, at least in some examples, interchangeably.

[0080] In the example shown, the wearable device includes a latch 142, a loop 144, and a latched buckle 140 are configured to engage so as to secure the wearable device around an appendage, such as a wrist. For example, a user may place wearable pod 101 on a top of a wrist, and insert latch 142 through loop 144 adjacent the bottom of the user's wrist, whereby latch 142 engages latched buckle 140. Note while the wearable device is described as being configured to encircle a wrist, and various other embodiments facilitate attachment to any other appendage of the user, including an ankle, neck, ear, etc.

[0081] FIGS. 2A and 2B are diagrams depicting an exploded front view and an exploded perspective view, respectively, of a wearable device, according to some embodiments. Diagram 200 of FIG. 2A depicts a wearable device in an exploded front view, the wearable device including a top pod cover 202 and a bottom pod cover 206 that are configured to enclose an interior region within a cradle 207 having anchor portions 209 that securely couples strap band 220 and band 222 to cradle 207. Strap band 220 is shown to include an inner portion 220a upon which an electrode bus 231 is disposed thereupon. Electrode bus 231 includes electrodes 233 and conductors coupled between electrodes 233 and circuitry within cradle 207. In some embodiments, a near field communications (“NFC”) system 212 can be disposed in contact on electrode bus 231, which may support system 212. Near field communication system 212 may include an antenna to receive/transmit via NFC protocols, and an active near field communication semiconductor device to receive/transmit data. An outer portion 220b is then formed to encap-

sulate electrode bus 231 and NFC system 212 in portions 220b and 220a to form strap band 220, which is anchored at anchor portion 209 to cradle 207. Band 222 is shown to include an inner portion 222a and an outer portion 222b that encapsulates a short-range antenna 214, such as a Bluetooth® LE antenna, and attaches to cradle 207 at anchor point 209. FIG. 2B is a diagram 250 that depicts an exploded perspective view of wearable device described in FIG. 2A.

[0082] FIGS. 3 and 4 are flow diagrams depicting examples of flows for forming a cradle and forming an anchored cradle, respectively, according to some embodiments. FIG. 3 is a flow 300 to form a cradle where, at 302, a metal-based cradle is molded. According to various examples, a metal injection molding (“MIM”) process may be used to form a cradle that is configured to rigidly house circuitry and to secure a strap band and a band to each other. According to some examples, the cradle can be formed using semi-solid metal (“SSM”) casting techniques. A cradle may also be formed thixomolding processes to form, for example, a magnesium-based cradle (“thixo magnesium cradle”) having sufficient strength and being relatively light-weight, according to some embodiments. At 304, a surface of the cradle is prepared by removing unnecessary material and cleaning the cradle, as an example. At 306, a layer is deposited on the surface of the cradle, such as during electro-deposition. In some cases, the layer is protective (e.g., corrosion resistant) and nonconductive. At 308 the metallic interior is accessed to form electrical contact so that, for example, the cradle can be electrically coupled to ground, which is a common ground for some circuitry and, in some cases, the bottom pod cover.

[0083] FIG. 4 is a flow 400 to form an anchored cradle, according to some examples. At 402 a metal-based cradle is received, an example of which is formed by flow 300 of FIG. 3. Further to flow 400 of FIG. 4, some components implemented in a cradle may be set for further processing (e.g., molding). For example, pins, such as pogo pins, can be set prior to molding to prepare formation of a communication port and/or a charging port, which may be implemented as a USB port. As another example, the temperature sensor can be set prior to molding, the temperature sensor configured to extend through the bottom pod cover. At 406, anchor portions of the cradle are formed on the attachment portions. In some embodiments, a first anchor portion of the cradle is formed on a first attachment portion at 408, and a second anchor portion is formed on a second attachment portion of the cradle at 410. Further, an isolation belt may be formed at 412 along sides of the cradle (e.g., the longitudinal sides), the isolation belt being configured to isolate metallic portions of a wearable device from electrically contacting each other. For example, a top pod cover may be electrically isolated from a bottom pod cover or other portions of the wearable device to facilitate capacitive touch sensing. According to some embodiments, the above-described blocks 408, 410, and 412 can be performed in parallel. In one instance, an anchored cradle can be formed in a polycarbonate molding process to form anchor portions and an isolation belt, as well as a layer below the cradle to secure the pins and temperature sensor in place. In some embodiments, one of blocks 408 and 410 can include encapsulating an antenna in an anchor portion, as described herein.

[0084] FIGS. 5A and 5B are diagrams depicting a front view and a perspective view, respectively, of an anchored cradle, according to some embodiments. FIG. 5A is a diagram 500 depicting a front view of an anchored cradle 507 having

anchor portions 509a and 509b formed at the distal ends of cradle 507. Also shown, and isolation belt 511 formed along a longitudinal side of cradle 507. Anchor portion 509a may include, for example, a Bluetooth® low energy (“LE”) antenna formed therein, and anchor portion 509b configured to receive an electrode bus and an NFC antenna (and NFC chip). FIG. 5B is a diagram 550 depicting a perspective view of an anchored cradle 507 of FIG. 5A. Further, diagram 550 depicts pins 580 and a temperature sensor 582 molded and integrated into anchored cradle 507.

[0085] FIGS. 6A to 6C are diagrams depicting formation of an intermediate assembly structure formed in molding process, according to some examples. Consider that an anchored cradle is placed in a mold for forming straps (e.g., strap bands and bands) for a wearable device. Diagram 600 of FIG. 6A depicts a front view of an anchored cradle 607 integrated with an inner strap portion 620a and an inner strap portion 622a. Inner strap portion 620a is secured to an anchor portion at an interface 680, whereby the interface materials of the anchor portion form relatively secure physical and chemical bonds. Similarly, inner strap portion 622a is secured to the other anchor portion and at an interface 682.

[0086] According to some embodiments, the interface materials that form the anchor portions can include, but are not limited to, polycarbonate materials, or other like materials. Polycarbonate may provide an interface to couple metal cradle 607 to an elastomer material used to form inner portions 620a and 622a. Thus, an interface materials, such as polycarbonate, bridges the difficulties of bonding metal and elastomers together in some cases. Anchor portions can be formed using polycarbonate molding techniques. According to some embodiments, an elastomer material may be a thermoplastic elastomer (“TPE”). In one embodiment, elastomer includes a thermoplastic polyurethane (“TPU”) material. In some examples, the elastomer has a hardness in a range of 58 to 72 Shore A. In one case, the lesser has a hardness in a range of 60 to 70 Shore A. An example of an elastomer is a GLS Thermoplastic Elastomer Versaflex™ CE Series CE 3620 by PolyOne of OH, USA.

[0087] FIG. 6B is a diagram depicting a perspective view of a strap band, going to some examples. Diagram 630 depicts a cavity 690 and apertures 634 in inner portion 620a formed by a mold. Apertures 634 can be for receiving electrodes. FIG. 6C is a diagram 660 depicting a perspective view of an assembly of an electrode bus with an inner portion 620a. As shown, electrode bus 631 includes electrodes 633, which are inserted through corresponding apertures 634 prior to a molding step (e.g., a second shot). According to some embodiments, an elastomer material, such as TPE or TPU, may be used to form a flexible substrate in which Kevlar™-based conductors are encapsulated. In one example, the flexible substrate is formed of TPE and has a hardness of approximately 85 to 95 Shore A (e.g., about 90 Shore A).

[0088] FIGS. 7A to 7B are diagrams depicting formation of another intermediate assembly structure formed in molding process, according to some examples. Diagram 700 of FIG. 7A depicts formation of outer portion 720a and outer portion 722b in a molding step. In particular, an anchored cradle 707 includes anchored portions 709a and 709b integrated and/or physically coupled to inner portion 722a and inner portion 720a, respectively, subsequent to the molding process described in FIGS. 6A to 6B. Further to FIG. 7A, anchored cradle and inner portions 720a and 722a can be inserted into a mold and material can be injected into the mold to form

outer portion **720b** over anchor portion **709b** and inner portion **720a**, and to form outer portion **722b** over anchor portion **709a** and inner portion **722a**. In some embodiments, inner portions **720a** and **722a** are formed with the same materials as outer portion **720b** and **722b**. Further, inner surface areas **790** and **792** may be integrated and/or coupled to respective surfaces of anchor portion **709b** and **709a** to form a secure mechanical coupling between metal cradle **707** and straps **720** and **722**. Diagram **750** of FIG. **7B** is a perspective view showing formation of outer portions **720a** and **722b**, whereby surface area **792** of outer portion **722b** forms a secure physical and/or chemical bond to an exposed surface of anchor portion **709a**.

[0089] A manufacturing process, according to some embodiments, includes placing an anchored cradle of FIG. **6A** on a fixture for alignment in a mold for receiving a “first shot” of an elastomer to form the inner portions, and the anchored cradle is then transition to receive a “second shot” of elastomer to form the outer portions integrally with the inner portions. Therefore, according to some embodiments, an anchored cradle can be formed in one or two polycarbonate molding steps, with a subsequent formation of a band (including one or more straps) in one or two elastomer molding steps.

[0090] FIGS. **8A** to **8C** are diagrams depicting exploded views of logic, circuitry, and components disposed within the interior of a cradle anchored to two straps, according to some embodiments. Diagram **800** is an exploded front view depicting a cradle **807** integrated with a strap **820** (or strap band) and a strap **822** (or band). A motor **844**, as a source of vibratory energy, and a battery **846** are assembled in the interior of cradle **807**. Next, one or more logic modules and/or circuits **842** are disposed over motor **844** and battery **846**. Light are positioned above logic modules and/or circuits **842** to emit light through a top pod cover (not shown).

[0091] FIG. **8B** is a diagram **830** depicting an exploded front perspective view, according some examples. As shown, a vibratory motor **844** and battery **846** are configured to be mounted within the interior of cradle **807**. Logic modules and/or circuits **842** are mounted over motor **844** and battery **846** (the mounting hardware is omitted for purposes of clarity). Light sources **841** are oriented above the logic modules and/or circuits **842**.

[0092] FIG. **8C** is an exploded perspective view of the components of FIG. **8B**. Logic modules and/or circuits **842** can include a touch-sensitive input/output (“I/O”) controller to detect contact with portions of a pod cover (not shown), a display controller to facilitate emission of light via an opaque or predominately opaque substrate to communicate information to a user, an activity determinator configured to determine an activity based on, for example, sensor data from one or more sensors (e.g., disposed in an interior region between pod covers, or disposed externally thereto). Further, logic modules and/or circuits **842** may include a bioimpedance (“BI”) circuit to use bioimpedance signals to determine a physiological signal (e.g., heart rate), and a galvanic skin response (“GSR”) circuit to use signals to determine skin conductance. Logic modules and/or circuits **842** may include a physiological (“PHY”) signal determinator configured to determine physiological characteristics, such as heart rate, respiration rate, among others, and a temperature circuit configured to receive temperature sensor data to facilitate determination of heat flux or temperature. A physiological (“PHY”) condition determinator implemented in logic modules and/or circuits **842** may be configured to implement heat

flux or temperature, or other sensor data, to derive values representative of a condition (e.g., a biological condition, such as caloric energy expended or other calorimetry-related determinations). Other structures, circuits, and/or functions within the scope of the present disclosure.

[0093] FIGS. **9A** and **9B** are diagrams depicting an assembly step in which one or more pod covers of a wearable pod are integrated into a wearable device, according to some embodiments. Diagram **900** depicts a top pod cover **902** oriented for assembly to enclose an interior region **990** of cradle **907** that includes logic, components, circuitry, etc. described, for example, in FIGS. **8A** to **8C**. At this stage of assembly, straps **920** and **922** are anchored to cradle **907**, which includes a temperature sensor **914** configured to protrude external to bottom pod cover **906**. Edges **913** of pod cover **902** may include adhesive/epoxy configured to form a fluid-resistant seal as a barrier to prevent fluids (e.g., gas, liquid, moisture, etc.) from entering interior region **990**. An isolation belt **915**, as shown, is configured to isolate top cover **902** and bottom cover **906**. Similarly, edges of pod cover **906** (and other portions) may also include epoxy to couple to form a wearable pod.

[0094] FIG. **9B** is diagram **950** depicting a bottom perspective view of elements shown in FIG. **9A**. Diagram **950** depicts top cover **902** having epoxy **919** or sealant in the interior of top cover **902** and disposed at or near edges **913**. A wired communications port includes a number of pins **941** (e.g., a USB port) disposed adjacent to magnets **916** mounted in cavities within the bottom **909** of cradle **907**. Magnets **916** are configured to form a magnetic attachment to a corresponding connector that can provide power, ground, and data signals via aperture **942** of bottom pod cover **906**. Also shown in FIG. **9B** is a temperature sensor **914** that extends through temperature **944** to contact skin of a user.

[0095] FIG. **10** is an example of a flow to form wearable device, according to some embodiments. Flow **1000** includes receiving a fix so magnesium cradle having anchor points at **1002**, and forming an antenna in a first anchor portion at **1004**. An example of an antenna being formed in a portion is described in, for instance, FIG. **26**. At **1006**, and neuter strap portion is formed attached to the anchor portions. At **1008**, an electrode bus can be disposed within the inner portion of the strap band, and an NFC antenna can be disposed over the electrode bus at **1010**. At **1012**, an outer strap portion is integrated with the inner strap portion and is further integrated with, or attached to, the anchor portions. At **1014** components including logic, sensors, circuitry, etc. are disposed in a cradle, and pod covers are attached at **1016**. The pod covers are sealed at **1018** to form a fluid-resistant barrier for a wearable pod or device.

[0096] FIG. **11** is an exploded view of an example of a wearable pod having, for example, an opaque surface, according to some embodiments. Diagram **1100** depicts a pod cover **1102** and a pod cover **1106** configured to house circuitry **1142** including one or more substrates **1140** (e.g., printed circuit board, such as a flex circuit board) and any number of associated processor modules, semiconductor devices (e.g., sensors, radio frequency or “RF” transceivers, etc.), electronic components (e.g., capacitors, resistors, sensors, etc.), and memory modules. Diagram **1100** depicts the structure and/or functionality of circuitry **1142** as logic **1111**. According to some embodiments, pod cover **1102** is shown to include touch-sensitive portions **1103** and a display portion **1104** disposed in a top surface **1102a** that predominantly



includes an opaque material, such as a metal, a nontransparent plastic, etc. Note that touch-sensitive portions of pod cover **1102** need not be limited to portions **1103**. For example in some examples, display portion **1104** may also be configured to function as touch-sensitive portion **1103**. As another example, one or more sides and/or surfaces of pod cover **1102** can be implemented as a touch-sensitive portion. An electrical isolator **1110** is shown in diagram **1100**, whereby electrical isolator **1110** is configured to electrically isolate touch-sensitive portions **1103** from logic **1111**, pod cover **1106**, and other components or elements of a wearable pod. In some examples, isolator **1110** can electrically isolate pod cover **1102** and its constituent materials from logic **1111**, pod cover **1106**, and other components or elements of a wearable pod.

[0097] According to some embodiments, pod cover **1102**, logic **1111**, and pod cover **1106** can be assembled to form a wearable pod that can be integrated into a band **1150** of one or more attachment members (e.g., one or more straps, etc.) to form a wearable device. A wearable pod and/or wearable device may be implemented as data-mining and/or analytic device that may be worn as a strap or band around or attached to an arm, leg, ear, ankle, or other bodily appendage or feature. In other examples, a wearable pod and/or wearable device may be carried, or attached directly or indirectly to other items, organic or inorganic, animate, or static. Note, too, that wearable pod enough be integrated into band **1150** and can be shaped other than as shown in FIG. **11** for example, a wearable pod circular or disk-like in shape with display portion **1104** disposed on one of the circular surfaces.

[0098] According to some embodiments, logic **1111** includes a number of components formed in either hardware or software, or a combination thereof, to provide structure and/or functionality for elemental blocks shown. In particular, logic **1111** includes a touch-sensitive input/output (“I/O”) controller **1112** to detect contact with portions of pod cover **1102**, a display controller **1114** to facilitate emission of light, an activity determinator **1116** configured to determine an activity based on, for example, sensor data from one or more sensors **1130** (e.g., disposed in an interior region between pod covers **1102** and **1106**, or disposed externally). A bioimpedance (“BI”) circuit **1117** may facilitate the use of bioimpedance signals to determine a physiological signal (e.g., heart rate), and a galvanic skin response (“GSR”) circuit **1119** may facilitate the use of signals representing skin conductance. A physiological (“PHY”) signal determinator **1118** may be configured to determine physiological characteristic, such as heart rate, among others, and a temperature circuit **1120** may be configured to receive temperature sensor data to facilitate determination of heat flux or temperature. A physiological (“PHY”) condition determinator **1121** may be configured to implement heat flux or temperature, or other sensor data, to derive values representative of a condition (e.g., a biological condition, such as caloric energy expended or other calorimetry-related determinations). Logic **1111** can include a variety of other sensors, some which are described herein, and others that can be adapted for use in the structures described herein.

[0099] Touch-sensitive portions **1103** are configured to detect contact by an item or entity as an input to logic **1111**. According to some embodiments, touch-sensitive portions **1103** are coupled to touch-sensitive input/output (“I/O”) controller **1112**, which is configured to detect a capacitance value at one or more touch-sensitive portions **1103**. Further, touch-sensitive I/O controller **1112** can be configured to detect a

change from one value of capacitance relative to a touch-sensitive portion **1103** to another value of capacitance. If the value of capacitance is within a range of capacitive values that define a contact as a valid “touch,” touch-sensitive I/O controller **1112** can generate a signal including data describing touch-related characteristics of the contact. Examples of a range of capacitance values include approximate values of 0.75 pF to 2.4 pF, or other equivalent values. Further, examples of items or entities for which a “touch” is detected can include tissue (e.g., a finger), a capacitive stylus (or the like), etc. Touch-related characteristics, for example, can include a number of touches per unit time, a time interval during which a touch is detected, a pattern of different durations per unit time (e.g., such as Morse code or other simplified schemes).

[0100] While touch-related characteristics may be a function of time, various implementations need not so limited. For example, consider an implementation of pod cover **1102** with multiple touch-sensitive portions **1103**. Touch-related characteristics in this case may also include an order of touching touch-sensitive portions **1103** to simulate, for instance, a swiping gesture from left-to-right or right-to-left. Other types-related characteristics are possible.

[0101] Display controller **1114** is configured to receive signals indicative of, for example, a mode of operation of a wearable pod, a value associated with a physiological signal (e.g., a heart rate), a value associated with an activity (e.g., a number of steps, a percentage of completion for a goal, etc.), and other similar information. Further, display controller **1114** is configured to cause selective emission of light via display portion **1104**, the emission of light having certain characteristics, such as symbol shapes and colors, to convey specific information.

[0102] Bioimpedance circuit **1117** includes logic in hardware and/or software to apply and receive electrical signals include bioimpedance-related information, which physiological signal determinator **1118** can receive and determine one or more physiological characteristics. For example, physiological signal determinator **1118** can extract a heart rate and/or a respiration rate from one or more bioimpedance signals. One or more examples implementing bioimpedance signals to derive physiological signal values are described in U.S. patent application Ser. No. 13/831,260 filed on Mar. 14, 2013, U.S. patent application Ser. No. 13/802,305 filed on Mar. 13, 2013, and U.S. patent application Ser. No. 13/802,319 filed on Mar. 13, 2013, all of which are incorporated by reference herein. A galvanic skin response circuit **1119** includes logic in hardware and/or software to apply and receive electrical signals that includes skin conductance-related information. According to some embodiments, logic **1111** is configured to use electrodes in a first mode to determine bioimpedance signals, and to use at least one for the electrodes in a second mode to determine galvanic skin conductance. Therefore, one or more electrodes may have multiple functions or purposes. Temperature circuit **1120** includes logic in hardware and/or software to apply and receive electrical signals that includes thermal energy-related information, which, for example, physiological condition determinator **1121** can use to derive values representative of a condition of a user, such as a caloric burn rate, among other things.

[0103] Examples of other sensors **1130** include accelerometer(s), an altimeter/barometer, a light/infrared (“IR”) sensor, an audio sensor (e.g., microphone, transducer, or others), a

pedometer, a velocimeter, a GPS receiver, a location-based service sensor (e.g., sensor for determining location within a cellular or micro-cellular network, which may or may not use GPS or other satellite constellations for fixing a position), a motion detection sensor, an environmental sensor, a chemical sensor, an electrical sensor, a mechanical sensor, a light sensor, and others.

[0104] FIG. 12 is a diagram depicting a touch-sensitive I/O controller, according to some embodiments. Diagram 1200 depicts a touch-sensitive I/O controller 1220 including a touch-sensitive detector 1221, a signal decoder 1222, an action control signal generator 1224 and a context determinator 1226. According to some embodiments, touch-sensitive detector 1221 is coupled to a surface of a pod cover 1202 and is configured to receive one or more signals via a conductive path 1212, the one or more signals indicating a value of detected capacitance. A detected capacitance value can be determined responsive to contact by tissue (e.g., finger 1201) with a portion of pod cover 1202. Touch-sensitive detector 1221 can also be coupled to pod cover 1202 to detect a capacitive value based on contact in a display portion 1203. In some examples, a surface of a pod cover 1202 can include to a surface portion of a substrate, such as a metal substrate, regardless of whether pod cover 1202 is covered in a coating (e.g., anodized or the like).

[0105] Signal decoder 1222 is configured to receive one or more signals to decode or otherwise determine a command based on one or more detected capacitance values, according to some examples. As an example, signal decoder 1222 may decode an enable command to enable decoding of one or more detected capacitance signals, thereby enabling a wearable pod to acquire user input via touch. Or, signal decoder 1222 may decode a disable command to disable decoding of one or more signals detected capacitive signals, thereby preventing inadvertent contact (e.g., during sleep, etc.) from being interpreted as being a valid touch. Further, signal decoder 1222 is further configured to decode a number of detected capacitance values to identify patterns of the detected capacitance values, whereby signal decoder 1222 can decode a pattern of detected capacitance values as a specific command. Signal decoder 1222 can determine a pattern of detected capacitance values based on, for example, a quantity of detected capacitance values per unit time, a time interval during which a detected capacitance value is detected, a pattern of varied durations per unit time and/or different detected capacitance values, etc. Thus, signal decoder 1222 can decode detected capacitance values to determine a command as a function of time.

[0106] Further to the above-described examples, signal decoder 1222 can identify a first pattern of detected capacitance values associated with a first command to, for example, disable implementation of a subset of subsequent detected capacitance values, thereby disabling implementation by a wearable pod of subsequent detected capacitance values (e.g., turning “off” a ‘cap touch’ input feature to exclude inadvertent touches). Signal decoder 1222 can identify a second pattern of detected capacitance values associated with a second command (e.g., a mode command) to, for example, transition the wearable pod to a mode of operation as a function of a capacitance pattern. Also, signal decoder 1222 can transmit a signal indicating a mode command to action control signal generator 1224, which can directly or indirectly effectuate a change in mode of operation. Or, in some other examples, a mode controller of FIG. 15B can be implemented to cause a

change in mode. In some embodiments, action control signal generator 1224 can cause, directly or indirectly, a particular pattern of the light 1214 to be emitted via display 1203 based on the decoded command.

[0107] Context detector 1226, which is optional, may be configured to receive sensor data 1210 and/or data indicating a state of activity (e.g., whether an activity is running, sleeping, or the like). Based on sensor data 1210 and/or activity state data, context detector 1226 can detect context of the wearable pod (e.g., a type of activity in which a user is engaged). Context detector 1226 can transmit context data to signal decoder 1222, which, in turn, can be configured to implement a first set of commands based on one pattern of capacitance values based on a first context (e.g., a person is sleeping), and is further configured to implement a second set of commands based on the identical pattern of detected capacitance value based on a second context (e.g., a person is moving). Thus, context detector 1226 can enable a wearable pod to generate different commands using the same pattern of detected capacitance values based on different contexts.

[0108] FIGS. 13A to 13D are diagrams depicting various aspects of an interface of a wearable pod, according to some examples. FIG. 13A is a diagram 1300 depicting a perspective view of a pod cover 1302 including a display portion 1304 of an interface. As an interface of a wearable pod, an interface can include a portion of pod cover 1302 that is configured to either accept user inputs or provide an output to a user, or both. Therefore, display portion 1304 can be configured to both output information to a user and accept user input. According to some embodiments, pod cover 1302 includes a conductive material, such as metal, to facilitate touch-sensitive interfacing with a wearable pod. As shown, pod cover 1302 has an elongated shape and includes at least a top surface into side surfaces, all of which are configured to form an interior region into which interior components, such as circuitry, can be disposed. Note that various other embodiments, pod cover 1302 can be formed of any shape including, for example, a circular-shaped cover. In some cases, pod cover 1302 can include a surface treatment (e.g., stamped pattern) including cosmetically-pleasing features.

[0109] FIG. 13B is a diagram 1330 depicting a top view of pod cover 1302 including display portion 1304. According to some examples, display portion 1304 includes pixelated symbols formed in an opaque material, such as a metal, a non-transparent plastic, etc. Further, the pixelated symbols may be formed in material to form a predominately opaque material. Other portions of pod cover 1302 can also be formed in an opaque material.

[0110] FIG. 13C is a diagram 1360 depicting an enhanced view of display portion 1304. As shown, a display portion can include pixelated symbol 1362 representing a crescent moon (e.g., related to sleep activities and characteristics), pixelated symbol 1364 representing a clock (e.g., related to reminders or information regarding various things, such as sleep activities and workout activities), and pixelated symbol 1366 representing a running person (e.g., related to movement-related activities and characteristics). Further to FIG. 13C, pixelated symbols 1362, 1364, and 1366 are shown to include arrangements of symbol elements 1363. According to some embodiments, a symbol element 1363 may include a micro-perforation. Thus, pixelated symbols 1362, 1364, and 1366 may include arrangements of micro-perforations and/or emissions of light therefrom. The micro-perforations facilitate a display implementing an opaque material or predominately opaque

material, whereby a micro-perforation is difficult to see, or is otherwise not visible to most individuals without magnifying equipment.

[0111] FIG. 13D is a diagram 1390 that depicts an example of a density of micro-perforations per unit area in a predominately opaque material. As shown, a unit surface area 1394 of an opaque material, such as anodized aluminum, is shown to include four (4) quarters 1392 of micro-perforation. Area 1394 can be defined by the product of the side lengths, L, whereas the area 1392 is one-fourth ( $\frac{1}{4}$ ) an area defined by a circular (in this example) having a radius, R. In one example, micro-perforations 1391 have diameters of 30 microns (e.g., 0.03 mm) and L is 100 microns (e.g., 0.10 mm). Thus, micro-perforations 1391 in this example may account for about 7% of unit area 1394, and the opaque material is approximately 93% of unit area 1394. With these dimensions, the density of micro-perforations is approximately 100 micro-perforations per square millimeter. Other micro-perforation sizes and densities may be implemented.

[0112] According to one example, a predominately opaque material as a portion of a surface can be composed of about 93% opaque material and 7% transparent material per unit area. In another example, a predominately opaque material as a portion of a surface can be composed of about 85% to 98% opaque material per unit area (e.g., approximately 16 to 44 microns), whereas in other examples a predominately opaque material can be composed of about 67% to 99% unit area. In at least one example, a predominately opaque material can be composed of 51% opaque material per unit area. Accordingly, the diameters of micro-perforations 1391 can vary so long as the area consumed by micro-perforations 1391 do not, for example, consume more than 49% of an opaque material. Note while micro-perforations 1391 are depicted as being circular, the size and shape of micro-perforations 1391 are not so limited.

[0113] FIGS. 14A to 14D depict examples of micro-perforations, according to some examples. FIG. 14A is a diagram 1400 depicting a cross-section of a pod cover 1402 and micro-perforations 1405a extending from an outer surface 1411a, 1411b to an inner surface 1413, which is adjacent to light sources (not shown) that transmit light for emission via micro-perforations 1405a. FIG. 14B depicts an example of a tapered micro-perforation, according to some examples. Tapered micro-perforation 1405b is configured to include an opening having a diameter or size 1419a in inner surface 1413, whereas another opening may have a diameter or size 1417a in outer surface 1411a. As shown, diameter 1417a is less than diameter 1419a. According to some embodiments, the ratio of diameter 1419a to diameter 1417a can vary based on the depth 1433 of micro-perforation 1405b. In one example, the ratio can be larger as the depth 1433 increases. In another example, the differences in diameters 1417a and 1419b can vary by  $\pm 10$  microns. A larger-size diameter 1419a can increase collection of light or scattered light rays from a light source such as one or more LEDs.

[0114] FIG. 14C depicts an example of another tapered micro-perforation 1405c. In this example, micro-perforation 1405c has an opening in inner surface 1413 having a diameter 1436 and another opening an outer surface 1411b having a diameter 1435. In one example, size of diameter 1436 may be slightly larger than diameter 1435 as a function of depth 1434, which is less than depth 1433 of FIG. 14B. An example of one of depths 1433 and 1434 is approximately 300 microns, and can vary by 50% (or greater in some cases). Or, in some

examples diameters 1435 and 1436 are equivalent. The shading of micro-perforation 1405c may depict optically-transparent material disposed therein. In some examples, the optically-transparent material may be an optical adhesive, epoxy resin, or sealant having relatively high refractive indices ranging from 1.50 to 1.56, or higher. For example, the refractive index may range from 1.57 to 1.60, or greater. Rather, the optically-transparent material or filler disposed in micro-perforation 1405c may be configured to transmit 95% visible light (e.g., for sidewall areas determined by a diameter of a micro-perforation). The epoxy or filler material may prevent humidity and other environmental factors from affecting internal LEDs (or the like) and/or circuitry. FIG. 14D depicts an example of an angled micro-perforation, according to some embodiments. As shown, micro-perforation 1405 is formed to focus emission of light along at line 1440 at an angle "A," to focus light in a direction a user's eyes most likely are positioned. In this configuration, angle A places line 1440 non-orthogonal to the initial direction of emission from below an inner surface of pod cover 1402. Angle A thereby assists in directing luminosity toward a user and reduces the visibility of such information to other persons' eyes at other positions.

[0115] FIGS. 15A to 15D are diagrams depicting another example of a display portion for a wearable pod, according to some embodiments. Diagram 1500 depicts a wearable pod including a pod cover 1504 integrated or otherwise coupled (e.g., detachably coupled) to a band 1502 or strap 1502 to form a wearable device. In this example, display portion 1506 includes a variety of symbols having multiple functions to convey multiple types of information based on a mode of operation, a type of activity, a contacts, etc. Display portion 1506 can include symbol elements composed of micro-perforations. Further, the symbol elements may emit different colors of light based on the types of information being conveyed.

[0116] FIG. 15B is a diagram depicting another display portion interacting with a display controller, according to some examples. Diagram 1520 depicts a display portion 1521 that includes a display formed in predominately opaque material, whereby the symbol elements formed therein may include various arrangements of micro-perforations. Display controller 1540 includes either hardware or software, or a combination thereof, to implement an alert display controller 1542, a message display controller 1543, a heart rate display controller 1544, an activity display controller 1545, and a notification display controller 1546. Further, display controller 1540 can be coupled to a mode controller 1541, which is configured to provide mode data to display controller 1540. The mode data can describe a mode of operation, a context, an activity, or a condition in which a wearable pod is operating. Responsive to the mode data, display controller 1540 can implement one or more of the above-described controllers 1542 to 1546 to provide mode-specific via display portion 1521. As an example, display controller 1540 can identify a subset of light sources and/or micro-perforations to emit light through an arrangement of micro-perforations constituting one or more symbols indicative of a value of a physiological signal, such as a heart rate.

[0117] Alert display controller 1542 is configured to implement symbols 1522, 1524, and 1526 to provide alerts to a user. Upon detecting a notification to check an application residing, for example, on a mobile computing device, alert display controller 1542 may be configured to cause symbol 1522 to

emit light. Note that according to some embodiments, an illuminated symbol **1522** can alert a user to the availability of an insight. The term “insight” can refer to, for example, data correlated among a state of user (e.g., number of steps taken, number of our slapped, etc.) and other sets of data representing trends, patterns, and correlations to goals of a user (e.g., a target value of a number of steps per day) and/or supersets of generalized (e.g., average values) of anonymized data for a population at-large. With insight data, the user can understand how an activity (e.g., running, etc.) can affect other aspects of health (e.g., amount of sleep as a parameter). In some embodiments, insight data can include feedback information. For example, insights can include data derived by the structures and/or functions set forth in U.S. Pat. No. 8,446,275, which is herein incorporated by reference to illustrate at least some examples.

[0118] Should a reminder or notification arise that requires a user to hydrate or consume water, alert display controller **1542** is configured to cause symbol **1526** to illuminate. Alert display controller **1542** is configured to maintain calendared events and times, and is further configured to receive reminders from another computing device, such as a mobile phone. When emitting light, symbol **1524** may alert a user as a reminder to undertake one of variety of actions based on time or a calendar event. Further, symbol **524** may illuminate with different colors and/or with other symbols in display portion **1521** to indicate one or more of a sleep reminder, a workout reminder, a meal reminder, a custom reminder, and the like.

[0119] Message display controller **1543** is configured to convey a message via display portion **1521**. While symbols **1528** and **1530** can have multiple functionalities, the following descriptions are in the context of conveying messages. For example, message display controller **1543** can cause symbol **1528** to emit light responsive to detecting that the wearable pod and/or a mobile computing device has received, or is receiving, a message of encouragement (electronic “dopamine”) from a friend or family regarding a user’s state or activity. Message display controller **1543** is configured to detect that a friend or family member has communicated a “love tap” (e.g., a gesture, like a squeeze or tap of a wearable pod in the other’s possession). To convey the love tap, message display controller **1543** is configured to cause symbol **1530** and symbols **1528** to emit light.

[0120] Heart rate display controller **1544** is configured to receive physiological signal information based on one or more sensors. For example, the physiological signal information can specify a heart rate related to, for example, a particular mode of operation (e.g., at rest, asleep, moving, running, walking, etc.). Upon receiving data representing a heart rate, heart rate display controller **1544** can select symbols **1530**, **1532**, **1535** in one or more of symbols **1533** to convey heart rate information. In some cases, symbol **1534** indicates a minimum heart rate and symbol **1532** indicates a maximum heart rate. In this context, symbol **1530** may indicate a heart rate measurement is being performed or has been performed.

[0121] Activity display controller **1545** is configured to receive motion or movement-related signal information based on one or more sensors. For example, the motion data can specify a number of motion units (e.g., steps) relative to a goal of total motion units, or the motion data can specify percentage of completion of a user’s activity goal (e.g., a number of steps per day). As such, activity display controller **1545** is configured to select a number of symbols **1533** to specify an amount of progress is being made to a goal. Also,

activity display controller **1544** can select either symbol **1536** to specify progress toward a sleep goal or symbol **1538** to specify progress to a movement goal.

[0122] Notification display controller **1546** is configured to receive data representing a power level of a battery supplying power to a wearable pod. Based on an amount of charge stored in the battery, the notification display controller **1546** can cause symbol **1539** to emit light to indicate a charge level. Notification display controller **1546** is also configured to receive data representing an indication that a user’s action either regarding a wearable pod or a mobile computing device (e.g., an application) has been implemented. To confirm implementation, the notification display controller **1546** is configured to emit light via symbol **1537**.

[0123] FIG. 15C is a diagram depicting an example of an activity display controller interacting with a display portion, according to some examples. Diagram **1550** depicts a display portion **1551** coupled to an activity display controller **1545**. Activity display controller **1545** can receive data originating as accelerometer signals indicative of an activity, and can determine a value indicative of an activity (e.g., an amount of steps toward a goal). Activity display controller **1545** can also determine whether sleep-related information is to be displayed or whether movement-related information as to be displayed, and can identify a quantity of lights from which to emit light, the quantity of lights being proportional to a value indicative of an activity. As shown, activity display controller **1545** is configured to convey information related to a movement-related activity, and thus causes symbol **1556** to illuminate (i.e., shown as shaded). Activity display controller **1545** is configured to determine a user’s progress relative to a goal and selects a subset of symbols from which to emit light. As shown, a user is at 70% toward a goal of 100%. Therefore, activity display controller **1545** causes symbol **1554** (e.g., 10%), symbol **1553** (e.g., 70%), and intervening symbols to illuminate (i.e., shown as shaded). Note that activity display controller **1545** may illuminate symbol **1552** upon reaching a goal, and may further illuminate symbols **1557** to indicate a user’s goal is surpassed (e.g., a user is at 110% of a goal).

[0124] FIG. 15D is a diagram depicting an example of a heart rate display controller interacting with a display portion, according to some examples. Diagram **1560** depicts a display portion **1561** coupled to a heart rate display controller **1544**. Heart rate display controller **1544** can determine that a heart rate is to be displayed, and can identify a quantity of lights and/or micro-perforations from which to emit light, the quantity of lights being proportional to a heart rate. As shown, heart rate display controller **1544** is configured to convey information related to heart rate, and thus causes symbol **1562** to illuminate (i.e., shown as shaded). Heart rate display controller **1544** is configured to determine a user’s heart rate relative to a minimum heart rate (“Min HR”) associated with symbol **1566** and to a maximum heart rate (“Max HR”) associated with symbol **1564**. Further, heart rate display controller **1544** is configured to determine an approximate value of the heart rate relative to gradations from, for example, from 62 beats per minute (“BPM”), which is associated with symbol **1565**, to 150 BPM, which is associated with symbol **1567**. Note that in some examples, each symbol illuminated from symbol **1565** indicates an additional 11 beats per minute (e.g., +/-2 to 4 bpm). In some embodiments, heart rate display controller **1544** can include a heart rate range adjuster **1548** that is configured to track a user’s maximum and minimum heart rates during one or more activities and can adjust the

maximum heart rate values and minimum heart rate values associated with symbols **1567** and **1566**, respectively. Therefore, based on the wellness and health of a user's cardiovascular system and other factors, heart rate range adjuster **1548** can customize the gradations of symbols from symbol **1565** to symbol **1567** for a particular user. Note that the examples of the above-described display controllers are non-limiting examples can include controllers for displaying other information, such as a rate at which calories are burned, among other things.

[0125] FIG. 16 is an example of a flow to form a wearable pod, according to some embodiments. At **602**, a pod cover is received. For example, flow **600** can be by receiving a top pod cover including interface portions including one or more touch-sensitive portions and one or more display portions. In some examples, a top pod cover is configured to have a surface oriented away (e.g., away from a surface of a user) from a point of attachment to or positioning adjacent a user. At **604**, one or more touch-sensitive surface portions may be coupled to logic for detecting contact upon the touch sensitive surface. At **606**, a display portion is aligned adjacent to one or more sources of light such that perforations of the display portion are aligned to respective light sources. The one or more sources of light may be configured to emit light via a predominately opaque surface, at least in some examples. At **608**, anchor portions or structures are formed at one or more distal ends of a touch-sensitive wearable pod. In some examples, a wearable pod and its top pod cover can be elongated in dimensions such that the wearable pod has two or more sides longer than the other two or more sides. In one case, the longer sides extend across a surface of an appendage (e.g., across a wrist) of a user. Shorter sides can be at the distal ends relative to the center or centroid of a wearable pod and/or its cradle. At **610**, the top pod cover is isolated from logic and other portions of a touch-sensitive wearable pod. At **612**, the wearable pod is sealed. For example, a top pod cover can be sealed and a bottom pod cover can be sealed to form a fluid-resistant (e.g., gas-resistant, liquid-resistant, etc.) barrier.

[0126] FIG. 17 illustrates an exemplary computing platform disposed in a wearable pod configured to facilitate a touch-sensitive interface in an opaque or predominately opaque surface in accordance with various embodiments. In some examples, computing platform **1700** may be used to implement computer programs, applications, methods, processes, algorithms, or other software to perform the above-described techniques.

[0127] In some cases, computing platform can be disposed in wearable device or implement, a mobile computing device, or any other device.

[0128] Computing platform **1700** includes a bus **1702** or other communication mechanism for communicating information, which interconnects subsystems and devices, such as processor **1704**, system memory **1706** (e.g., RAM, etc.), storage device **17012** (e.g., ROM, etc.), a communication interface **1713** (e.g., an Ethernet or wireless controller, a Bluetooth controller and radio/transceiver, or other logic to communicate via a variety of protocols, such as IEEE 802.11a/b/g/n (WiFi), WiMax, ANT<sup>TM</sup>, ZigBee®, Bluetooth®, Near Field Communications ("NFC"), etc.) to facilitate communications via a port on communication link **1721** to communicate, for example, with a computing device, including mobile computing and/or communication devices with processors.

[0129] One or more antennas may be implemented as a portion of communication interface **1713** to facilitate wire-

less communication. Also, one or more antennas may be formed external to a wearable pod (e.g., external to a cradle and/or one or more pod covers).

[0130] Processor **1704** can be implemented with one or more central processing units ("CPUs"), such as those manufactured by Intel® Corporation, or one or more virtual processors, as well as any combination of CPUs and virtual processors. Computing platform **1700** exchanges data representing inputs and outputs via input-and-output devices **1701**, including, but not limited to, keyboards, mice, audio inputs (e.g., speech-to-text devices), user interfaces, displays, monitors, cursors, touch-sensitive displays, LCD or LED displays, and other I/O-related devices.

[0131] According to some examples, computing platform **1700** performs specific operations by processor **1704** executing one or more sequences of one or more instructions stored in system memory **1706**, and computing platform **1700** can be implemented in a client-server arrangement, peer-to-peer arrangement, or as any mobile computing device, including smart phones and the like. Such instructions or data may be read into system memory **1706** from another computer readable medium, such as storage device **1708**. In some examples, hard-wired circuitry may be used in place of or in combination with software instructions for implementation. Instructions may be embedded in software or firmware. The term "computer readable medium" refers to any tangible medium that participates in providing instructions to processor **1704** for execution. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media. Non-volatile media includes, for example, optical or magnetic disks and the like. Volatile media includes dynamic memory, such as system memory **1706**.

[0132] Common forms of computer readable media includes, for example, floppy disk, flexible disk, hard disk, magnetic tape, any other magnetic medium, CD-ROM, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, RAM, PROM, EPROM, FLASH-EPROM, any other memory chip or cartridge, or any other medium from which a computer can read. Instructions may further be transmitted or received using a transmission medium. The term "transmission medium" may include any tangible or intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine, and includes digital or analog communications signals or other intangible medium to facilitate communication of such instructions. Transmission media includes coaxial cables, copper wire, and fiber optics, including wires that constitute bus **1702** for transmitting a computer data signal.

[0133] In some examples, execution of the sequences of instructions may be performed by computing platform **1700**. According to some examples, computing platform **1700** can be coupled by communication link **1721** (e.g., a wired network, such as LAN, PSTN, or any wireless communication link or network, such as Bluetooth LE or NFC) to any other processor to perform the sequence of instructions in coordination with (or asynchronous to) one another. Computing platform **1700** may transmit and receive messages, data, and instructions, including program code (e.g., application code) through communication link **1721** and communication interface **1713**. Received program code may be executed by processor **1704** as it is received, and/or stored in memory **1706** or other non-volatile storage for later execution.

[0134] In the example shown, system memory **1706** can include various modules that include executable instructions

to implement functionalities described herein. In the example shown, system memory **1706** includes a touch sensitive I/O control module **1770**, a display controller module **1772**, an activity determinator module **1774**, and a physiological signal determinator module **1776**, one or more of which can be configured to provide or consume outputs to implement one or more functions described herein.

**[0135]** In at least some examples, the structures and/or functions of any of the above-described features can be implemented in software, hardware, firmware, circuitry, or a combination thereof. Note that the structures and constituent elements above, as well as their functionality, may be aggregated with one or more other structures or elements. Alternatively, the elements and their functionality may be subdivided into constituent sub-elements, if any. As software, the above-described techniques may be implemented using various types of programming or formatting languages, frameworks, syntax, applications, protocols, objects, or techniques. As hardware and/or firmware, the above-described techniques may be implemented using various types of programming or integrated circuit design languages, including hardware description languages, such as any register transfer language (“RTL”) configured to design field-programmable gate arrays (“FPGAs”), application-specific integrated circuits (“ASICs”), or any other type of integrated circuit. According to some embodiments, the term “module” can refer, for example, to an algorithm or a portion thereof, and/or logic implemented in either hardware circuitry or software, or a combination thereof. These can be varied and are not limited to the examples or descriptions provided.

**[0136]** In some embodiments, a wearable pod or one or more of its components (e.g., a touch-sensitive I/O controller or a display controller), or any process or device described herein, can be in communication (e.g., wired or wirelessly) with a mobile device, such as a mobile phone or computing device, or can be disposed therein.

**[0137]** In some cases, a mobile device, or any networked computing device (not shown) in communication with a wearable pod (or a touch-sensitive I/O controller or a display controller) or one or more of its components (or any process or device described herein), can provide at least some of the structures and/or functions of any of the features described herein. As depicted in FIG. **11** and/or subsequent figures, the structures and/or functions of any of the above-described features can be implemented in software, hardware, firmware, circuitry, or any combination thereof. Note that the structures and constituent elements above, as well as their functionality, may be aggregated or combined with one or more other structures or elements. Alternatively, the elements and their functionality may be subdivided into constituent sub-elements, if any. As software, at least some of the above-described techniques may be implemented using various types of programming or formatting languages, frameworks, syntax, applications, protocols, objects, or techniques. For example, at least one of the elements depicted in any of the figure can represent one or more algorithms. Or, at least one of the elements can represent a portion of logic including a portion of hardware configured to provide constituent structures and/or functionalities.

**[0138]** For example, a wearable pod or one or more of its components (e.g., a touch-sensitive I/O controller or a display controller), any of its one or more components, or any process or device described herein, can be implemented in one or more computing devices (i.e., any mobile computing device,

such as a wearable device, an audio device (such as headphones or a headset) or mobile phone, whether worn or carried) that include one or more processors configured to execute one or more algorithms in memory. Thus, at least some of the elements in FIG. **11** (or any other figure) can represent one or more algorithms. Or, at least one of the elements can represent a portion of logic including a portion of hardware configured to provide constituent structures and/or functionalities. These can be varied and are not limited to the examples or descriptions provided.

**[0139]** As hardware and/or firmware, the above-described structures and techniques can be implemented using various types of programming or integrated circuit design languages, including hardware description languages, such as any register transfer language (“RTL”) configured to design field-programmable gate arrays (“FPGAs”), application-specific integrated circuits (“ASICs”), multi-chip modules, or any other type of integrated circuit.

**[0140]** For example, a wearable pod or one or more of its components (e.g., a touch-sensitive I/O controller or a display controller), including one or more components, or any process or device described herein, can be implemented in one or more computing devices that include one or more circuits. Thus, at least one of the elements in FIG. **11** (or any other figure) can represent one or more components of hardware. Or, at least one of the elements can represent a portion of logic including a portion of circuit configured to provide constituent structures and/or functionalities.

**[0141]** According to some embodiments, the term “circuit” can refer, for example, to any system including a number of components through which current flows to perform one or more functions, the components including discrete and complex components. Examples of discrete components include transistors, resistors, capacitors, inductors, diodes, and the like, and examples of complex components include memory, processors, analog circuits, digital circuits, and the like, including field-programmable gate arrays (“FPGAs”), application-specific integrated circuits (“ASICs”). Therefore, a circuit can include a system of electronic components and logic components (e.g., logic configured to execute instructions, such that a group of executable instructions of an algorithm, for example, and, thus, is a component of a circuit). According to some embodiments, the term “module” can refer, for example, to an algorithm or a portion thereof, and/or logic implemented in either hardware circuitry or software, or a combination thereof (i.e., a module can be implemented as a circuit). In some embodiments, algorithms and/or the memory in which the algorithms are stored are “components” of a circuit. Thus, the term “circuit” can also refer, for example, to a system of components, including algorithms. These can be varied and are not limited to the examples or descriptions provided.

**[0142]** FIG. **18** is an exploded perspective view of an example of a wearable pod having, for example, a metal surface, according to some embodiments. Diagram **1800** includes a pod cover **1802** composed of conductive material, such as anodized aluminum in which the interior metal is conductive, a pod cover **1806** composed of similar material, and a cradle **1807** configured to be disposed within an interior region defined by pod covers **1802** and **1806**. Cradle **1807** is further configured to house circuitry, including but not limited to a bioimpedance circuit, a galvanic skin response circuit, an RF transceiver (e.g., a Bluetooth Low Energy transceiver), and other electronic components and devices. As

shown, cradle **1807** includes attachment portions **1877a** and **1877b** extending from distal ends of cradle **1807**, attachment portions **1877a** and **1877b** being configured to adhere to an interface material that can constitute one or more anchor portions. Diagram **1800** also depicts an isolation belt **1815** being formed at a region **1819** along or adjacent one or more longitudinal sides (e.g., sides **1817a** and **1817b**) of cradle **1807**. Region **1819** along sides **1817a** and **1817b** can include one or more edges of pod cover **1802** disposed adjacent to one or more edges of pod cover **1806**. A portion **1815a** of isolation belt **1815** may be disposed between one or more edges of pod cover **1802** and one or more edges of pod cover **1806** to electrically isolate at least a portion of pod cover **1802** from pod cover **1806** and/or cradle **1807** or other circuitry that need not be related to detecting touch.

[0143] Further to FIG. **18**, light sources **1841**, such as light-emitting diodes ("LEDs") or other sources of light, can be positioned to emit light to respective symbols in display portion **1804**. Also shown is a mounting frame **1803** in which to house light sources **1841** in corresponding apertures **1883**. Mounting frame **1803** also includes another aperture **1882** to enable a conductive path **1880** to extend from pod cover **1804** to a touch-sensitive I/O controller circuit (not shown). Other examples of light sources **1841** include, but are not limited to, interferometric modulator display (IMOD), electrophoretic ink (E Ink), organic light-emitting diode (OLED), or other display technologies.

[0144] FIG. **19** is an exploded front view of an example of a wearable pod having, for example, a metal surface, according to some embodiments. Diagram **1900** depicts elements having structures and/or functions as similarly-named or similarly-numbered elements of FIG. **18**. Note that edges **1903** of pod cover **1802** and edges **1906** of pod cover **1806** are configured to be adjacent each other, when assembled, at or near region **1919**. According to some embodiments, a portion **1915a** (e.g., a ridge or rib) is configured to isolate edges **1903** and edges **1906** from contacting each other, thereby facilitating touch-sense of capabilities of pod cover **1802** (e.g., by preventing electrical shorts or other conditions or phenomena).

[0145] FIGS. **20A** to **20B** are respective exploded perspective and exploded front views of a wearable pod including anchor portions, according to some embodiments. Diagram **2000** depicts elements having structures and/or functions as similarly-named or similarly-numbered elements of FIGS. **18** and **19**. Further, diagram **2000** depicts formation of anchor portions **1809a** and **1809b** on attachment portions at the distal ends of cradle **1807**. Also shown is portion **1915a** of an isolator belt that can be formed during the formation of anchor portions **1809a** and **1809b**. As such, the isolator belt and ridge **1915a** can be composed of a material used to form portions **1809a** and **1809b**. Diagram **2050** depicts elements having structures and/or functions as similarly-named or similarly-numbered elements of FIGS. **18** to **20A**. Further, diagram **2050** depicts formation of anchor portions **1809a** and **1809b** formed, for example, contemporaneous with the formation of portion **1915a** of an isolation belt and the formation of an under-layer material **2017**, all of which can be composed of a common material (e.g., an interface material). In some embodiments, anchor portions **1809a** and **1809b**, portion **1915a** of an isolation belt, and under-layer material **2017** can be composed of a thermoplastic. For example, the thermoplastic can include polycarbonate or other similar materials.

[0146] FIG. **20C** is a bottom perspective view of a pod cover implementing a sealant during assembly, according to some embodiments. Diagram **2070** depicts a pod cover **2002** having edges **2013** at least two of which may be disposed adjacent to edges of a bottom pod cover once assembled. Diagram **2070** also shows a sealant **2078** applied on an inner surface portion of pod cover **2002** at or adjacent to one or more edges **2013** of pod cover **2002** to form a fluid-resistant bond to a cradle, an isolation belt, or another structure. In one example, a fluid-resistant bond or barrier is formed to withstand intrusions of water at 1 ATM. Arrangements of micro-perforations **2082** are shown to extend from an inner surface **2079** of a portion of pod cover **2002** to an outer surface **2081** of pod cover **2002**.

[0147] FIG. **20D** is a diagram depicting a perspective front view of a wearable pod being assembled as part of a wearable device, according to some embodiments. Diagram **2080** depicts a pod cover **2002** and a pod cover **2006** being brought together to form respective seals to encapsulate the interior structures and circuitry. For example, when assembled, pod covers **2002** and **2006** enclose a light diffuser **2099** (e.g., for diffusing LED-generated light), which may be optional, mounting frame **2003**, and cradle **2007**. Further, straps **2020** and **2022** are respectively molded on anchor portions **1809b** and **1809a**, respectively, whereby anchor portions **1809a** and **1809b** are composed of interface materials configured to securely couple cradle **2007** to straps **2020** and **2022**. In some embodiments, cradle **2007** comprises a metal material and straps **2020** and **2022** may be composed of a pliable material, such as an elastomer. Note that logic may be disposed within cradle **2007** under mounting frame **2003**. Examples of such logic include a bioimpedance circuit disposed in cradle **2007** and configured to couple to a first subset of conductors to receive electrical signals embodying physiological data originating from points in space adjacent to blood vessels in tissue. Also, such logic can include a galvanic skin response circuit disposed in cradle **2007** and configured to couple to a second subset of conductors to receive electrical signals indicative of a conductance value across a portion of tissue. Further, a cross-section view X-X' of a portion of an isolation belt and the edges of pod covers **2002** and **2006** are depicted in FIGS. **21A** and **21B**.

[0148] FIGS. **21A** and **21B** are diagrams depicting a cross-section of a portion of an isolation belt, according to some examples. Diagram **2100** is a cross-section view of an assembled wearable pod including a pod cover **2102** attached to interior structures and a pod cover **2106** that is also attached to interior structures. Diagram **2100** also depicts an inset **2130** diagram that includes a cross-section view of an isolation belt. As shown in inset **2130** diagram of FIG. **21B**, an isolation belt **2115** formed on or adjacent a cradle **2107**. Isolation belt **2115** includes a portion **2115a** (or ridge **2115a**) that isolates pod cover **2102** from pod cover **2106**. According to some embodiments, a sealant **2170** is configured to form a fluid-resistant bond between pod cover **2102** and isolation belt **2115** and/or **2107**.

[0149] FIG. **22** depicts an example of a flow to form a touch-sensitive pod cover for a wearable pod, according to some examples. Flow **2200** includes forming a pattern at **2202** on a substrate, such as a metal substrate. At **2202**, a cosmetic pattern may be formed on a top surface using stamping or CNC-based machine patterning. Prior to **2202**, a pod cover can be singulated or separated from other metal. In some examples, the pod cover is an aluminum metal substrate. At



**2204**, the contours (e.g., the dimensions and spatial characteristics) of the pod cover are formed. Forming the contours include forming shapes of the sides and top surfaces. At **2206**, a coating can be formed on the surface of the pod cover. For example, an aluminum pod cover can be anodized to form covered surface on the pod cover. At **2208**, a portion of the pod cover is etched to provide access to the aluminum metal substrate (e.g., under the coating) for purposes of electrically coupling the pod cover to, for example, a touch-sensitive I/O control circuit to detect a touch event. For example, a portion of an inner surface of a top pod cover may be etched to facilitate formation of an electrical path to couple one or more touch-sensitive portions of the pod cover to touch-detection logic. At **2210**, perforations may be formed in a touch-sensitive portion of the pod cover. In some examples, the perforations and/or micro-perforations can be formed by drilling a number of perforations with a laser to form one or more symbols. At **2212**, an optically-transparent sealant can be applied to the perforations and/or micro-perforations for form a display portion.

[0150] FIG. 23 depicts an example of a flow for a touch-sensitive wearable pod, according to some embodiments. Flow **2300** includes setting a cradle and components in a first mold. For example, the components can include a temperature sensor and pins (e.g., pogo pins) to form a USB connector (or other types of connectors). At **2304**, an insulator belt is formed and, at **2306**, one or more anchor portions may be formed at one or more attachment portions at one or more distal ends of a cradle. In some examples, the formation of anchor portions includes molding over metal surfaces of the one or more attachment portions with an interface material having properties to facilitate bonding to an elastomer. In at least one example, a thermoplastic material is molded over a magnesium metal surface of one or more cradle attachment portions. In various embodiments, the various thermal plastic materials are suitable for the above-described implementation. In at least one embodiment, the thermal plastic material includes polycarbonate or equivalent. At **2308**, a portion of a pod cover can be etched to provide for electrical contact to a touch-detection circuit. At **2310**, one or more pod covers are selected and a sealant **2312** may be applied thereto. For example, an epoxy may be applied adjacent to one or more edges of a top pod cover, whereby the epoxy may contact a one or more surface of a cradle disposed within an interior region formed between the top pod cover and a bottom pod cover. Note that flow **2300** is not intended to be exhaustive in may be modified within the scope of the present disclosure.

[0151] FIG. 24 is a diagram depicting an antenna configured for implementation in a wearable pod having a metal-lized interface, according to some embodiments. Diagram **2400** includes an antenna **2402** having terminals **2403** and **2405** formed in a first end, the terminals being configured to couple a transceiver disposed in a region enclosed by or defined by a top pod cover and a bottom pod cover, neither of which are shown. As such, antenna **2402** is configured to be implemented external to a metal-based enclosure formed by the pod covers of a wearable pod. Diagram **2400** further shows that antenna **2402** includes a stacked portion **2406** and an extended portion **2408**. Stacked portion **2406** is a portion of metal (e.g., planar metal) that is configured to be oriented in a “stacked” position over an attachment portion, whereas extended portion **2408** is a portion of metal that is configured to “extend” beyond the attachment portion. In some embodiments, extended portion **2408** includes a greater amount of

surface area than stacked portion **2406**. Further, diagram **2400** depicts a gap **2413** in antenna **2402** that separates a metal portion **2410** from a metal portion **2420**, the gap **2413** extending from adjacent one corner **2490** to an opposite corner **2492**. Opposite corner **2042** is disposed diagonally from the other corner **2490** as shown. Note that metal portion **2410** is coupled to metal portion **2420** at a transition portion **2419**, which, at least in some examples, has the smallest width dimension across the surface area of antenna **2402**. In some examples, metal portion **2410** and metal portion **2420** may have equivalent surface areas. In at least one example, metal portion **2410** is disposed predominantly in stacked portion **2406**, whereas metal portion **2420** is disposed predominantly in extended portion **2408**. In some embodiments, stacked portion **2406** is defined, at least in one example, by a portion **2411** of a non-conductive gap **2413**. Diagram **2400** also depicts a number of holes **2418** in antenna **2402** that are configured to align with alignment posts (not shown) on an under-anchor portion during antenna placement. According to some embodiments, antenna **2402** can be configured as a Bluetooth® antenna, such as Bluetooth low energy (Bluetooth LE) antenna, the specifications of which are maintained by Bluetooth Special Interest Group (“SIG”) of Kirkland, Wash., USA. According to other embodiments, antenna **2402** can be designed to receive radio frequency (“RF”) signals associated with other wireless communication protocols, including, but not limited to various WiFi protocols, cellular data signals, etc. According to various other embodiments, other antenna shapes for antenna **2402** are also the scope of the present disclosure. As such, antenna **2402** can serve as antenna for multiple types of RF signals, such as Bluetooth and WiFi.

[0152] FIGS. 25A to 25C depict examples of an antenna oriented relative to an attachment portion of a cradle, according to some embodiments. FIG. 25A is a diagram **2500** depicting a front view of a cradle **2507** having an attachment portion **2577a** extending from a distal end of cradle **2507**, and an attachment portion **2577b** extending from another distal end of cradle **2507**. In this example, cradle **2507** has elongated dimensions, whereby attachment portion **2577a** extends longitudinally (longitudinal direction **2501**) and/or circumferentially away from a center point **2503** of cradle **2507**. In one example, cradle **2507** is composed of metal, such as magnesium, and is configured to be disposed between a top pod cover the bottom pod cover (not shown). Cradle **2507** was further configured to have an interior region for housing circuitry and to accept conductors, such as terminals **2403** and **2405** of FIG. 24, that extend externally from cradle **2507**.

[0153] Further to diagram **2500**, a stacked portion **2406** of planar metal disposed at a first distance to a portion of attachment portion **2577a** of metal cradle **2507**, whereas a portion of extended portion **2408** may be disposed at a second distance (from the portion of attachment portion **2577a**), which is greater than the first distance. In some non-limiting examples, a portion of stacked portion **2406** may parallel or substantially parallel (e.g., non-intersecting in a region) to a portion of attachment portion **2577a**. In some cases, a portion of stacked portion **2406** may be shaped to have one or more radii of curvature as a portion of attachment portion **2577a**.

[0154] In some examples, antenna **2402** can include a stacked portion **2406** that traverses a first region from a radial plane **2513** to a radial plane **2515**, the first region including attachment portion **2577a**. Extended portion **2408** is shown to traverse a second region at an angular distance,  $d_2$ , which is



greater than an angular distance between radial plane 2513 and radial plane 2515. Note that the second region excludes attachment portion 2577a, wherein radial plane 2513 and radial plane 2515 extend radially from a line 2512 parallel to a bottom plane 2588 coextensive with a portion of a bottom of cradle 2507. Radial plane 2517 extends from line 2512 without passing through attachment portion 2577a.

[0155] According to other examples, attachment portion 2577a and a short-range communication antenna 2402 may include bottom surface portions that are coextensive with a curved surface 2511 having one or more radii centered at a point (e.g., on line 2512) in a region below the bottom pod cover. In various implementations, curved surface 2511 may be configured to facilitate attachment to a strap configured to encircle a portion of a wrist (or other circularly-shaped appendages).

[0156] Attachment portion 2577b is configured to extend at a greater distance from a side of a cradle 2507 than attachment portion 2577a to, for example, accommodate different structures and/or functions. As shown, attachment portion 2577b has a surface coextensive with a curved surface 2599 extending from a radial plane 2505 to a radial plane 2598. Radial planes 2505 and 2598 can extend radially from line 2510. According to some embodiments, attachment portion 2577b can be configured to support circuitry, such as conductors, electrodes, a collection of electrodes, electrode bus, and circuitry, such as near-field communications devices (e.g., NFC semiconductor chip).

[0157] FIG. 25B is a diagram 2550 depicting a magnified front view of a cradle 2507 having an attachment portion 2577a extending from a distal end of cradle 2507. As shown, extended portion 2408 is shown to traverse a region 2559 at an angular distance,  $d_2$ , which is greater than angular distance,  $d_1$ . Note that stacked portion 2406 that traverses a region 2558 that includes attachment portion 2577a. Note that region 2558 can include in interface material, such as polycarbonate, when forming an anchor portion. Similarly, region 2559 may include some interface material as well.

[0158] FIG. 25C is a diagram 2570 depicting a magnified perspective view of a cradle 2507 having an attachment portion 2577a extending from a distal end 2599 of cradle 2507. In the example shown, stacked portion 2406 and extended portion 2408, at least in one example, are separated by a portion 2411 of a non-conductive gap 2413. Portion 2411 of non-conductive gap 2413 can include a portion of the plane 2580 that may be orthogonal or substantially orthogonal to plane 2582, which can be coextensive with a surface of attachment portion 2577a. Further, a portion of the interface material may be disposed in gap 2411 when an anchor portion is formed. According to other embodiments, a shortest distance between plane 2582 and stacked portion 2410 may be greater than the shortest distance(s) between extended portion 2408 and plane 2582 as the shortest distances between plane 2582 and stacked portion 2410 are configured to minimize interference for metallic surface of attachment portion 2577a during operation of antenna 2402.

[0159] FIG. 26 is an exploded perspective view of an anchor portion, according to some embodiments. Diagram 2600 includes a cradle 2607 having an under-anchor portion 2679a formed (e.g., molded) thereupon. An antenna 2402 is aligned such that posts 2610 pass through holes 2612 during assembly. According to some embodiments, antenna 2402 is secured to the surface of under-anchor portion 2679a by heat staking posts 2610 (e.g., deforming the tops of posts 2610 to

expand at diameters larger than holes 2612). In one case, the material of posts 2610 are heated and pressure is applied thereto to deform the posts. An over-anchor portion 2679b can be formed (e.g., molded) over antenna 2402 and under-anchor portion 2679a to form a portion 2609a.

[0160] FIG. 27 is an example of a flow to manufacture a communications antenna in a wearable pod and/or device, according to some embodiments. In flow 2700, an antenna is selected, whereby the antenna has a first surface area that extends beyond a second surface area associated with an attachment portion a cradle for a wearable pod, the first surface area being greater than the second surface area. At 2074, an under-anchor portion on the attachment portion maybe formed. Forming the under-anchor portion can include configuring the surface of the under-anchor portion to receive the antenna at 2706. For example, the surface of the under-anchor portion can be configured to include posts extending from the surface of the under-anchor portion. In some cases, a portion of the interface material can be disposed in a first portion of a gap in the antenna, the gap being coextensive with a first plane that is orthogonal or is substantially orthogonal (i.e., more orthogonal than not, or  $\pm 30\%$  from a vector normal to the surface) to a second plane coextensive with a surface of the attachment portion. The under-anchor portion can be formed by shaping surface of the under-anchor portion to be coextensive with a curved surface having one or more radii centered at a point in a region below a bottom of the cradle.

[0161] Further, an antenna can be disposed at 2708 upon the surface of the under-anchor portion. For example, the holes in the antenna may be aligned with the posts, and the antenna can be placed on the surface of the under-anchor portion. For example, the antenna may be disposed on a surface of the under-anchor portion at a distance from a surface area associated with the attachment portion. In at least one example, the posts can be deformed to lock the antenna in position. At 2710, an over-anchor portion may be formed over the antenna and the under-anchor portion to form an anchor portion configured to attach to, for example, a strap composed of the elastomer. Further, the under-anchor and/or over-anchor portions may be composed of an interface material configured to bind to the cradle and to an elastomer. An example of an interface material is polycarbonate, and an example of an elastomer is a thermoplastic elastomer ("TPE"). In one embodiment, an elastomer includes a thermoplastic polyurethane ("TPU") material.

[0162] In one embodiment, selecting the antenna can include selecting a short-range antenna including terminals coupled to a Bluetooth circuit in a cradle of a wearable pod. The antenna includes a stacked portion of planar metal configured to be disposed at a first distance from the attachment portion of metal cradle, and an extended portion of the planar metal configured to be disposed at a second distance, which is greater than the first distance. Also, selecting the antenna can include selecting a Bluetooth antenna to transmit and receive radio signals implementing a Bluetooth protocol. In addition, selecting the antenna can include selecting an antenna having a first metal portion electrically isolated from a second metal portion by a gap extending diagonally or substantially diagonal (i.e., more diagonal than not, or  $\pm 30\%$  from a line passing through two corners) from adjacent one corner of the antenna to an opposite corner of the antenna.

[0163] FIG. 28 is a diagram depicting an antenna configured for implementation in a wearable pod having a metal-lized interface, according to some embodiments. Diagram

**2800** includes a cradle **2807** including an anchor portion **2809b** at which a near field communication (“NFC”) system is disposed. Anchor portion **2809b** is formed with a channel **2819** having a channel support floor **2820** and channel walls **2813**. Channel **2819** is configured to support one or more layers of material above plane **2884**, which is coextensive at least a portion of channel floor **2820**. As shown, near field communication system **2870** includes a communication device **2880** and an antenna **2882**, whereby near-field communication antenna **2882** has a first end disposed in channel **2819** of anchor portion **2809b**. In this example, near field communication system **2870** is disposed external to cradle **2807**. Further, near field communication system **2870** may be disposed external to a periphery of a first pod cover and a second pod cover (neither are shown) over cradle **2807**. Communications device **2880** may have a potting compound formed thereupon.

[0164] In diagram **2800**, antenna **2882** may include a subset of terminals (not shown) disposed at a first end of the antenna in channel **2819**, the subset of terminals being coupled to near-field communication device **2880** mounted on the first end of antenna **2882**. According to some embodiments, near-field communication device **2880** may include an active near-field communication device that may be configured to receive power from adjacent the near-field communication antenna upon which radio frequency radiation is received. This amount of power may be sufficient to cause near field communication device **2880** to transmit data including, for example, a communication device ID. Antenna **2882** includes a metal-based pattern configured to receive near-field communications signals and may include polyamide. According to some embodiments, a region between antenna **2882** and plane **2884** may include one or more other layers, one of which may include an electrode bus as described herein. As such, an electrode bus can provide support for antenna **2882** as well as near field communication device **2880**.

[0165] Further to diagram **2800**, a communications device identifier extractor **2890** is configured to program an identifier into a memory (not shown) in cradle **2807**. The identifier uniquely identifies near field communications device **2880**. As shown, communication device identifier extractor **2890** may be configured to transmit radiation **2898** to cause near field communications device **2880** to transmit an identifier as data **2896**. Then, a communication device identifier extractor can program identifier as data **2894** into memory. In some cases, communication device identifier extractor **2890** may be used during assembly, final test and/or packaging stages of manufacture. A memory in cradle **2807** can store data representing the identifier of near-field communication device **2880**, memory being disposed in a wearable pod. The identifier is accessible to facilitate activation of the near-field communication device. For example, consumer can couple the memory in Internet network to activate, for example, a credit card account.

[0166] According to some embodiments, near-field communication antenna is configured to facilitate radio reception and/or transmission of signals in accordance with near field communication interface and protocols, such as those set forth and/or maintain by International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) of Geneva, Switzerland.

[0167] FIGS. **29A** and **29B** are perspective views of an attachment portion and an anchor portion, respectively, according to some embodiments. Diagram **2900** of FIG. **29A**

depicts attachment portion **2977b** prior to formation of an anchor portion **2809b**, as shown in diagram **2950** in FIG. **29B**.

[0168] FIG. **30** is a diagram depicting another example of a near field communication antenna implemented in a wearable device, according to some examples. Diagram **3000** depicts a near field communication antenna **3082** having terminals **3003** and **3005** being configured to couple via anchor portion **3009b** to circuitry in a cradle **3007** (e.g., a metal cradle), the antenna including planar metal disposed in a layer of material, such as polyamide. A near-field communication device (not shown) in cradle **3007** can be coupled to the near-field communication antenna **3082** via terminal **3003** and **3005**. In some examples, near-field communication antenna may include another set of terminals (not shown) to perform either transmit or receive operations, or both, of the near-field communication device (and/or to provide power to the antenna for communication or processing).

[0169] FIG. **31** is an example of a flow to manufacture a short-range communications antenna in a wearable pod and/or device, according to some embodiments. In flow **3100**, an antenna is selected at **3102**, whereby the antenna has a width dimension configured to be disposed in a wearable strap. For example the width dimension of the antenna is less than the width of the strap and/or wearable pod (e.g., a width less than a top or bottom pod cover). In another example, the width of the antenna is less than the distance between channel walls formed in an anchor portion. In particular, an antenna having a width dimension sized less than a width dimension of a channel may be selected. At **3104**, a cradle having an attachment portion for a wearable pod can be selected, and an anchor portion may be formed on the attachment portion. The anchor portion can be composed of an interface material configured to bind to the cradle and to an elastomer, and the anchor portion can also include a channel to provide support. In one case, the anchor portion as a surface shaped to be coextensive with, for example, a curved surface having one or more radii centered at a point in a region below a bottom of the cradle.

[0170] At **3106**, an inner portion of a wearable strap is formed coupled to an anchor portion including the channel. At **3108**, a portion of the antenna may be disposed in the channel and/or a part of an inner portion of a wearable strap located adjacent a wearable pod. According to some embodiments, a portion of the antenna disposed in the channel may also include and/or be coupled to a near field communications device (e.g., a near-field communication semiconductor device). In particular, terminals of antenna can be coupled to circuitry of a near-field communication semiconductor device disposed on the antenna or substrate that includes an antenna.

[0171] At **3110**, a determination is made whether near field communication logic is external. In particular, a determination is made whether the near field communication device is located external or internal to a cradle. If the near field communication device disposed within a cradle, flow **3100** moves to **3112** at which antenna conductors or terminals are attached coupled to internal logic, including a near-field communication device. Otherwise, flow **3100** moves to **3114** at which a near field communication device mounted on the antenna is encapsulated as an outer portion of the strap is formed at **3116**. At **3118**, identifier associated with logic in the near field communication device is identified. For example, an electromagnetic field can be applied adjacent to the antenna, and the identifier can be read. The identifier may be stored in memory

at 3120. For example, identifier can be programmed in a memory residing in the cradle for subsequent activation by a user.

[0172] FIG. 32 is a diagram depicting examples of an electrode-based wire bus for facilitating physiological characteristic sensing, according to some embodiments. Electrode or wire bus wire bus 3200, and components coupled with the electrode bus 3200 are depicted. Electrode wire bus 3200 may include a bus substrate 3201 that may be made from a flexible and electrically non-conductive material including but not limited to a thermoplastic elastomer and rubber, for example. In one example, the elastomer material can include, for example, TPE or TPU, to form a flexible substrate in which Kevlar™-based conductors are encapsulated. In one example, the flexible bus substrate 3201 is formed of TPE and has a hardness of approximately 85 to 95 Shore A (e.g., approximately 90 Shore A in some cases). A side view of bus substrate 3201 depicts a wire 3212 encapsulated between an upper surface 3201a and a lower surface 3201b of the bus substrate 3201. Wire 3212 may be coupled 3207 with a pad 3203 (shown in dashed line) and pad 3203 may be coupled with an electrode 3202. Electrode 3202 may be coupled with a skirt 3204 and may include a pin 3206 that is positioned in an aperture 3205 of the pad 3203. A dimension of the pin 3206 may be selected to be slightly greater than a diameter of the aperture 3205 so that when the pin 3206 is inserted into the aperture 3205 a press fit is established between the pin 3206 and aperture 3205. Press fitting the pin 3206 into the pad 3203 may provide for a pressure fit that retains the electrode 3202 in contact with the pad 3203 and may also provide for a low electrical resistance connection between the electrode 3202 and pad 3203. The press fit may also be operative to securely couple the skirt 3204, pad 3203 and electrode with one another. Crimping, soldering, or other techniques may be used to couple the pad 3203 and the electrode 3202 with each other, and the press fit is one non-limiting example of how the pad 3203 and electrode may be coupled with each other. A portion of pin 3206 may extend outward of the lower surface 3201b of the bus substrate 3201. After the wire bus 3200 has been fabricated (e.g., by injection molding) the exposed portion of the pin 3206 may be used for electrical continuity testing of one or more of the pad 3203, the electrode 3204, and wire 3212.

[0173] Wire 3212 may be connected with a portion of pad 3203 using soldering, crimping, wrapping, or welding for example. As one example, wire 3212 may be laser welded to a portion of pad 3203. Pad 3203, the electrode 3202 or both may be made from an electrically conductive material including but not limited to a metal, a metal alloy, copper, gold, silver, platinum, aluminum, stainless steel, and alloys of those metals. As one example, pad 3203 may be a copper (Cu) washer. Wire 3212 may include insulation 3213 that may be stripped to expose a conductor 3214 that may be connected with the pad 3203. Wire 3212 may be routed along a path in the wire bus 3200 and may exit the wire bus 3200 at a distal end 3209. A portion of the wire 3212 positioned at the distal end 3209 may be stripped to expose conductor 3214 and the conductor 3214 may be tinned (e.g., with solder) in preparation for connecting the conductor 3214 with another structure, such as an electrical node, printed circuit board (PCB) trace, or circuitry, for example. A portion of the wire 3212 positioned at the distal end 3209 may be dressed for subsequent connection with other structures. There may be more

electrodes 3202, pads 3203, skirts 3204 and wires 3212 than depicted as denoted by 3221 and 3223.

[0174] Bus substrate 3201 may include alignment structures (e.g., see 3407 in FIGS. 34 and 35) that may be used to mount other components to the wire bus 3200, such as an antenna and a near field communication chip, for example. Bus substrate 3201 may include a thickness  $t$  that may be 1 mm or less in thickness. The material used for bus substrate 3201 may be selected to sustain a continuous pull load of about 2 kg and to sustain a maximum pull load of about 8 kg. Actual force loads may be application dependent and the foregoing are non-limiting examples.

[0175] In example 3240, electrode 3202 and skirt 3204 may be positioned relative to an aperture 3241 of an inner strap of a strap band (not shown). A material 3243, such as a material used to form an outer strap of the strap band (e.g., via injection molding). Wire bus 3200, skirt 3204, or structures in a mold may include channels, ports, or other structures configured to provide a path for material 3243 to enter into aperture 3241. From left to right in example 3240, material 3243 (e.g., a thermoplastic elastomer) enters into aperture 3241, fills the aperture 3241 and connects with skirt 3204 along an interface 3245. Skirt 3204 may be made from a material that interfaces with material 3243 to establish a seal between the skirt 3204 and the aperture 3241. A temperature of material 3243 may be operative to heat skirt 3204 and the heat may be operative to form a seal between the electrode 3202 and skirt 3204, skirt 3204 and aperture 3241 or both. Material 3243 may not interface with the electrode 3202 (e.g., a metal material for electrode 3202) and skirt 3204 may be operative as a material that interfaces with electrode 3202 and with material 3243. In some embodiments, skirt 3204 may be made from an interface material configured to integrate electrodes 3203 with a material used to form a strap band, a band, or the like. According to some examples, skirt 3204 may be composed of a polycarbonate material or like material. In some examples, skirt 3204 may expand in dimension when contacted by material 3243 or heat in material 3243 as denoted by 3204e.

[0176] In example 3250, electrode 3202 may include a pin 3206 and skirt 3204 may include an aperture 3204a through which the pin 3206 may be inserted. A mold in which the wire bus 3200 is molded or a jig may include a support structure 3230 having a post 3231 upon which the pad 3203 is mounted. Wire 3212 (e.g., stripped to expose conductor 3214) may be connected with the pad 3203 by soldering, crimping, wire wrapping, welding, or by application of an electrically conductive adhesive or epoxy, for example. A material for the bus substrate 3201 may be formed over the pad 3203 and wire 3212. Post 3231 may prevent the material from entering into the aperture 3205 of the pad 3203 so that in a subsequent processing step, pin 3206 of electrode 3202 and skirt 3204 may be connected with the pad 3203. As described above, a pressure or friction fit may be used to connect the pad 3203 with the pin 3206 of the electrode 3202.

[0177] Examples 3212a-3212d depict various configurations for wire 3212. In example 3212a, wire 3212 may include a conductor 3214 surrounded by an insulator 3213. In example 3212b, wire 3212 may include a conductor 3214 surrounded by an insulator 3213 and the conductor 3214 surrounding a core 3215 (e.g., a concentrically positioned core). Core 3215 may be made from a high strength material such as a composite, Kevlar, fibers, carbon fiber, or the like, for example. Core 3215 may be electrically conducting or electrically non-conducting. Core 3215 may be used to struc-

turally strengthen wire 3212 against forces that may be caused by stretching wire bus 3200 or a strap band that includes the wire bus 3200. In example 3212c, wire 3212, sans insulation 3213, may include the conductor 3214 surrounding the core 3215. In example 3212d, wire 3212 may include a conductor 3214 (e.g., sans insulation 3213 and core 3215).

[0178] FIG depicts examples of a top, side, and bottom plan views of an electrode or wire bus, according to some examples. In a top view 3300, electrodes 3202 may be positioned on bus substrate in alignment with an axis 3301. There may be more or fewer electrodes 3202 disposed on bus substrate 3201 than depicted and those electrodes 3202 may be positioned in alignment with each other or some or all of the electrodes 3202 may not be aligned with one another. Bus substrate 3201 may have a different shape than depicted. For example, bus substrate 3201 may have a taper 3302 in its width. Wires 3212 may be routed along a path in the bus substrate 3201. The path may be determined by one or more wire guides 3325 (depicted in dashed line) positioned in a mold or jig (not shown) that may be used to form the wire bus 3200. Wire guide 3325 may include a slot or channel 3325c in which a portion of the wire 3212 may be positioned. Side portions of electrodes 3202 may be coupled with the skirt 3204.

[0179] In a side view 3320, a portion of the pins 3206 of electrodes 3202 may extend outward of lower surface 3201b of bus substrate 3201. In other examples the pins may not extend outward of lower surface 3201b or may be cut, trimmed, grounded down or otherwise machined to be flush with or inset from lower surface 3201b. Wire bus 3200 may be formed from a material and may include components (e.g., core-reinforced wires) configured to allow flexing, pulling, stretching, twisting of the wire bus 3200 as denoted by 3303. The material for bus substrate 3201 and its associated components may be selected to withstand a range of torsional loads that may be applied to the wire bus 3200 and/or strap bands the wire bus 3200 is positioned in.

[0180] In a bottom view 3340, wires 3212 may be coupled 3207 with their respective pads 3203 and the pads 3203 may include a connection portion configured to receive the wire 3212. Pads 3203 may also include a flat (as will be described below) that allows one of the wires 3212 to be routed past the pad 3203 to another pad 3203.

[0181] FIG. 34 is a diagram depicting an example of a can electrode-wire bus implementing a wire bridge, according to some examples. As shown, wire bridge 3410 may be operative to position wires 3212 for attachment to another structure (e.g., internal to a wearable pod) and may also be used to dress the wires 3212 into a configuration for connection to another structure. A surface of the wire bus 3200 may include one or more structures 3417 configured to receive a component to be connected with the wire bus 3200. Structures 3417 may include a post, a pillar, a notch, a groove, etc., for example.

[0182] FIG. 35 is a diagram depicting an example of a surface of a wire bus including a substrate in which an antenna is formed, according to some examples. As shown, surface 3201b of the wire bus 3200 includes a substrate 3421 having an antenna 3422 coupled 3426 to, for example, a near field communication ("NFC") semiconductor device or chip 3420. Substrate 3421 may be a flexible substrate that may be mounted to wire bus 100 using the structures 3417. For example, structure 3417 may be posts and substrate 3421 may include apertures that match positions with and mate with

structures 3417. Other components may be coupled with wire bus 3200 and the above mentioned substrate 3421 is a non-limiting example. Components coupled with wire bus 3200 may include wires or other types of interconnect structures that may be connected with other components.

[0183] FIG. 36 is a diagram depicting examples of relative spacing and dimensions of electrodes disposed in a wire bus, according to some embodiments. In example 3600, in a side view of wire bus 3200, electrodes 3202 may be positioned relative to one another by a spacing 3202s. In other examples, electrodes 3202 may be spaced apart from one another by a pitch 3202p (e.g., as measured between centers of pins 3206). Electrodes 3202 may have a height 3202h (e.g., as measured from upper surface 3201a to an uppermost surface of the electrode 3202). In example 3610, pairs of adjacent electrodes 3202 may be spaced apart by spacing 3202s or pitch 3202p, and an inner most electrodes 3202' in each pair may be spaced apart by a distance 3202i or a pitch 3202j (e.g., as measured between pin 3206 centers of electrodes 3202'). Spacing 3202s, 3202i and/or pitches 3202p, 3202j may be selected to position the electrodes 3202 within a target range 3620r, when the wire bus 3200 is included in a system or device that positions the electrodes into contact with a surface of a body portion, such as skin on a wrist, arm, leg, neck, torso, etc. As one example, target range 3620r may be determined by a range of sizes for human wrists ranging from skinny wrists having a small circumference and large wrists having a larger circumference. Although there may be some outlier wrist sizes above and below the target range 3620r, the target range 3620r may be selected to capture wrist sizes for a majority of a population of users. Target range 3620r may encompass a portion of a circumference of those wrists that is positioned on a bottom side of the wrists, for example. Electrodes 3202 positioned within the target range 3620r may be positioned to sense or otherwise detect structures or properties on the skin or beneath the skin (e.g., subcutaneous). For example, subcutaneous structures may include blood vessels or other tissues associated with the sympathetic nervous system (SNS); whereas, skin conductance may be a property measured by contact of electrodes with a surface of the skin. In some examples, electrodes 3202 may be components of a biometric sensor system, such as one that senses bioimpedance (BI). Wire bus 3200 may be positioned in a strap band that is mounted to a wrist or other body portion, and as that strap band shifts its position relative to the body portion, the electrodes 3202 may be positioned within the target range 3620r such that reliable signals may be received from electrodes 3202.

[0184] Electrode height 3202h may be selected to provide sufficient contact pressure between the electrode 3202 and a skin surface the electrode 3202 is brought into contact with when the strap band or other device that carries the wire bus 3200 is mounted to a body portion, such as an arm or wrist for example. As will be described below, an upper surface of electrode 3202 may include a surface area (e.g., X\*Y) operative to minimize contact resistance between the electrode 3202 and a skin surface it is placed into contact with and/or to improve a signal-to-noise ratio (S/N) of signals generated by the electrode 3202. The upper surface of the electrode 3202 may have an arcuate shape configured to provide comfort when the electrode 3202 is engaged with the body portion and/or to increase surface area of the electrode 3202.

[0185] FIG. 37 illustrates examples of wire routing configurations and connection to conductive pads formed in a

wire bus, according to some embodiments. In example 3700 a back view of skirt 3204 and pad 3203 includes, for example, a flat 3709 formed in the pad 3203 and operative to allow wire 3212 to be routed pass the pad 3203 for connection with another pad 3203, for example. Pad 3203 may include a notch 3707 where a stripped end of wire 3212 may be positioned for connection of the wire 3212 with the pad 3203. Skirt 3204 may include one or more shot channels 3704. Wire bus 3200 may be positioned in another structure, such as an inner strap band that includes an aperture denoted by dashed line 3720 through which the electrode 3202 and its skirt 3204 may be disposed. A material may be introduced (e.g., injected as part of an injection molding process) into the shot channels 3704 and flow into voids or spaces in the pad 3203, skirt 3204, pad 3203, and into aperture 3720. In example 3710, the material 3730 may fill in and seal a space between the aperture 3720 and the skirt 3204. The material 3730 may also encapsulate structures in the wire bus 3200, such as wires 3212, portions of pad 3203, and portions of skirt 3204, for example. Material 3730 may be introduced into shot channels 3703 via one or more shot ports formed in the wire bus 3200 and aligned with shot channels 3704 during an injection molding process, for example.

[0186] FIG. 38 is a side view 3800 depicts one example of an electrode and related structures, according to some embodiments. As shown, electrode-wire bus 3200 may include an electrode 3202, a skirt 3204, and a pad 3203, among other things. Pin 3206 of electrode 3202 may be inserted 3801 into an aperture 3204a of skirt 3204 and then into aperture 3205 of pad 3203. Electrode 3202 may include a grooved portion 3202g that is positioned in contact with the skirt 3204 and may open into one of the shot channels 3704. The material 3730 (e.g., a thermoplastic elastomer) may flow through shot channels 3704 and a portion of the material 3730 may flow into grooved portion 3202g as well as into other portions (e.g., aperture 3720) as was described above.

[0187] FIG. 39 depicts profile views 3910 and 3920 of other examples of electrode structures, according to some embodiments. As shown, an electrode structure may include an electrode 3202, a skirt 3204, and a pad 3203 formed in wire bus 3200. Pin 3206 of electrode 3202 may include a slot 3206g that may divide a portion of the pin 3206 into sides 3206a and 3206b. Pin 3206 may be inserted 3801 through aperture 3204a and into aperture 3205 of pad 3203. Insertion through aperture 3205 may cause sides 3206a and 3206b to deflect inward toward each other and then expand outward away from each other upon exiting the aperture 3205. The outward expansion of sides 3206a and 3206b may exert force against walls of aperture 3205 and provide a press fit or friction fit between the pad 3203 and the pin 3206, such that the electrode 3202 is securely coupled with pad 3203. The press fit or friction fit may also be operative to securely couple the skirt 3204 between the pad 3203 and the electrode 3202. Front and rear sides of skirt 3204 may include recessed portions 3204c and 3204d. Material 3730 may flow into recessed portions 3204c and 3204d, groove 3202g, and into pad 3203 via opening 3206f in pin 3206.

[0188] FIG. 40 illustrates views of yet other examples of an electrode structure, according to some embodiments. For example, electrode structure can include electrode 3202, a skirt 3204, and a pad 3203 that may be included in a wire bus 3200 are depicted. An uppermost portion 4002u of electrode 3202 may have a height 4002h (e.g., as measured from a top of the skirt or from surface 3201a of bus substrate 3201) that

may be in a range from about 1.0 mm to about 2.5 mm. Height 4002h may be determined in part by a thickness of an aperture (e.g., 3720) that surrounds the electrode 3202 when wire bus 3200 is positioned in another structure, such as an inner strap, for example. If a material that forms the aperture is thick (e.g., 2.0 mm thick), then height 4002h may be higher than would be the case if the material that forms the aperture is thin (e.g., 1.0 mm thick). In some examples, height 4002h may vary among the electrodes 3202. For example, one electrode 3202 may have a height 4002h of approximately 1.5 mm and another electrode 3202 may have a height 4002h of approximately 1.7 mm.

[0189] A surface area 4002a of electrode 3202 may be in a range from about 8.0 mm<sup>2</sup> to about 20 mm<sup>2</sup>. For example, surface 4002a may have a dimension of about 4.0 mm in a X-dimension and about 4.00 mm in a Y-dimension for an area of about 16 mm<sup>2</sup>. Area for surface 4002a may be selected to provide a desired signal-to-noise ratio (S/N) in circuitry coupled with electrode 3202 (e.g., via wire 3212).

[0190] FIG. 41 is a diagram depicting an example of an assembly of a strap band that including a wire bus, an inner strap, and an outer strap, according to some embodiments. In a rear view, wire bus 3200 may be positioned in a previously fabricated lower strap 4100. Inner strap 4100 may include a portion 4100e configured to connect inner strap 4100 with another structure or component. Inner strap 4100 may be connected with another structure or component as part of the previous fabrication. Inner strap 4100 may include apertures 4102 formed in the inner strap 4100 during the previous fabrication. Wire bus 3200 may be moved 4110 into position in inner strap 4100 with its electrodes 3202 and skirts 3204 aligned with apertures 4102 as denoted by dashed lines 4130 which represent an outline of a desired alignment with the apertures 4102 when the wire bus 3200 is positioned in the inner strap 4100. Inner strap 4100 may include a cavity 4135 formed during the previous fabrication and configured to receive the wire bus 3200. Cavity 4135 may mirror an outline of an outer perimeter of the wire bus 3200. The outer strap 4150 will be formed over the connected wire bus and lower strap in a subsequent processing step as will be described below. Outer strap 4150 may also include a portion 4150e configured to connect outer strap 4150 with another structure or component. Portions of surface 3201a of bus substrate 3201 may include a glue, adhesive or the like applied to surface 3201a and operative to facilitate connecting wire bus 3200 with inner strap 4100 (e.g., connecting bus substrate with cavity 4135).

[0191] FIG. 42 depicts an example of a wire bus coupled to an inner strap or inner strap portion, according to some embodiments. Portions 4202 of surface 3201a of bus substrate 3201 may have an adhesive or glue applied to surface 3201a, for example, a pressure sensitive adhesive tape may be applied to one or more portions 4202 of surface 3201a. Wire bus 3200 and inner strap 4100 may be brought into contact 4103 with each other with electrodes 3202 and skirts 3204 aligned 4205 with apertures 4102 as described in reference to FIG. 41. After wire bus 3200 is connected with inner strap 4100, electrodes 3202 extend outward of their respective apertures 4102, and the wire bus 3200 and the inner strap 4100 form sub-assembly 4200.

[0192] In FIG. 43 one example of an outer strap 4340 being formed on sub-assembly 4200 (e.g., wire bus 3200 coupled with an inner strap 4100) is depicted. Sub-assembly 4200 may be positioned in a mold 4310 including features for an

outer strap 4340. A material 4320 (e.g., 3730) such as a thermoplastic elastomer may be injected into mold 4310 to form the outer strap 4340 around the sub-assembly 4200. The outer strap 4340 and inner strap 4200 may form a strap band 4300 that includes portions of the wire bus 3200 encapsulated in the strap band 4300 (e.g., the electrodes 3202 extend outward of inner strap 4200). The material 4320 may flow into shot channels 3704 of skirts 3204 and may seal apertures 4102 as was described above. Inner strap 4200 and outer strap 4340 may be integral with one another after the molding process, such that there may be no visible demarcation of where the inner strap 4200 interfaces with the outer strap 4340. Materials for the inner and outer straps may be the same materials or different materials. Materials for the inner and outer straps may have different colors and may have different surface features or ornamentation. As shown in FIG. 43, a strap band 4300 may be formed with a thermoplastic elastomer material 4320 encapsulating the circuitry therein (e.g., an electrode-wire bus, an NFC chip, an antenna, etc.) to protect it from environmental conditions. Further, interface materials of the skirt and the anchor portions (e.g., as described herein) ensure that elastomer material 4320 bonds/integrates with metal (e.g., stainless steel electrodes and magnesium cradle in the wearable pod).

[0193] A system may include one or more strap bands, with one of the strap bands being configured as strap band 4300 and another of the strap bands not including the wire bus 3200. The system may include two strap bands 4300 with each strap band 4300 having its own encapsulated wire bus 3200 and associated wires 3212, pads 3203, electrodes 3202, and skirts 3204, for example. The number and placement of electrodes 3202 in the two strap bands 4300 may be the same or different (e.g., one strap band 4300 may have four electrodes 3202 and the other strap band 4300 may have two electrodes 3202). Each strap band in the system may include fastening hardware (e.g., a buckle, a clasp, a latch, etc.) configured to couple the two strap bands with each other and/or to mount the two strap bands to a structure, such as a portion of a human body, such as the arm, the wrist, the leg, the torso, the neck, etc., for example. A system may include two strap bands with each strap band coupled with a device. For example, distal ends of each strap band in the system may couple with a main module that may include structures (e.g., circuitry, PCB traces, etc.) that couple with wires 3212 positioned at the distal end or one or both of the strap bands.

[0194] FIG. 44 depicts top, side and bottom views of one example of a strap band 4300 that includes an encapsulated wire bus 3200 and sealed electrodes 3202. An aperture 4410 configured to accept 4411 fastening hardware for strap band 4300 may be formed by a portion 4201 (e.g., see 4201 in FIGS. 42 and 43) and the molding process of FIG. 43. Strap band 4300 may be flexible 3303 as described above. Moreover, prior to the molding of the outer strap 4340, the substrate 3421 including the antenna 3422 and near field communication chip 3420 may be positioned on the wire bus 3200. Upper surface 4002u of electrodes 3202 (see FIG. 40) may extend above a surface 4300i (e.g., an inner surface) of the inner strap 4200 by a height 4300h in a range from about 1.0 mm to about 2.0 mm, for example. In some examples, height 4300h may vary among the electrodes 3202. For example, one electrode 3202 may have a height 4300h of approximately 0.9 mm and another electrode 3202 may have a height 4300h of approximately 1.2 mm. Subsequent to forming the strap band 4300, a demarcation between the inner strap 4200 and outer strap

4340 may not be discernible (e.g., visually) and the inner and outer straps may appear as a single integrated unit.

[0195] FIG. 45 depicts examples 4550-4580 of fastening hardware that may be coupled with a strap band 4300. In example 4550 a buckle 4510 may include an aperture 4511 through which a sleeve 4512 may be inserted 4513. A pin 4514 may be inserted 4515 into the sleeve 4512 to secure the buckle 4510 to aperture 4410 in the strap band 4300 as depicted in examples 4560-4580. Pin 4514 may be a spring pin or spring bar 4516 (e.g., like those used with watch bands) that may replace pin 4514, sleeve 4512 or both. Spring pin 4516 may include dimensions configured to allow the spring pin 4516 to be inserted 4517 into aperture 4511 of buckle 4510, or if sleeve 4512 is used, then insertion 4517 into sleeve 4512.

[0196] Referring now to FIG. 48, various views 4810-4850 of the strap band 4300 are depicted. Strap band 4300 depicted in views 4810 to 4850 is just one non-limiting example and strap band 4300 may include more or fewer elements than depicted in FIG. 48 and may have an appearance that differs from the examples depicted in FIG. 48. Strap band 4300 may include one or more colors. Strap band 4300 may include one or more surface finishes (e.g., glossy, flat, matte, etc.). Strap band 4300 may be translucent or transparent (e.g., to reveal structure beneath surfaces 4300o and/or 4300i). After strap band 4300 has been fabricated as described above (e.g., in reference to FIGS. 41-45), inner strap 4200 and outer strap 4340 may not be discernible (e.g., visually discernable) and strap band 4300 may appear as a unitary whole (e.g., no visible seams or structures that would indicate strap band 4300 is composed of inner and outer straps). Strap band 4300 may include surface features and/or ornamentation (e.g., for esthetic purposes) on outer surface 4300o and/or inner surface 4300i, for example. Although views 4810-4850 depict dressed wires 3212d, actual configurations for the wires 3212 may be application dependent and are not limited to the examples depicted herein.

[0197] In views 4810-4850, the buckle 4510 is depicted attached to strap band 4300; however, the strap band 4300 need not include the buckle 4510 and the types of fastening hardware that may be coupled with strap band 4300 are not limited to examples depicted herein. Although actual dimensions for strap band 4300 may be application dependent, strap band 4300 may have a width 4821 (see view 4820) in a range from about 8 mm to about 15 mm, for example. In some examples, a width of the strap band 4300 may vary along a length of the strap band 4300. For example, strap band 4300 may be wider at the buckle 4510. Width 4821 may be the smallest width of strap band 4300, for example. A thickness of strap band 4300 may vary along a length of the strap band 4300 (e.g., strap band 4300 may be thicker at distal end 3209); however, notwithstanding the height 4300h of the electrodes 3202 above surface 4300i, strap band 4300 may include a thickness 4831 (see view 4830) in a range from about 0.9 mm to about 3.2 mm, for example. Strap band 4300 may include thickness 4831 along portions of the strap band 4300 that are positioned into contact with a body portion of a user when a device that includes strap band 4300 is worn by the user, such as a portion of an arm adjacent to a wrist of the user. Thickness 4831 may be selected to be the thinnest portion of strap band 4300.

[0198] FIG. 46 depicts one example of a flow diagram 4600 for a method of fabricating a wire bus 3200. At a stage 4602 a pad (e.g., 3203) may be positioned on a pad mount (e.g.,

3230) of a wire bus mold. At a stage 4604 a wire (e.g., 3214 of 3212) may be connected with a portion of the pad. At a stage 4606 the wire may be routed along a wire path. At a stage 4608 a flexible electrically non-conductive material (e.g., a thermoplastic elastomer) is injected into the wire bus mold to form a bus substrate (e.g., 3201) that includes one or more pads with each pad having a wire connected to it. At a stage 4610 the bus substrate may be removed from the wire bus mold. At a stage 4612, a skirt (e.g., 3204) having a shot channel (e.g., 3704) may be connected with an electrode (e.g., 3202). At a stage 4614 the shot channels in the skirts may be aligned with a shot port formed in the bus substrate by a port structure in the wire bus mold. At a stage 4616 the electrode may be connected with the pad (e.g., the electrode 3202 with its connected skirt 3204).

[0199] FIG. 47 depicts one example of a flow diagram 4700 for a method of fabricating a strap band (e.g., 4300) that includes a wire bus 3200. At a stage 4702 a flexible electrically non-conductive material (e.g., a thermoplastic elastomer) may be injected into an inner strap mold. At a stage 4704 an inner strap (e.g., 4100) may be removed from the inner strap mold. At a stage 4706 a wire bus (e.g., 3200) may be aligned with the inner strap. At a stage 4708 the wire bus may be positioned into contact with the inner strap while maintaining alignment between the wire bus and the inner strap. At a stage 4710 the inner strap and its connected wire bus (e.g., sub-assembly 4200) may be positioned in an outer strap band mold. At a stage 4712 a flexible electrically non-conductive material (e.g., a thermoplastic elastomer) may be injected into the outer strap mold. At a stage 4714 a strap band may be removed from the outer strap mold. At a stage 4716 a decision may be made as to whether or not to attach fastening hardware (e.g., 4510, 4512, 4514) to the strap band. If a NO branch is taken, then the flow 4700 may terminate. On the other hand, if a YES branch is taken, then flow 4700 may transition to another stage, such as a stage 4718, for example. At the stage 4718, the fastening hardware is attached to a portion of the strap band.

[0200] Reference is now made to FIG. 49 where examples 4940 and 4960 of a strap band 4900 positioned on a body portion 4990 are depicted. Here, for purposes of explanation, a non-limiting example of a body portion is a wrist; however, the present application is not limited to a wrist and strap band 4900 may be used with other body portions, including but not limited to the torso, the neck, the head, the arm, the leg, and the ankle, for example.

[0201] In example 4940, electrodes 4902 of strap band 4900 may be configured to sense signals, such as biometric signals, from structures of body portion 4990 positioned in a target region 4991. As one non-limiting example, the structure of interest may include the radial artery 4992 and the ulnar artery 4994. The radial artery 4992 is the largest artery that traverses the front of the wrist and is positioned closest to thumb 4995. Ulnar artery 4994 runs along the ulnar nerve (not shown) and is positioned closest to the pinky finger 4993. The radial 4992 and ulnar arteries arch together in the palm of the hand and supply the fingers 4993, thumb 4995 and front of the hand with blood. A heart pulse rate may be detected by blood flow through the radial 4992 and ulnar arteries, and particularly from the radial artery 4992. Accordingly, strap band 4900 and electrodes 4902 may be positioned within the target region 4991 to detect biometric signals associated with the

body, such as heart rate, respiration rate, activity in the sympathetic nervous system (SNS) or other biometric data, for example.

[0202] Target, region 4991 is depicted as being wider than the wrist 4990 and spanning a depth along the wrist 4990 to illustrate that variations in body anatomy among a population of users will result in differences in wrist sizes and some user's may position the strap band 4900 closer to the hand; whereas, other user's may position the strap band 4900 further back from the hand. Now the view in example 4940 is a ventral view of the hand 4990; however, the wrist 4990 has a circumference C that may vary  $\Delta C$  among users. Arrows 4994 indicate a width of the wrist 4990 for the example 4940; however, in a population of users, circumference (see 4971 of example 4960) of a wrist may vary from a minimum Min (e.g., a very small wrist) to a maximum Max (e.g., a very large wrist). To accommodate variations in wrist circumference  $\Delta C$  from Min to Max, dimensions of strap band 4900, dimensions of electrodes 4902 and positions of the electrodes 4902 relative to each other and relative to other structures the strap band 4900 may be coupled with, may be selected to position the electrodes 4902 within the target region 4990 for wrist sizes spanning a minimum wrist size of about 135 mm in circumference to a maximum wrist size of about 180 mm in circumference, for example. In other examples, the dimensions and positions may be selected to position the electrodes 4902 within the target region 4990 for wrist sizes spanning a minimum wrist size of about 130 mm in circumference to a maximum wrist size of about 200 mm in circumference. For example, within the target region 4990, electrodes of strap band 4900 may be positioned to sense signals from the radial 4992 and ulnar 4994 arteries for wrist circumferences within the aforementioned 130 mm to 200 mm range, even when the strap band 4900 overlays a flat or curved surface of the wrist 4990 or is displaced to the left, the right, up, or down as denoted by arrow for S on wrist 4990 due to variations in where user's like to place their strap bands on their wrist 4990. Therefore, the strap band 4900 may not require an exact centered location on wrists 4990 in order for electrodes 4902 to sense signals from structure in the target region 4991 (e.g., 4992 and 4994).

[0203] Some of the electrodes 4902 may have signals applied to them (e.g., are driven) and are denoted as D; whereas, other electrodes 4902 may pick up signals (e.g., receive signals) and are denoted as P. Positioning and sizing of the electrodes 4902 that are adjacent to each other (e.g., a driven D electrode next to a pick-up P electrode) may be selected to prevent those electrodes from contacting each other when the strap band 4900 is bent or otherwise curved when donned by the user. For example, if electrodes 4902 lie on an approximately flat portion of wrist 4990, then adjacent electrodes 4902 (e.g., a D and P) may not be significantly urged inward toward each other because they are lying on an approximately planar surface. On the other hand, if electrodes 4902 lie on a curved portion of wrist 4990, then adjacent electrodes 4902 (e.g., a D and P) may be urged inward toward each other, and if the adjacent electrodes are spaced to close to each other, then their inward deflection might bring them into contact with each other (e.g., they become electrically coupled) and the signal being received by the pick-up P electrode will be the signal being driven on the drive D electrode and not the signal from structure in target region 4991.

[0204] Example 4960 depicts a cross-sectional view of wrist 4990 along a dashed line AA-AA. A circumference of



the wrist 4990 is denoted as 4971 and will vary based on wrist size. As depicted, strap band 4900 is positioned on a ventral portion of wrist 4990 in a region 4975 that is relatively flat; however, in the target region 4991, moving left or right away from 4975 towards the boundary of the target region 4991, the surface of wrist 4990 becomes curved. Moreover, wrist 4990 has curvature in a region 4973 of a dorsal portion of the wrist 4990. Although many users will likely wear a device that includes the strap band 4900 in a prescribed manner in which the electrodes 4902 of the strap band 4900 are placed against the bottom of the wrist 4990 (e.g., the ventral portion), some users may prefer to place the strap band 4900 and its electrodes 4902 on the dorsal portion 4973 where the surface of wrist 4990 includes curvature. In either case, strap band dimensions and electrode dimensions and placement may be selected to establish sufficient contact of the electrodes 4902 with skin of the wrist 4990 within the target region 4991 so that signals driven onto drive D electrodes are coupled with wrist 4990 and signals from wrist 4990 are received by pick-up electrodes P.

[0205] Moving now to FIG. 50 where a side view of a strap band 4900 coupled with a device 4950, such as a wearable pod, is depicted. Here, wearable pod 4950, a band 4920, and strap band 4900 may form a system 5000. Device 4950 may include circuitry, one or more processors (e.g., DSP,  $\mu$ P,  $\mu$ C), memory (e.g., non-volatile memory), data storage (e.g., for algorithms configured to execute on the one or more processors), one or more sensors (e.g., temperature, motion, biometric, ambient light), one or more radios (e.g., Bluetooth—BT, WiFi, near field communications—NFC), circuit boards, a power source, a display (e.g., LED, OLED, LCD), transducers (e.g., a loudspeaker, a microphone, a vibration engine), one or more antennas, a communications interface (e.g., USB), a capacitive touch interface, etc. for example. Device 4950 may include an arcuate inner surface 4950i having a curvature selected to prevent or minimize rotation of system 5000 around wrist 4990 (or other body portion) when system 5000 is donned by a user. Preventing or minimizing rotation of system 5000 may be operative to maintain position of electrodes 4902 within the target region 4991 and/or maintain contact between the electrodes 4902 and skin within the target region 4991. Device 4950 may include ornamentation 4951 (e.g., for esthetic purposes) on an upper surface 4953.

[0206] Band 4920 may be a mechanical band, that is, a band configured to couple with strap band 4900 for donning system 5000 on a body portion of a user, such as the wrist 4990 of FIG. 49. Band 4900 may be purely passive (e.g., no electronics disposed in it) or may be active (e.g., includes circuitry and/or passive and/or active electronic components). Band 4920 may include a latch 4921 configured to mechanically couple with a buckle 4910 disposed on strap band 4900. Latch 4921 and a portion of band 4920 may be inserted through a loop 4913 disposed on strap band 4900. Band 4920 may include an inner surface 4920i and an outer surface 4920o. When band 4920 is inserted into loop 4913 and buckle 4910 a portion of inner surface 4920i may contact a portion of an outer surface 4900o of strap band 4900.

[0207] Strap band 4900 may include a plurality of electrode 4902 positioned on and extending outward of an inner surface 4900i. Electrodes 4902 and a portion of inner surface 4900i may be positioned in contact with skin in target region 4991 (e.g., skin on wrist 4990) when the system 5000 is donned by a user. In addition to electrodes 4902, strap band 4900 may house other components, such as wires for coupling elec-

trodes 4902 with circuitry, antenna, a power source, circuitry, integrated circuits (IC's), passive electronic components, active electronic components, etc., for example.

[0208] Strap band 4900 and band 4920 may couple with device 4950 at attachment points denoted as 4915 and 4925 respectively. For purposes of explanation, attachment points 4915 and 4925 may be used as non-limiting examples of reference points for dimensions described herein. Further, dashed line 4914 on strap band 4900 and dashed line 4924 on band 4920 may be used as non-limiting examples of reference points for dimensions described herein.

[0209] Turning now to FIG. 51 where a top plan view 5110 and a side view 5120 of a strap band 4900 are depicted. In view 5110 (e.g., looking down on inner surface 4900i), dashed line 4915 may serve as a reference point for dimensions A-E. Strap band 4900 may include wires 4912 that exit strap band 4900 proximate its connection point with another structure, such as device 4950 of FIG. 50, for example. Wires 4912 may be coupled with electrodes 4902 and may be coupled with circuitry (e.g., circuitry in device 4950). An overall length of strap band 4900 as measured from line 4915 to line 4914 may be dimension A. Dimension B may be a distance from line 4915 to an edge of electrode 4902. Dimension C may be a distance from line 4914 to an edge of electrode 4902. Dimension D may be a distance between inner facing edges of the two innermost electrodes 4902. Dimension D' may be a distance between centers of the two innermost electrodes 4902, with distance D' being greater than the distance D (i.e.,  $D' > D$ ). Dimension E may be a distance between edges of adjacent electrodes 4902.

[0210] Dimensions A-E are presented in side view in view 5120. In side view 5120, strap band 4900 may include an arcuate portion as denoted by arrows for 5103. Strap band 4900 may be flexible along its length (e.g., from 4915 to 4914). Although some dimensions other than D' are measured from edge-to-edge (e.g., dimension E between edges of adjacent electrodes 4902), center-to-center dimensions may also be used and the present application is not limited to edge-to-edge or center-to-center dimensions for measurements described herein. Side view 5120 depicts electrodes 4902 extending outward of inner surface 4900i of strap band 4900.

[0211] FIG. 52 depicts profile views 5200 and 5250 of a system 5000 including strap band 4900. Views 5200 and 5250 depict the system 5000 in a configuration the system would have if donned on a user (e.g., system 5000 attached to wrist 4990 of FIG. 49). In view 5200, device 4950 is coupled with band 4920 and strap band 4900 with band 4920 inserted through loop 4913 and latch 4921 coupled with buckle 4910. Electrodes 4902 are depicted positioned along inner surface 4900i and having dimensions X and Y. Buckle 4910 includes a gap having a width dimension W that is greater than the Y dimension of electrodes 4902 (e.g.,  $W > Y$ ), so that sliding 4910s buckle 4910 along the strap band 4900 in the direction of arrows for 4910s will allow the buckle 4910 to slide past the electrodes 4902 without making contact with and without establishing electrical continuity with the electrodes 4902.

[0212] Moving to view 5250 where the aforementioned dimensions A-E are depicted along with dimensions for other components of system 5000, namely, dimension G for wearable pod device 4950 and dimension H for band 4920. Dimensions A-E, X, Y, W and G-H may be selected to form a system 5000 that when donned by a user having a body portion circumference (e.g., a circumference of a wrist) in a range from about 130 mm to about 200 mm, will position the



electrodes **4902** within the target region **4991** with sufficient contact force with skin in the target region to obtain a high signal-to-noise-ratio for circuitry that receives signals from pick-up electrodes **P** (e.g., the two innermost electrodes **4902**) in response from signals driven onto drive electrodes **4902** (e.g., the two outermost electrodes **4902**). Although a range from about 135 mm to about 180 mm may be a typical range of wrist sizes found in a population of users, the larger range of from about 130 mm to about 200 mm may represent outlier ranges that are not typical but nevertheless may occasionally be encountered in a population of users. For example, a very skinny wrist of about 130 mm or a very large wrist of about 200 mm may be corner case exceptions to the more typical range beginning at about 135 mm and ending at about 180 mm of circumference.

[0213] Reference is now made to FIG. 53 where views of strap band **4900** and relative dimensions and positions of components of strap band **4900** are depicted. In view **5300**, a system **5000** may include the following example dimensions in millimeters (mm) with an example dimensional tolerance of  $\pm 0.2$  mm or less (e.g.,  $\pm 0.1$  mm): dimension **H** for band **4920** may be 80.0 mm (e.g., from **4924** to **4925** in FIG. 50); dimension **G** for device **4950** may be 45.0 mm (e.g., from **4925** to **4915** in FIG. 50); dimension **A** for strap band **4900** may be 95.0 mm (e.g., from **4915** to **4914** in FIG. 50); dimension **B** from **4915** to an edge of outermost electrode **4902** may be 32.0 mm; dimension **E** from an edge of outermost electrode **4902** to an edge of adjacent innermost electrode **4902** may be 4.0 mm; dimension **D** from an edge of innermost electrode **4902** to an edge of the other innermost electrode **4902** may be 31.5 mm edge-to-edge or dimension **D'** for innermost electrodes **4902** may be 36.0 mm center-to-center; distance **E** from an edge of innermost electrode **4902** to the other outermost electrode **4902** may be 4.0 mm; distance **C** from an edge of the outermost electrode **4902** to **4914** may be 5.5 mm; and a distance **S** of band **4920**, strap band **4900** or both may be 10 mm-11 mm (e.g., a width of the band **4920** and/or strap band **4900**). As one example, distance **D** may be approximately one-third ( $\frac{1}{3}$ ) the dimension **A** for strap band **4900**, such that if **A**=95.0 mm, then **D** may be approximately 31.6 mm, with a tolerance of  $\pm 0.2$  mm or less (e.g.,  $\pm 0.1$  mm).

[0214] Next, consider that a strap band may be configured to dispose a first subsets of electrodes **4902** at about 61 mm along the strap from center of wearable pod **4950** (e.g.,  $(45 \text{ mm}/2)+32 \text{ mm}+4.5 \text{ mm}$  (width of 1<sup>st</sup> electrode)+2.0 mm (half-way between first two electrodes)=61 mm). Also consider, that the second subset of electrodes are located a total of 105.5 mm from the center of wearable pod **4950**. In this example, the first subset is disposed about 58% along a curvilinear line (e.g., following the strap) between the center of the wearable pod to the second subset of electrodes. In some embodiments, the first subset of electrodes may be disposed at ratio of 0.45 to 0.70 relative to the distance at which the second subset of electrodes are disposed (e.g., 45% to 70% of the distance).

[0215] In view **5320**, example dimensions for electrodes **4902** may include a **X** dimension of 4.5 mm and a **Y** dimension of 4.5 mm. Electrodes **4902** may have a height **Z** above inner surface **4900i** of strap band **4900** of 1.5 mm. Dimensional tolerances for dimensions **X**, **Y**, and **Z** may be  $\pm 0.2$  mm or less (e.g.,  $\pm 0.1$  mm). In view **5320** dimension **W** of buckle **4910** may be selected to be greater than dimension **Y** of electrode **4902** to provide clearance between opposing

edges of electrode **4902** and buckle **4910** so that as buckle **4910** slides **4910s** along strap band **4900**, the buckle **4910** does not make contact with electrodes **4902** (e.g., the opposing edges). Dimension **W** may be selected to be about 0.3 mm to about 0.6 mm greater than dimension **Y** of electrodes **4902**. For example, if dimension **Y** is 4.5 mm, then dimension **W** may be 5.0 mm. Buckle **4910** may include guides **4910g** configured to engage with features **4910p** on inner surface **4900i** of strap band **4900** (see view **5340**). For example, prior to attaching loop **4913** to strap band **4900**, strap band **4900** may be inserted through an opening **4910o** of buckle **4910** and guides **4910g** may engage features **4910p** to allow indexing (e.g., a mechanical stop) of the buckle **4910** as it slides **4910s** along the strap band **4900**. The indexing may allow a user of the system **5000** to adjust the fit of the system **5000** to their individual wrist size (e.g., by sliding **4910s** the buckle **4910** along strap band **4900**), while also providing tactile feedback caused by guides **4910g** engaging features **4910p** as the buckle slides **4910s** along the strap band **4900**. Guides **4910g** may also be operative to fix the position of the buckle **4910** on the strap band **4900** after the user adjustment has been made so that the buckle **4910** does not move (e.g., buckle **4900** remains stationary unless moved by the user).

[0216] Dimensions **X**, **Y**, and **Z** of electrodes **4902** may be selected to determine a surface area of the electrodes **4902** (e.g., for surfaces of electrodes **4902** that are urged into contact with skin in target region **4991**). For example, surface area for electrodes **4902** may be in a range from about 10 mm<sup>2</sup> to about 20 mm<sup>2</sup>. In some examples, structure connected with the electrodes **4902** may cover some portion of the surface of the electrodes **4902** and/or sidewall surfaces of the electrodes **4902** and reduce their actual surface area (e.g., skirts **4904** that surround the electrodes **4902**, material of strap band **4900**). For example, with dimensions **X** and **Y** being 4.5 mm such that electrodes **4902** have an actual surface area of 20.25 mm<sup>2</sup>, an effective surface area of the electrodes **4902** that may be exposed above inner surface **4900i** for contact with skin may be 18 mm<sup>2</sup>.

[0217] In view **5340**, structure on inner surface **4900i** of strap band **4900** is depicted in greater detail than in view **5300**. For example, proximate **4915** a portion of dimension **B** may be arcuate and dimension **B** may include dimensions **B1** and **B2**, where dimension **B1** may be the curved portion of **B**. The **Y** dimension for only one of the electrodes **4902** is depicted; however, for purposes of explanation it may be assumed that the **Y** dimensions of the other electrodes **4902** are identical. In view **5340**, strap band **4900** may have a width **S** of 10.0 mm and a thickness **T** of 2.0 mm measured between inner **4900i** and outer **4900o** surfaces. Thickness **T** may be the thinnest section of strap band **4900** and strap band **4900** may be thicker along portions of dimension **B1**. Thickness **T** may be in a range from about 0.9 mm to about 3.2 mm, for example. The following are another example of dimensions in millimeters (mm) for strap band **4900** with example dimensional tolerances of  $\pm 0.2$  mm or less (e.g.,  $\pm 0.1$  mm): dimension **B1** may be 16.91 mm; dimension **B2** may be 15.02 mm; dimension **X** for electrodes **4902** may be 4.46 mm; dimension **Y** for electrodes **4902** may be 4.46 mm; dimension **E** between adjacent electrodes **4902** may be 3.54 mm; may be 3.54 mm; dimension **D** (edge-to-edge) may be 32.54 mm or **D'** (center-to-center) may be 37.0 mm; and distance **C** may be 5.96 mm.

[0218] Attention is now directed to FIG. 54 where side view **5400** and top plan view **5410** of a wire bus **4901w** is depicted.

Wire bus 4901w may be a sub-assembly that is encapsulated (e.g., by injection molding) or otherwise incorporated into strap band 4900. Electrodes 4902 may be mounted on wire bus 4901w and wires 4912 may be connected with electrodes 4902 by a process such as soldering, welding, crimping, for example. Some of the dimensions as described above in regards to FIGS. 51 to 53 may be determined in part by dimensions and placement of electrodes 4902 on wire bus 4901w. As one example a length of wire bus 4901w may be selected to span dimension A of strap band 4900 so that electrodes 4902 on wire bus 4901w are positioned within the target range 4991. Similarly, dimensions B, E, X, Y, D, D', C, S, and T on strap band 4900 may be determined in part by dimensions, positions and sizes of electrodes 4902 on wire bus 4901w. Wire bus 4901w may be made from a material such as a thermoplastic elastomer (e.g., TPE or TPU). The material for wire bus 4901w may be a flexible material. Wire bus 4901w may have a thickness 4901t in a range from about 0.3 mm to about 1.1 mm, for example. Skirt 4904 may be made from a polycarbonate material, for example.

[0219] Electrodes 4902 may include pins 4906 used in mounting the electrodes 4902 to wire bus 4901w. A distance (e.g., a pitch) between centers of pins 4906 may determine the spacing between electrodes 4902 on strap band 4900. For example, spacing 4906 may determine an edge-to-edge distance 4902s between adjacent electrodes 4902 and the distance 4902s may determine distance E on strap band 4900. As another example, an edge-to-edge distance 4902i or a center-to-center distance 4902j between the innermost electrodes 4902' may determine distances D and D' respectively on strap band 4900. A height 4902h from a surface 4901a of wire bus 4901w to a top of electrodes 4902 may determine height Z (see view 5320 of FIG. 53) on strap band 4900, for example. Due to the material used to form the strap band 4900 over the wire bus 4901w the dimension for Z will typically be less than the dimension for 4902h. For example, if Z is 1.5 mm, then 4902h may be 1.7 mm. There may be more or fewer electrodes 4902 on wire bus 4901w as denoted by 5423. Skirts 4904 may be coupled with electrodes 4902 and may be operative as an interface between materials for the strap band 4900 and electrodes 4902 and may form a seal around the electrodes 4902. Skirts 4904 and material used to form the strap band 4900 around the wire bus 4901w may reduce actual surface area of the electrodes to an effective surface area as described above.

[0220] FIG. 55 depicts various examples of electrodes 4902. In example 5500, electrode 4902 may include an arcuate surface and a pin 4906. Height 4902h may be measured from a top surface to a bottom surface of electrode 4902. In example 5510, electrode 4902 may include a groove 4902g and a pin 4906 that includes a slot 4906g. Height 4902h may be measured from a top surface to a surface of groove 4902g. Groove 4902g may be surrounded by skirt 4904 described above in reference to FIG. 54.

[0221] In example 5520, different shaped for electrode 4902 are depicted. Electrode 4902 may have a shape including but not limited to a rectangular shape, a rectangle with rounded corners, a square shape, a square with rounded corners, a pentagon shape, a hexagon shape, a circular shape, and an oval shape, for example.

[0222] In example 5530, surfaces of electrode 4902 may have surface profiles including but not limited to a planar surface 5531, a planar surface 5531 with rounded edges 5533, a sloped surface 5535, an arcuate surface 5537 (e.g., convex),

and an arcuate surface 5539 (e.g., concave). Arcuate surface 5539 may include rounded edges 5538. Surface profiles of electrodes 4902 may be configured to maximize surface area of the electrodes 4902 that contact skin, to provide a comfortable interface between the electrode and the user's skin (e.g., for prolong periods of use, such as 24/7 use), to maximize electrical conductivity for improved signal to noise ratio (S/N), for example.

[0223] In example 5540, electrode 4902 with a planar surface profile 5541 and electrode 4902 having an arcuate surface profile 5543 are depicted engaged with skin of body portion 4990 (e.g., a wrist). After the electrodes 4902 are disengaged with the skin, each electrode 4902 may leave an impression in the skin denoted as 5541d and 5543d. After a period of time has elapsed after the disengaging, the impression 5543d from the electrode 4902 having the arcuate surface profile 5543 may be less pronounced and may fade away faster than the more pronounced impression 5541d left by the electrode 4902 with the planar surface profile 5541. Accordingly, some surface profiles for electrodes 4902 may be more desirable for esthetic purposes (e.g., minimal impression after removal) and for comfort purposes (e.g., sharp edges may be uncomfortable).

[0224] Suitable materials for electrodes 4902 include but are not limited to metal, metal alloys, stainless steel, titanium, silver, gold, platinum, and electrically conductive composite materials, for example. Electrodes 4902 may be coated 5401s with a material operative to improve signal capture, such as silver or silver chloride, for example. Electrodes 4902 may be coated 5401s with a material operative to prevent corrosion or other chemical reactions that may reduce electrical conductivity of the electrodes 4902 are damage the material of the electrodes 4902. Examples of substances that may cause corrosion or other chemical reactions include but are not limited to body fluids such as sweat or tears, salt water, chlorine (e.g., from swimming pools), water, household cleaning fluids, etc.

[0225] Reference is now made to FIG. 56 where examples of circuitry coupled with electrodes 4902 of a strap band 4900 are depicted. In example 5600, electrodes 4902 are depicted engaged into contact with skin of body portion 4990 within target region 4991. Outermost electrodes 4902 may be coupled (e.g., via wires 4912) with drivers 5601d and 5602d operative to apply a signal to the outermost electrodes 4902 (e.g., driven D electrodes 4902). Innermost electrodes 4902 may be coupled (e.g., via wires 4912) with receivers 5601r and 5602r operative to receive signals picked up by innermost electrodes 4902 from electrical activity on the surface of and/or within body portion 4990. Drivers 5601d and 5602d may be coupled with driver circuitry 5620 and receivers 5601r and 5602r may be coupled with pickup circuitry 5630. A control unit 5610 may be coupled with driver circuitry 5620 and with pickup circuitry 5630. Control unit 5610 may include one or more processors, data storage, memory, and algorithms operative to control driver circuitry 5620 and pickup circuitry 5630 to process data received by pickup circuitry 5630, and to generate data used by driver circuitry 5620 to output driver signals coupled with drivers 5601d and 5602d, for example. As one example, electrodes 4902 may sense and/or generate signals associated with biometric functions of the body, such as bioimpedance (BI). Control unit 5610 may perform signal processing of signals associated with driver circuitry 5620 and/or pickup circuitry 5630, or an external resource 5680 and/or cloud resource 5699 in communication 5611 (e.g., via a wired or wireless communication

link) may perform some or all of the processing. For example, control unit **5610** may transmit **5611** data to **5680** and/or **5699** for processing. External resource **5680** and/or cloud resource **5699** may include or have access to compute engines, data storage, and algorithms that are used to perform the processing.

[0226] In example **5640**, strap band **4900** may include a plurality of electrodes **4902** coupled with a switch **5651** that is controlled by a control unit **5650**. Control unit **5650** may command switch **5651** to couple one or more of the electrodes **4902** with driver circuitry **5652** such that electrodes **4902** so coupled become driven electrodes D. Control unit **5650** may command switch **5651** to couple one or more of other electrodes **4902** with pickup circuitry **5654** such that electrodes **4902** so coupled become pick-up electrodes P. There may be more or fewer of the electrodes **4902** as denoted by **5423**. Processing of signals and/or data may be handled by control unit **5650** and/or by external resource **5680** and/or cloud resource **5699** using communications link **5611** as described above. Algorithms and/or data used in the processing may be embodied in a non-transitory computer readable medium (e.g., non-volatile memory, disk drive, solid state drive, DRAM, ROM, SRAM, Flash memory, etc.) configured to execute on one or more processors, compute engines or other compute resources in control unit **5610**, **5650**, external resource **5680** and cloud resource **5699**. Electrodes **4902** in example **5640** may be used to cover additional surface area on body portion **4990** as may be needed to accommodate differences in size of body portion **4990** among a user population. External resource **5680** may be a wireless client device, such as a smartphone, tablet, pad, PC or laptop and may execute an algorithm or application (APP) operative to determine which electrodes **4902** to activate via switch **5651** as driver D or pick-up P electrodes. A user may enter information about their wrist size or other body portion size as data used by the APP to make electrode **4902** selections. Control unit **5610** and/or **5650** may be included in device **4950** of FIG. **50**, for example.

[0227] FIG. **57** depicts profile views of systems **5710-5730** that include strap band **4900**. System **5710** may include device **4950**, band **4920**, and strap band **4900**. Band **4920** and strap band **4900** may be made from a thermoplastic elastomer such as TPE, TPU, TPSV, or others, for example. The thermoplastic elastomer may be covered with an exterior fabric material **5711**, such as cloth or nylon, for example. The electrode **4902** and fastening hardware **4913**, **4921**, **5740** may be anodized or coated with a surface finish such as a colored chrome finish, for example. In system **5710**, buckle **4910** may be replaced with a buckle **5740** configured to slide **4910**s along the exterior fabric material **5711** without damaging the fabric material **5711**.

[0228] System **5720** may include a faux leather exterior surface material **5721** which may have a variety of finishes such as matte, flat, glossy, etc. The finishing layer can be added prior to molding. An example of synthetic leather is known as "leatherette," among others. The fastening hardware of system **5720** may be coated with a surface finish as described above.

[0229] System **5730** includes band **4920** and strap band **4900** that may be from a material **5731**, such as a thermoplastic elastomer such as TPE, TPU, TPSV, or others, for example. Inner surface **4900i** of strap band **4900** includes features operative to index buckle **4910** as was described above in reference to FIG. **53**. Material **5721** which may have

a variety of finishes such as matte, flat, glossy, etc. The fastening hardware of system **5730** may be coated with a surface finish as described above. Device **4950** may include top and bottom portions made from a material such as anodize aluminum that may be anodized in a variety of colors, for example. An upper surface may include ornamental elements **4951**.

[0230] FIG. **58** is a diagram depicting examples of various components configured to determine one or more physiological characteristics, according to some examples. Diagram **5800** includes a physiological information generator **5810** including a sensor selector **5820**, a signal driver **5830**, and a signal receiver **5840**. Physiological information generator **5810** is configured to generate data (e.g., sensor signal data) representing one or more physiological characteristics associated with a user that is wearing or carrying electrodes **5802** and **5804**. Diagram **5800** also depicts a physiological signal component correlator **5850** including a peak detector **5852** and an adaptive signal-to-noise ("SNR") characterizer **5854**, and a physiological characteristic determinator **5860**. In some examples, the components depicted in diagram **5800** may be disposed in a wearable device including a wearable housing and any number of electrodes or any number of the electrode pairs. An array of electrodes may be disposed at a surface of the wearable housing (e.g., a surface confronting tissue of a user), at least a portion of the array including a first subset of electrodes **5802** configured to drive a first signal to a target location and a second subset of electrodes **5804** configured to receive a second signal from the target location. The second signal may be a sensor signal that includes physiological signal components from which data representing one or more physiological characteristics may be extracted.

[0231] Signal driver **5830** may include a drive signal adjuster **5832**, according to some examples. Drive signal adjuster **5832** may be configured to determine a drive signal magnitude (e.g., a drive current magnitude) for a bioimpedance signal to capture a sensor signal that includes data representing a physiological-related component (e.g., pre-processed signal data including data representing physiological characteristics, such heart rate, a galvanic skin response value ("GSR"), a respiration rate, an amount of calories expended, a rate at which energy is expended, etc. Drive signal adjuster **5832** also may be configured to select the drive current signal magnitude as a function of an impedance of a sample of a tissue (e.g., skin, vascular structures, interstitial cellular structures, etc.) such as that of a user. Signal driver **5830** is configured to drive the bioimpedance signal to one or more drive electrodes, such as electrode **5802**, that are configured to convey the bioimpedance signal to a sample of tissue (e.g., at a wrist or any other portion of an organism).

[0232] In view of the foregoing, drive signal adjuster **5832** may include hardware and/or software configured to apply adjustable current signal magnitude to tissue, for example, responsive to an impedance value associated with an impedance value associated with an interface at which electrodes **5802** contact (or nearly contact) tissue. In some instances, an inherent impedance value associated with the interface between the electrode and tissue may arise due to an electrochemical interaction (e.g., between electrons from a current signal and ions associated with biological tissue). As this biologically-induced impedance may vary from person to person (e.g., to different levels of hydration, different minerals and/or nutrients consumed, etc.), drive signal adjuster **5832** is configured to adjust a drive current magnitude to

accommodate various values of impedance at the electrode-tissue interface. As an example, drive signal adjuster **5832** may be configured to adjust a drive current responsive to changes in impedance caused by a buildup of sweat, a movement to other adjacent tissue, etc. Further, drive signal adjuster **5832** may be configured to determine a dynamic range of operation based on the impedance of the sample of tissue, and to select a drive current magnitude for the dynamic range of operation.

[0233] Sensor selector **5820** includes an electrode contact state evaluator **5822**, which is configured to determine a state of contact for one or more drive electrodes **5802** and one or more sink electrodes **5804** (or pick-up electrodes **5804**). In some examples, electrode contact state evaluator **5822** is configured to determine whether an electrode is contacting (or is sufficiently contacting) tissue. To illustrate, consider a case in which there are four electrodes composed of two pairs of drive and pick up electrodes (e.g., a tetrapolar electrode system), whereby one drive electrode **5802** is floating or otherwise not in contact with tissue. Electrode contact state evaluator **5822** can detect the now “tripolar” electrode system, and can generate data indicating such state. Other components of physiological information generator **5810** may use this information, such as drive signal adjuster **5832** to determine or select a modified current profile or magnitude with which to apply to the drive electrode in contact with tissue.

[0234] View of the foregoing, electrode contact data evaluator **5822** facilitates physiological characteristics determination in cases in which less than all electrodes are in contact with tissue. Further, electrode contact state evaluator **5822** can determine a state in which a negligible amount (e.g., none) of the electrodes are in contact with tissue, and then can generate data indicating that a wearable device including electrodes **5802** and **5804** are “off body.” Thus, bioimpedance drive signals may cease or otherwise be reduced and frequency so as to save or otherwise conserve power.

[0235] Signal receiver **5840** includes one or more channel processors configured to process (e.g., amplify and/or filter) and one or more signal channels, and is configured to receive sensor data signals from one or more sink electrodes **5804**, the sensor data signals including received bioimpedance signals that include a physiological signal components. In the example shown, signal receiver **5840** includes one or more first gain amplifiers, such as an instrumentation amplifier (“INA”) channel processor **5841**, and one or more second gain amplifiers, such as a physiological channel processor **5842**. According to some examples, one or more physiological channel processors **5842** can adjust and apply gain configured for a specific physiological characteristic, such as heart rate (e.g., heart rate channel), respiration rate (e.g., respiration rate channel), and/or galvanic skin response (“GSR”) (galvanic skin response channel), etc.

[0236] In view of the foregoing, one or more gain amplifiers of a signal receiver **5840** may be configured to adjust gain based on an impedance of the tissue and/or body of an organism, according to some embodiments. A gain for instrumentation amplifier (“INA”) channel processor **5841** can be adjusted based on, for example, a received bioimpedance signal or sensors data signal, which, in turn, may be derived from an adjusted drive current. With adjustable drive currents and adjustable gains for each channel, signal receiver **5840** may facilitate an optimized or otherwise enhanced signal-to-noise (“SNR”).

[0237] Physiological signal component correlator **5850** is configured to extract one or more physiological characteristics from a portion of a physiological-related signal component. According to some embodiments, physiological signal component correlator **5850** and/or one or more of its components (e.g., some or all components) may be configured to operate in a time domain rather than in a frequency domain. As shown, physiological signal component correlator **5850** may include a peak detector **5852** and an adaptive signal-to-noise characterizer **5854**. Peak detector **5852** is configured to detect a portion of the physiological-related signal component for determining whether the portion includes data representative of a physiological characteristic, such as data indicative of a heart rate or pulse wave. Peak detector **5852** is thus configured to identify a magnitude of a sample, for example, in a window of time that may include biometric data. Adaptive signal-to-noise characterizer **5854** may be configured to determine data representing a value of a signal-to-noise ratio for a portion of a received bioimpedance signal (e.g., a second signal, such as an amplified signal from signal receiver **5840**) including data representing the one or more physiological characteristics. Also, adaptive signal-to-noise characterizer **5854** may be configured to adapt the value of a signal-to-noise ratio over time and/or for other samples. Note that adaptive signal-to-noise characterizer **5854** may be configured to adapt the value of a signal-to-noise ratio as a function of an impedance of tissue. Note, in accordance with some embodiments, physiological signal component correlator **5850** may include one or more components bid to operate in the frequency domain. Physiological characteristic determinator **5860** may be configured to derive (e.g., from data generated by physiological signal component correlator **5850**) physiological signals representative of one or more physiological characteristics.

[0238] According to some embodiments, one or more components depicted in FIG. **58** and subsequent thereto may be implemented in BI Logic circuit **1117** of FIG. **11** or any other disclosed structure. Further, signal receiver **5840** can be implemented in association with pickup circuitry **5630** of FIG. **56** and/or signal driver **5830** may be implemented in association with driver circuitry **5620** of FIG. **56**, according to some examples.

[0239] FIG. **59** is a diagram of an example of an electrode contact state evaluator, according to some examples. Diagram **5900** depicts an electrode contact state evaluator **5950** coupled to a repository **5952** including state data **5954**, which includes data to determine a state for one or more electrodes and control data for transmitting to other components to, for example, generate bioimpedance signals based on state data **5954**. Further, electrode contact state evaluator **5950** is configured to sense a state of contact relative to one or more electrodes **5912** in, for example, a strap **5910** or band of a wearable computing device.

[0240] In the example shown, electrode contact state evaluator **5950** can detect that drive electrode **5913** is floating or otherwise is not contacting tissue. In some cases, a bioimpedance signal may still be applied to tissue to determine physiological characteristics. For example, drive electrode **5914** can be configured to transmit a bioimpedance signal via tissue (not shown) to sink electrodes **5912**. As such, electrode contact state evaluator **5950** can detect the states of each of the electrodes and retrieve control data from state data **5954**, whereby the state data can be transmitted as data **5960** for other components to operate responsive to the state described

above. Thus, a driver current signal magnitude may be selected on a drive current profile associated with the state of contact of for electrodes shown in diagram 5900.

[0241] In another example, electrode contact state evaluator 5950 can determine that a predominant amount of electrodes are in a state indicative of other than contacting tissue (e.g., adjacent a medium or any other material other than tissue). In this example, electrode contact state evaluator 5950 can generate “off body” state data 5962 indicating the wearable computing device is likely not worn. Further, electrodes 5912, 5913, and 5914 may be coupled such that if not coupled to tissue, electrodes may be associated with a particular state, voltage, or current (e.g., pulled up to a potential). In some examples, a DC offset may be applied to a drive electrode to facilitate ion-electron exchange

[0242] FIG. 60 is an example of a number of current profiles with which a drive signal adjuster may adjust current, according to some examples. Diagram 6000 depicts a drive signal adjuster 6002 including a current profiler 6004 and a current selector 6006. Current profiler 6004 can be configured to profile an impedance range of a body or a tissue based on a drive current (e.g., 75 uA, 100 uA, or 120 uA). As shown, current profiler 6004 can determine a number of relationships 6010 in which a voltage between drive contacts may start to saturate. As different individuals have different chemical and biological compositions, a tissue or body impedance may vary over different drive currents. In this example, current profiler 6004 generates a number of relationships 6010 to identify three levels of impedance. A low level of impedance is related to those individuals in which saturation begins between 75 and 100 uA, a medium level of impedance is related to those individuals which saturation begins between 100 and 125 uA, and a high level of impedance is related to those individuals in which saturation occurs above 125 uA. Note that fewer or more levels of impedance can be determined for any current profile. Accordingly, different dynamic ranges 6030 and 6032 also may be determined and employed by current selector 6006 when selecting a drive current for a bioimpedance signal. In some examples, drive signal adjuster 6006 may access current profiles 6010 to drive a specific adjusted current into an electrode. Note that as an impedance of a tissue or a portion of the body changes over time, current profiler 6004 can detect such changes in apply a different current profile (e.g., a different level of impedance) when generating a bioimpedance signal.

[0243] FIG. 61 is a diagram depicting a signal receiver, according to some examples. Diagram 6100 includes a signal receiver 6102 configured to receive a bioimpedance signal from an electrode, and is further configured to apply an adjusted gain to a sensor signal (or received bioimpedance signal) for generating and amplified signal 6160. Amplified signal 6160 includes data representing a portion of a physiological-related signal component that includes data representing a physiological characteristic. Signal receiver 6102 includes channel processors configured to adjust, for example, a first gain to calibrate a magnitude of a sensor signal into a range of magnitude values to form a calibrated sensor signal. The magnitude of the sensor signal may be a function of the impedance of the tissue. Further, another channel processor may be configured to adjust a second gain to calibrate a magnitude of a physiological signal into a range of physiological signal magnitude values.

[0244] Signal receiver 6102 is shown to include an instrumentation amplifier (“INA”) channel processor 6110, which,

in turn, includes a received signal characterizer 6112 and a gain adjuster 6114. In one example, instrumentation amplifier (“INA”) channel processor 6110 is configured to receive a received bioimpedance signal that is composed of a carrier wave (e.g., 32 kHz square or sinusoidal waveform) and physiological-related signal components. In this example, a wearable device is configured to drive (or clock) one or more processing units (e.g., CPUs or micro controllers) at a clock rate of 32 kHz and a signal driver, according to some examples, can generate a bioimpedance signal of the same (or similar frequency) so as to minimize or otherwise reduce noise. Received signal characterizer 6112 is configured to detect a peak value over a unit of time, whereby the peak value is used to characterize an aspect of the bioimpedance signal. For example, in the 3 V powered system, a gain is selected such that an amplified signal is between 1.4 V and 1.6 V. The peak value is associated with 1.3 V or 1.7 V, INA gain adjuster 6114 is configured to adjust the gain accordingly.

[0245] Signal receiver 6102 is also shown to include a physiological channel processor 6120 that further includes a received physiological signal characterizer 6122 and a secondary gain adjuster 6124. Physiological channel processor 6120 is configured to amplify the signal associated with a physiological characteristic, such as heart rate or respiration rate. For example, consider that received physiological signal characterizer 6122 is configured to determine (e.g., digitized) a peak value, a median (or average) value, and a low value. Secondary gain adjuster 6124 is configured to use one or more thresholds for adjusting a gain of physiological channel processor 6120 so as to ensure optimal amplification for further processing.

[0246] FIG. 62 is a diagram depicting a physiological signal component correlator, according to some examples. Diagram 6200 includes a physiological signal component correlator 6202 is configured to receive amplified signal data 6201, for example, from one or more above-identified amplified signal channels. Amplified signal data 6201 may include a portion of the physiological-related signal component that includes data representing a physiological characteristic, the amplified signal being derived from bioimpedance signal based on an impedance value of a tissue. As shown, physiological signal component correlator 6202 includes a peak detector 6210 and a parameter updater 6216. Peak detector 6210 is configured to determine a comparable or equivalent portion of the sample or portion of a physiological-related signal component being analyzed to contact the physiological characteristic, such as the characteristics of a pulse wave. Further, peak detector 6210 may operate, going to some examples, in the time domain to determine an equivalent portion in sampled signal (e.g., an equivalent peak magnitude in equivalent part of a sampled signal). According to some examples, operation in a time domain may employ fewer computational resources and/or power than otherwise might be the case. Thus, peak detector 6210 can operate continuous or nearly continuous mode of string processing.

[0247] To illustrate operation of peak detector 6210, consider the following. Peak detector 6210 includes a data model comparator 6212 is configured to compare a data model 6250 to a sample 6252 of amplified signal 6201 over window of time 6270. We detecting heart rate, a window 6270 may be up to, for example, 1.5 times a period between heart beats. As shown, data model 6250 is a representation of a computed or determined physiological characteristic (e.g., a pulse wave 6260 having a magnitude 6254 at time t1) based on physi-

ological-related signal components. As shown, sample 6262 may include any number of noise components. Peak identifier 6214 may be configured to identify a magnitude 6256 (at time t<sub>2</sub>) of portion 6252 of the physiological-related signal component. Further, data model comparator 6212 may be configured to detect a match between magnitudes 6254 and 6256 (e.g., one or more peak or maximum values) to establish a matched value of a physiological characteristic, whereby the magnitudes may or may not occur substantially at the same time during a window of time, such as window of time 6270. The matched value or other representations of the detected physiological characteristic can be generated as data 6272, which may be sent directly or indirectly to a physiological characteristic determinator.

[0248] According to some examples, data model comparator 6212 is configured to perform correlation operation 6280, such as an autocorrelation operation, on the data representing data model 6270 and data representing portion 6252 of the physiological-related signal component embodied in amplified signal 6201. In other examples, data model comparator 6212 is configured to use any known techniques to determine a correlation (e.g., “sliding correlation”) between the 6250 and sample 6252. In one case, data model comparator 6212 may perform a Pearson correlation operation or the like. By correlating magnitudes and/or peak values between the data model 6250 and sample 6252, peak detector 6210 may operate insensitive or nearly insensitive to a number of maximum values or magnitudes in a signal pattern.

[0249] According to some embodiments, data model 6250 is updated periodically or a periodically to reflect a trend in changes in physiological characteristics (e.g., an increase or decrease in heart rate, respiration rate, or GSR values). Therefore, a magnitude 6256 and other characteristics of sample 6252 may be applied to adjust data model 6250. In other examples, data model 6250 may be developed and maintained as an empirically-generated signal model that includes one or more characteristics (e.g., in terms of magnitude, time, etc.) based on success of or any subsequent sample so that data model 6250 in accordance with trends in a physiological characteristic. In other examples, data model 6250 may be formed by accumulation (e.g., accumulating a signal in a window).

[0250] Data 6220 may be generated as a result of a correlation between data model 6250 and sample 6252 for subsequent processing. Data 6220 may include the value representing a peak period, a window size, a magnitude of the peak value (e.g., a time t<sub>2</sub>), and the like. Parameter updater 6216 is configured to use this or other data to update the parameters for performing peak detection. For example, data 6220 may include updated magnitudes and signal shapes for modifying the data representing data model 6250. According to some examples, physiological signal component correlator 6202 may include one or more input filters tuned for respiration rate bandwidth, heart rate bandwidth, GSR bandwidth, and the like. Note further that side peaks may correlate at least by factor 0.3 for respiration rates and 0.5 for heart rate signal components, according to some examples.

[0251] FIG. 63 is a diagram depicting an example of components of a physiological signal component correlator, according to some embodiments. Diagram 6300 includes a peak variability validator 6302, an adapted signal-to-noise characterizer 6310, and a confidence indicator generator 6340. Confidence indicator generator 6340 is configured to generate confidence factor data 6344 that is indicative of

whether physiological signal data 6342 represents a valid physiological characteristic, such as a valid pulse wave magnitude. Confidence indicator generator 6340 may be configured to determine a confidence indicator value representative of a degree of likelihood that the matched value is representative of the physiological characteristic. Confidence indicator generator 6340 generates confidence factor data 6344 based on data from peak variability validator 6302 and data from adapted signal-to-noise characterizer 6310.

[0252] Peak variability validator 6302 may be configured to determining a time interval between a first magnitude (e.g., a first peak value) and another magnitude (e.g., a second peak value), and to calculate a rate indicative of the value of the physiological characteristic (e.g., a heart rate). Further, confidence indicator generator 6340 may be configured to determine a confidence indicator value based on validating that the rate is within a range of valid rates associated with the physiological characteristic. For example, confidence indicator generator 6340 may be configured to determine a validate a rate over a time interval is within a range of valid heart rates are associated with a heart rate as the physiological characteristic. In some examples, peak variability validator 6302 is configured to define or otherwise maintain time range during which a next magnitude of the physiological characteristic is expected. For example, at a heart rate of 60 bpm a next heartbeat is expected to fall at about 1 second from a previous heart beat. As such, peak variability validator 6302 detects whether a subsequent magnitude or peak value of the physiological characteristic falls outside expected changes in values of heart rates, respiration rates, GSR values, etc. In some examples, peak variability validator 6302 generates data representing either an enable signal or disable signal for generating confidence factor data 6344 by confidence indicator generator 6340.

[0253] Adapted signal-to-noise characterizer 6310 may be configured to adapt a value of a signal-to-noise ratio to form an adapted value of the signal-to-noise ratio based on a bio-impedance signal (e.g., signal based on an impedance value of tissue). Further, adapted signal-to-noise characterizer 6310 may be configured to characterize an adapted value of the signal-to-noise ratio to form a characterized value of the signal-to-noise ratio. Some cases, confidence indicator 6340 is configured to validate the characterized value of the signal-to-noise ratio for determine confidence factor data 6344. According to some embodiments, adapted signal-to-noise characterizer 6310 is configured to characterize the signal-to-noise ratio relative to the amount of noise in sample 6316 over data model 6312. Also, adapted signal-to-noise characterizer 6310 is configured to determine a signal-to-noise value that, for example may be adapted over time or may be adapted responsive to signals derived by different values of impedance (including different drive magnitudes), or both. As shown, and operation 6314 may yield a difference signal 6324 for result 6320, which indicates an amount of noise (e.g., the difference signal 6324) relative to a magnitude 6322. In some examples, the characterization value can be assigned or otherwise indicate relative value of a signal to noise ratio whereby relatively high signal-to-noise ratios may have relatively high characterization values. As such, relatively high characterization values indicate a favorable degree of quality of a signal embodying physiological characteristic. In some cases, confidence indicator generator 6340 can use any combination of the characterization value from adapted signal-to-noise characterizer 6310 and data from peak variability vali-

dator **6302** to generate confidence factor data **6344**. According to some examples, the signal-to-noise ratio can be adapted or otherwise updated subsequently.

[**0254**] In some embodiments, physiological characteristic determinator **6350** receives confidence factor data **6344** and physiological signal data **6342** and generates the physiological signal such as a heart rate, respiration rate, and the like. Note that physiological characteristic determinator **6350** can use the confidence factor data **6344** and a variety of ways. For example, when calculating heart rate physiological characteristic determinator **6350** may receive 8 peak values and 8 corresponding confidence indicator values. Should all the confidence indicator values indicate valid data (e.g., a relatively high likelihood that the detected 8 signals and peak values are accurate), then a heart rate will be validate. But if less than 8 confidence indicator values are indicative of a relatively high likelihood of a detected heart rate, then physiological characteristic determinator **6350** may invalidate the 8 peak values or require further additional information to ensure accurate processing. Physiological characteristic determinator **6350** can determine physiological characteristic, such as heart rate, a respiration rate, a galvanic skin resistance value, data representing an affective state or mode, an amount of energy expenditure, an amount of calories expended, and the like

[**0255**] FIG. **64** is a diagram depicting exemplary operation of a parameter updater, peak variability validator, and an adapted signal-to-noise ratio characterizer, according to various examples. Diagram **6400** includes a parameter updater **6402**, a peak variability validator **6420**, and an adapted signal-to-noise characterizer **6440**.

[**0256**] According to some embodiments, parameter updater **6402** may use a relationship defined by an exponential moving average (“EMA”) **6404** to estimate confidence factor (e.g., a window confidence) by applying EMA **6404** on a detected peak value. “EMA<sub>n-1</sub>” is a previous EMA value, “alpha” is a value based on a SNR value (e.g., a factor, a multiple/inverse multiple of SNR, or a speed parameter), and “x” is a new value for EMA. Also, parameter updater **6402** may update or estimate a new window size and/or a window shift at **6406** based on a new peak period, where “N” is a window size, “Fw” is a window factor (e.g., a constant value), “Nmax” is a maximum window length, “Fs” is a sample rate, “T” is a peak period, and “Shmax” represents a maximum window shift. Parameter updater **6402** may update a window error at **6408** between the latest window and a window accumulator (e.g., including a data model signal) for determining an adaptive signal-to-noise ratio.

[**0257**] A peak variability validator **6420** a variance at **6410** is determine to indicate whether a signal magnitude is within limits (e.g., are valid), according to some examples. In the example shown, a variance is calculated to determine whether it's below a variance limit, where T is a detected period, “TEMA” is an exponential averaging for T, and a variance\_ limit may be defined as a limit value (e.g., 0.2 for heart rate, or 0.4 for breathing).

[**0258**] Adapted signal-to noise characterizer **6440** may generate a signal to noise ratio or were a value indicative thereof. At **6442**, signal-to-noise ratio is determined, where P<sub>sig</sub> represents signal power equal 1, whereby noise power is normalized to 1. P<sub>noise</sub> represents normalized noise power. In some examples, a value of alpha may be calculated as one tenth of a value of SNR for determining a new value of alpha that is indicative of the quality of the SNR value.

[**0259**] FIG. **65** illustrates an exemplary computing platform disposed in a device configured to facilitate physiological signal determination in accordance with various embodiments. In some examples, computing platform **6500** may be used to implement computer programs, applications, methods, processes, algorithms, or other software to perform the above-described techniques.

[**0260**] In some cases, computing platform can be disposed in wearable device **6590c** or implement, a mobile computing device **6590b**, or any other device, such as a computing device **6590a**.

[**0261**] Computing platform **6500** includes a bus **6502** or other communication mechanism for communicating information, which interconnects subsystems and devices, such as processor **6504**, system memory **6506** (e.g., RAM, etc.), storage device **6508** (e.g., ROM, etc.), a communication interface **6513** (e.g., an Ethernet or wireless controller, a Bluetooth controller, etc.) to facilitate communications via a port on communication link **6521** to communicate, for example, with a computing device, including mobile computing and/or communication devices with processors. Processor **6504** can be implemented with one or more central processing units (“CPUs”), such as those manufactured by Intel® Corporation, or one or more virtual processors, as well as any combination of CPUs and virtual processors. Computing platform **6500** exchanges data representing inputs and outputs via input-and-output devices **6501**, including, but not limited to, keyboards, mice, audio inputs (e.g., speech-to-text devices), user interfaces, displays, monitors, cursors, touch-sensitive displays, LCD or LED displays, and other I/O-related devices.

[**0262**] According to some examples, computing platform **6500** performs specific operations by processor **6504** executing one or more sequences of one or more instructions stored in system memory **6506**, and computing platform **6500** can be implemented in a client-server arrangement, peer-to-peer arrangement, or as any mobile computing device, including smart phones and the like. Such instructions or data may be read into system memory **6506** from another computer readable medium, such as storage device **6508**. In some examples, hard-wired circuitry may be used in place of or in combination with software instructions for implementation. Instructions may be embedded in software or firmware. The term “computer readable medium” refers to any tangible medium that participates in providing instructions to processor **6504** for execution. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media. Non-volatile media includes, for example, optical or magnetic disks and the like. Volatile media includes dynamic memory, such as system memory **6506**.

[**0263**] Common forms of computer readable media includes, for example, floppy disk, flexible disk, hard disk, magnetic tape, any other magnetic medium, CD-ROM, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, RAM, PROM, EPROM, FLASH-EPROM, any other memory chip or cartridge, or any other medium from which a computer can read. Instructions may further be transmitted or received using a transmission medium. The term “transmission medium” may include any tangible or intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine, and includes digital or analog communications signals or other intangible medium to facilitate communication of such instructions. Transmission media includes coaxial



cables, copper wire, and fiber optics, including wires that comprise bus 6502 for transmitting a computer data signal.

[0264] In some examples, execution of the sequences of instructions may be performed by computing platform 6500. According to some examples, computing platform 6500 can be coupled by communication link 6521 (e.g., a wired network, such as LAN, PSTN, or any wireless network, including WiFi of various standards and protocols, Blue Tooth®, Zig-Bee, etc.) to any other processor to perform the sequence of instructions in coordination with (or asynchronous to) one another. Computing platform 6500 may transmit and receive messages, data, and instructions, including program code (e.g., application code) through communication link 6521 and communication interface 6513. Received program code may be executed by processor 6504 as it is received, and/or stored in memory 6506 or other non-volatile storage for later execution.

[0265] In the example shown, system memory 6506 can include various modules that include executable instructions to implement functionalities described herein. System memory 6506 may include an operating system (“O/S”) 6532, as well as an application 6536 and/or logic module 6559. In the example shown, system memory 6506 includes a drive signal adjuster module 6550, INA channel processor module 6552, physiological channel processor module 6554, and physiological signal component correlator module 6556 (collectively “the Depicted Modules”) including any number of modules (not shown), one or more of which can be configured to provide or consume outputs to implement one or more functions described herein.

[0266] In at least some examples, the structures and/or functions of any of the above-described features can be implemented in software, hardware, firmware, circuitry, or a combination thereof. Note that the structures and constituent elements above, as well as their functionality, may be aggregated with one or more other structures or elements. Alternatively, the elements and their functionality may be subdivided into constituent sub-elements, if any. As software, the above-described techniques may be implemented using various types of programming or formatting languages, frameworks, syntax, applications, protocols, objects, or techniques. As hardware and/or firmware, the above-described techniques may be implemented using various types of programming or integrated circuit design languages, including hardware description languages, such as any register transfer language (“RTL”) configured to design field-programmable gate arrays (“FPGAs”), application-specific integrated circuits (“ASICs”), or any other type of integrated circuit. According to some embodiments, the term “module” can refer, for example, to an algorithm or a portion thereof, and/or logic implemented in either hardware circuitry or software, or a combination thereof. These can be varied and are not limited to the examples or descriptions provided.

[0267] In some embodiments, the Depicted modules or one or more of their components (e.g., a motion recovery controller), or any process or device described herein, can be in communication (e.g., wired or wirelessly) with a mobile device, such as a mobile phone or computing device, or can be disposed therein.

[0268] In some cases, a mobile device, or any networked computing device (not shown) in communication with the Depicted modules or one or more of their components (or any process or device described herein), can provide at least some of the structures and/or functions of any of the features

described herein. As depicted in the above-described figures, the structures and/or functions of any of the above-described features can be implemented in software, hardware, firmware, circuitry, or any combination thereof. Note that the structures and constituent elements above, as well as their functionality, may be aggregated or combined with one or more other structures or elements. Alternatively, the elements and their functionality may be subdivided into constituent sub-elements, if any. As software, at least some of the above-described techniques may be implemented using various types of programming or formatting languages, frameworks, syntax, applications, protocols, objects, or techniques. For example, at least one of the elements depicted in any of the figure can represent one or more algorithms. Or, at least one of the elements can represent a portion of logic including a portion of hardware configured to provide constituent structures and/or functionalities.

[0269] For example, the Depicted modules, or any of their one or more components, or any process or device described herein, can be implemented in one or more computing devices (i.e., any mobile computing device, such as a wearable device, an audio device (such as headphones or a headset) or mobile phone, whether worn or carried) that include one or more processors configured to execute one or more algorithms in memory. Thus, at least some of the elements in the above-described figures can represent one or more algorithms. Or, at least one of the elements can represent a portion of logic including a portion of hardware configured to provide constituent structures and/or functionalities. These can be varied and are not limited to the examples or descriptions provided.

[0270] As hardware and/or firmware, the above-described structures and techniques can be implemented using various types of programming or integrated circuit design languages, including hardware description languages, such as any register transfer language (“RTL”) configured to design field-programmable gate arrays (“FPGAs”), application-specific integrated circuits (“ASICs”), multi-chip modules, or any other type of integrated circuit.

[0271] For example, the Depicted modules, including one or more components, or any process or device described herein, can be implemented in one or more computing devices that include one or more circuits. Thus, at least one of the elements in the above-described figures can represent one or more components of hardware. Or, at least one of the elements can represent a portion of logic including a portion of circuit configured to provide constituent structures and/or functionalities.

[0272] According to some embodiments, the term “circuit” can refer, for example, to any system including a number of components through which current flows to perform one or more functions, the components including discrete and complex components. Examples of discrete components include transistors, resistors, capacitors, inductors, diodes, and the like, and examples of complex components include memory, processors, analog circuits, digital circuits, and the like, including field-programmable gate arrays (“FPGAs”), application-specific integrated circuits (“ASICs”). Therefore, a circuit can include a system of electronic components and logic components (e.g., logic configured to execute instructions, such that a group of executable instructions of an algorithm, for example, and, thus, is a component of a circuit). According to some embodiments, the term “module” can refer, for example, to an algorithm or a portion thereof, and/or



logic implemented in either hardware circuitry or software, or a combination thereof (i.e., a module can be implemented as a circuit). In some embodiments, algorithms and/or the memory in which the algorithms are stored are “components” of a circuit. Thus, the term “circuit” can also refer, for example, to a system of components, including algorithms. These can be varied and are not limited to the examples or descriptions provided.

[0273] Although the foregoing examples have been described in some detail for purposes of clarity of understanding, the above-described inventive techniques are not limited to the details provided. There are many alternative ways of implementing the above-described invention techniques. The disclosed examples are illustrative and not restrictive.

What is claimed:

1. A method comprising:
  - receiving an amplified signal including a portion of the physiological-related signal component that includes data representing a physiological characteristic, the amplified signal being derived from bioimpedance signal based on an impedance value of a tissue;
  - identifying a magnitude of the portion of the physiological-related signal component;
  - comparing the magnitude of the portion of the physiological-related signal component against another magnitude of a data model for the physiological characteristic in a time-domain to form a matched value;
  - establishing the matched value of the physiological characteristic;
  - determining a confidence indicator value representative of a degree of likelihood that the matched value is representative of the physiological characteristic;
  - determining a value of the physiological characteristic based on the matched value and the confidence indicator value.
2. The method of claim 1, wherein determining the value of the physiological characteristic comprises:
  - determining one or more of a heart rate, a respiration rate, a galvanic skin resistance value, data representing an affective state or mode, an amount of energy expenditure and an amount of calories expended.

3. The method of claim 1, wherein identifying the magnitude of the portion of the physiological-related signal component comprises:

identifying the magnitude during a window of time.

4. The method of claim 1, wherein comparing the magnitude of the portion of the physiological-related signal component against the another magnitude of the data model comprises:

identifying a peak magnitude of the portion of the physiological-related signal component.

5. The method of claim 4, wherein identifying the peak magnitude comprises:

performing an autocorrelation operation on data representing the data model and the portion of the physiological-related signal component.

6. The method of claim 1, further comprising:

determining a time interval between the magnitude and the another magnitude; and

calculating a rate indicative of the value of the physiological characteristic.

7. The method of claim 6, wherein determining the confidence indicator value comprises:

validating the rate is within a range of valid rates associated with the physiological characteristic.

8. The method of claim 7, wherein validating the rate is within the range of valid rates comprises:

validating the rate over the time interval is within a range of valid heart rates associated with a heart rate as the physiological characteristic.

9. The method of claim 1, further comprising:

adapting a value of a signal-to-noise ratio to form an adapted value of the signal-to-noise ratio based on the bioimpedance signal being based on the impedance value of the tissue.

10. The method of claim 9, further comprising:

characterizing the adapted value of the signal-to-noise ratio to form a characterized value of the signal-to-noise ratio.

11. The method of claim 11, wherein determining the confidence indicator value comprises:

validating the characterized value of the signal-to-noise ratio.

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|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|
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#### 摘要(译)

实施例总体上涉及可穿戴设备，其实现金属盒盖中的触敏界面和/或生物阻抗感测以确定生理特征，例如心率。根据一个实施例，一种方法包括接收放大信号，该放大信号包括生理相关信号分量的一部分，该部分包括表示生理特征的数据，该放大信号基于组织的阻抗值从生物阻抗信号导出，并且识别幅度一部分生理相关信号成分的一部分。而且，该方法可以将该部分的大小与数据模型的另一大小（例如，在时域中）进行比较以形成匹配值。此外，该方法可以确定表示匹配值代表生理特征的似然度的置信度指标值，并且基于匹配值和置信度指标值确定生理特征的值。

