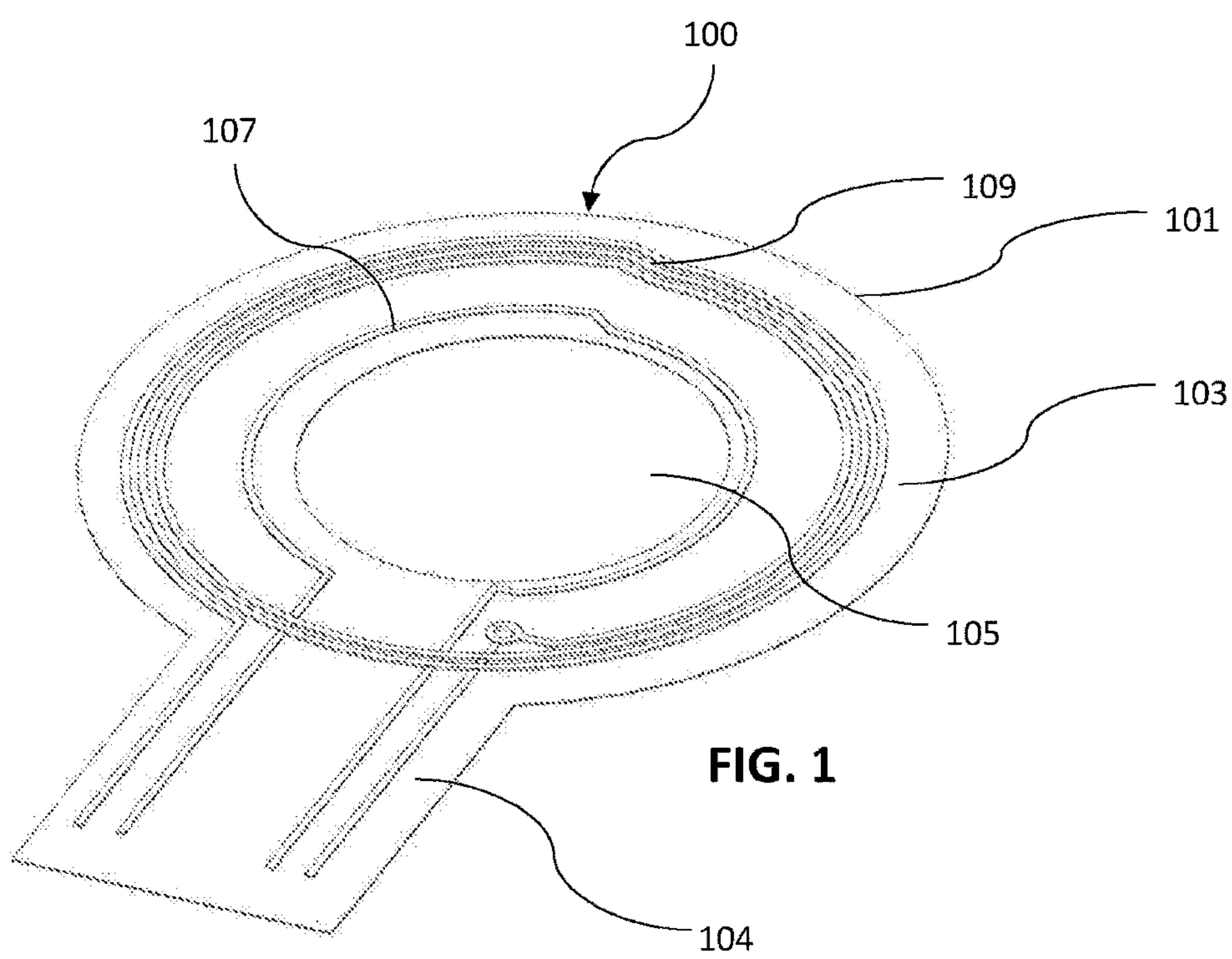


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(54) Title of the Invention: **Printed circuit board structure**
Abstract Title: **Printed circuit board, aperture and antenna arrangement**

(57) A printed circuit board (PCB) antenna arrangement 100 comprises: a first region 103 bounding an aperture 105 through a PCB 101 with first 107 and second 109 antennas in the said region 103. The antennas 107, 109 may be spiral coils which may be coplanar with an inner coil and an outer coil or with interlaced coils. The aperture 105 may be located at a central region of the PCB 101 and this may provide a line of sight for a signal from an antenna or light emitting diode, on a further circuit board, which may be in a stacked formation with the PCB 101. The circuit boards used may be flexible and/or rigid and the antenna coils 107, 109 may transfer power and/or communication data in near and/or far fields and may use various frequencies and communication protocols. The antenna arrangement 100 may be housed and used in wearable articles or garments.



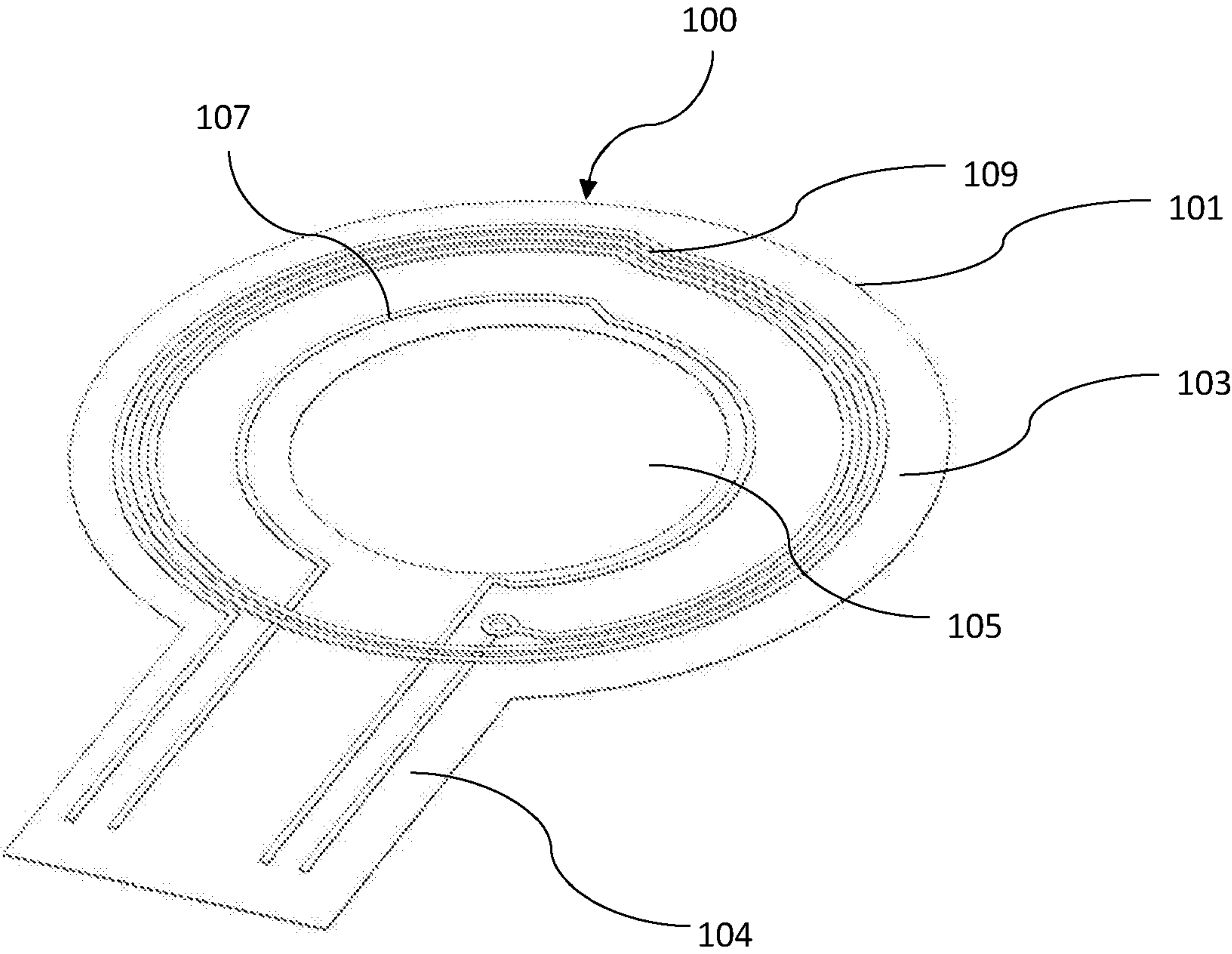


FIG. 1

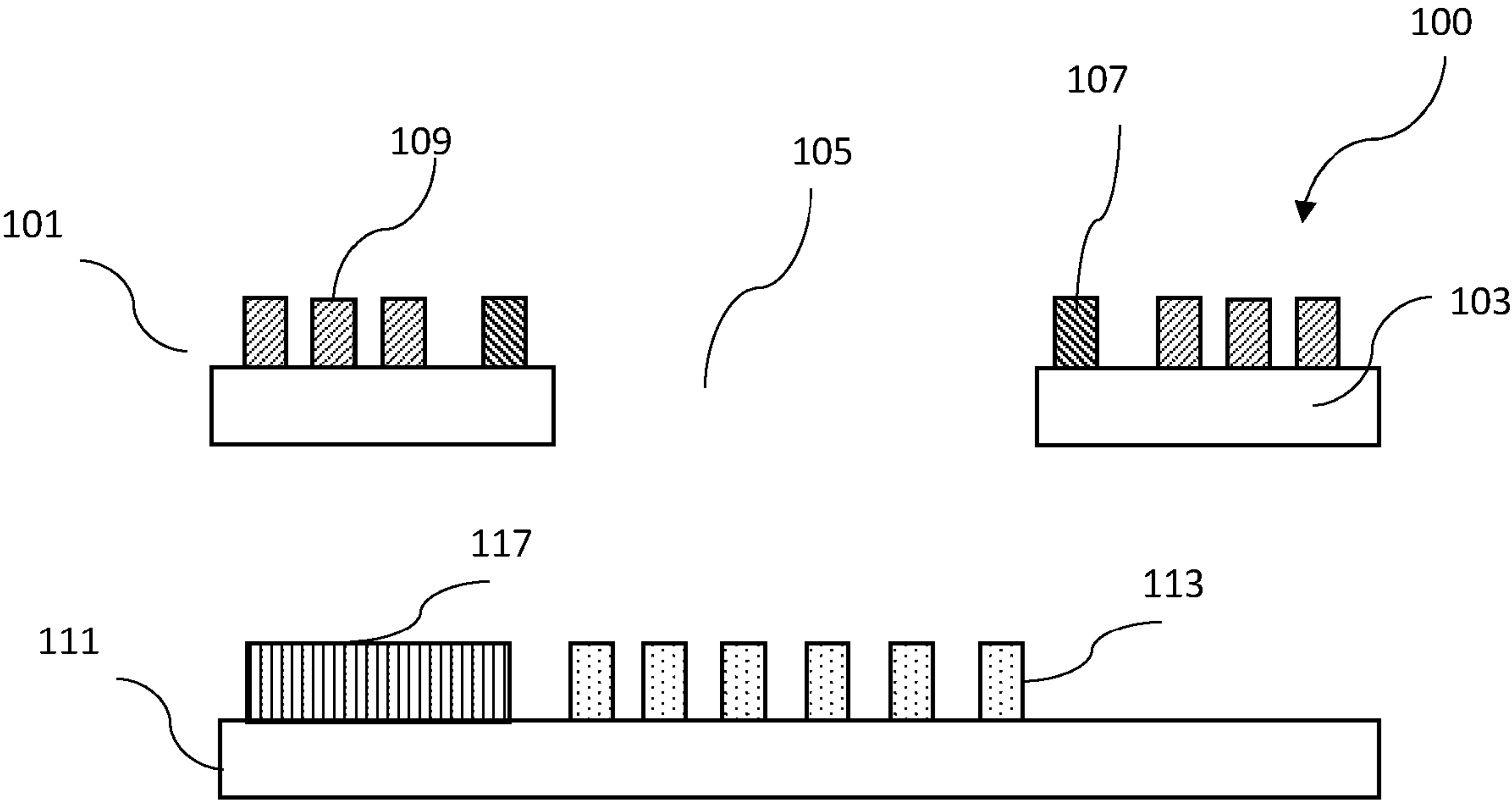


FIG. 2

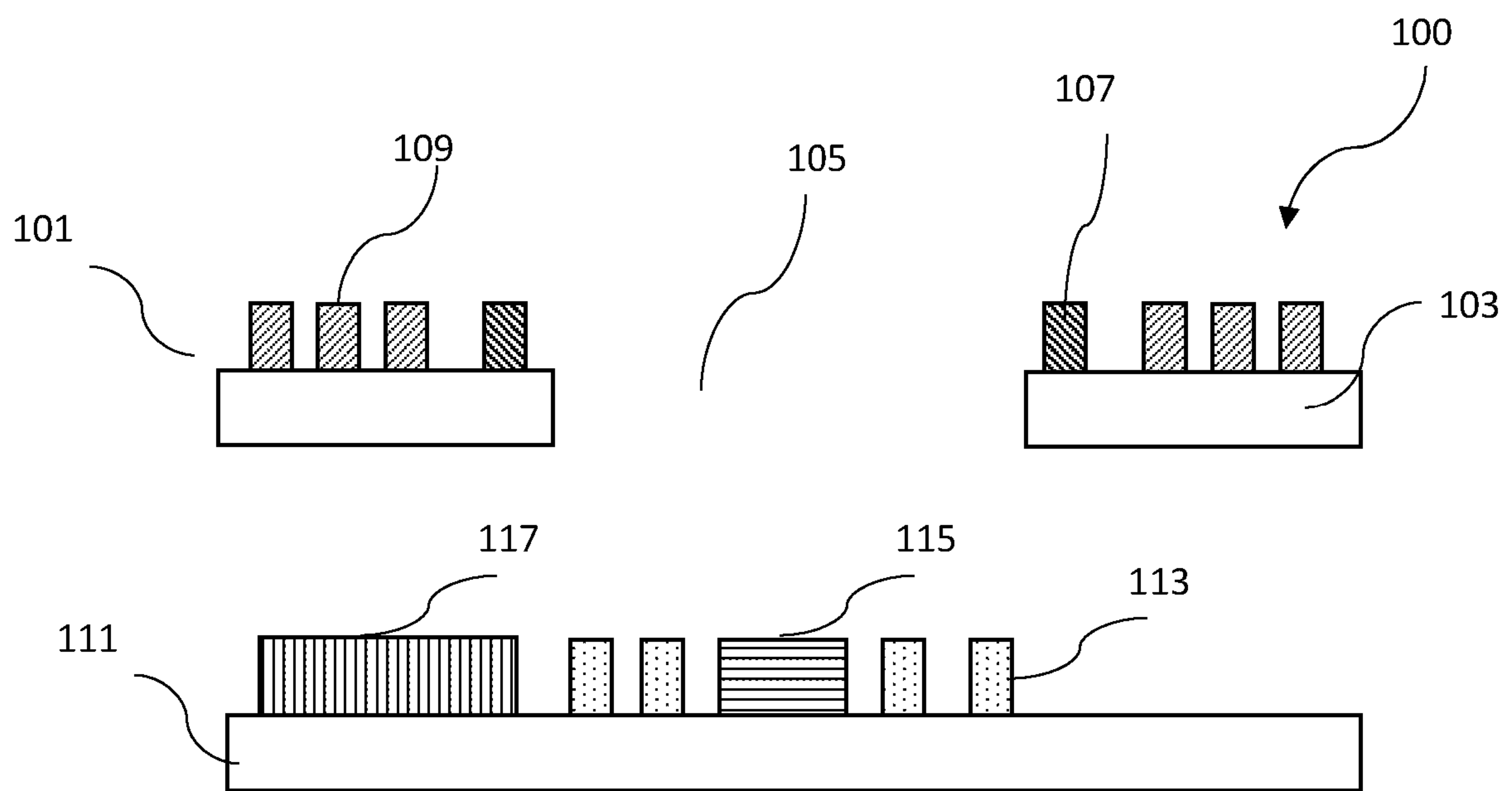


FIG. 3

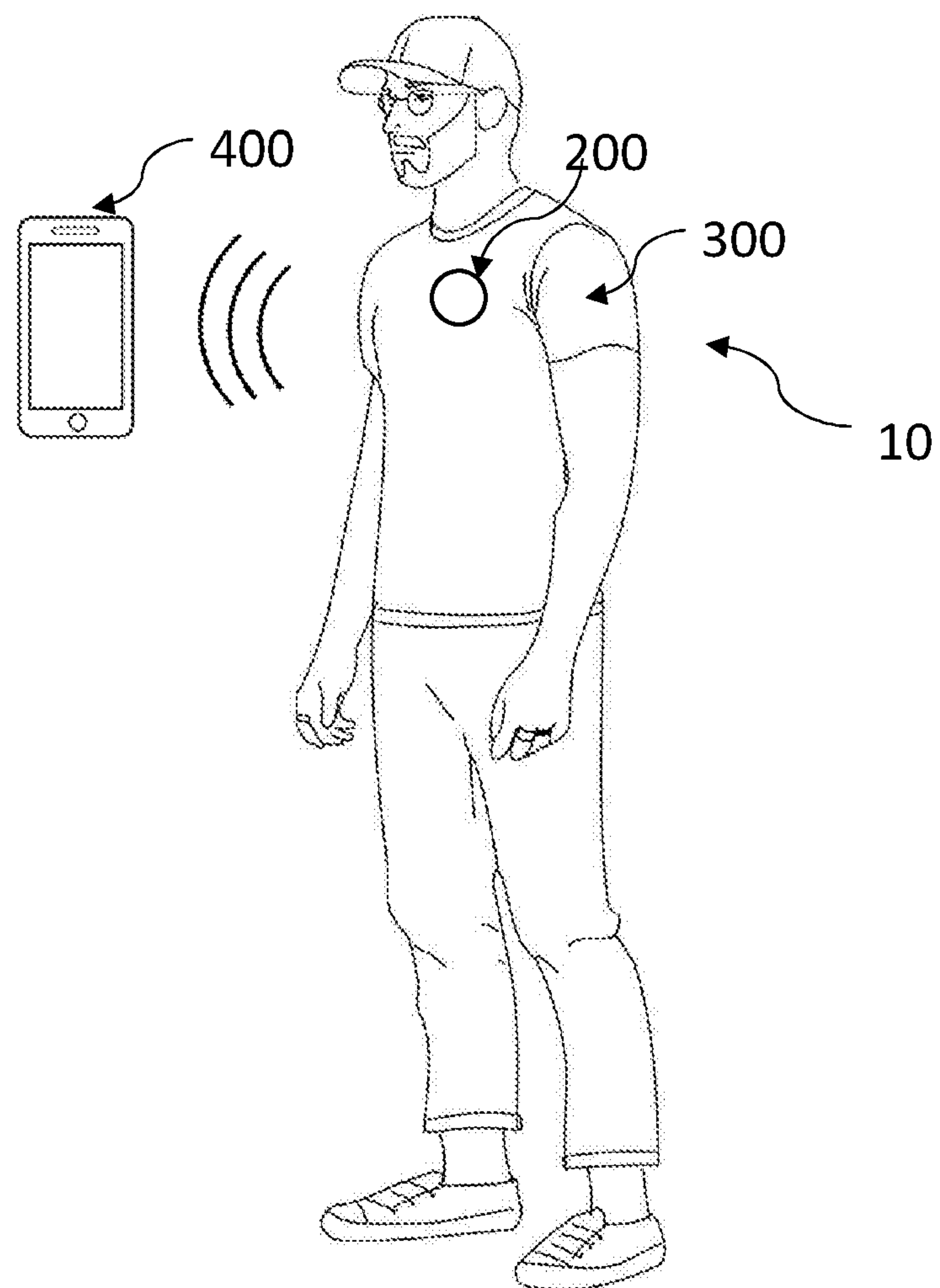


FIG. 4

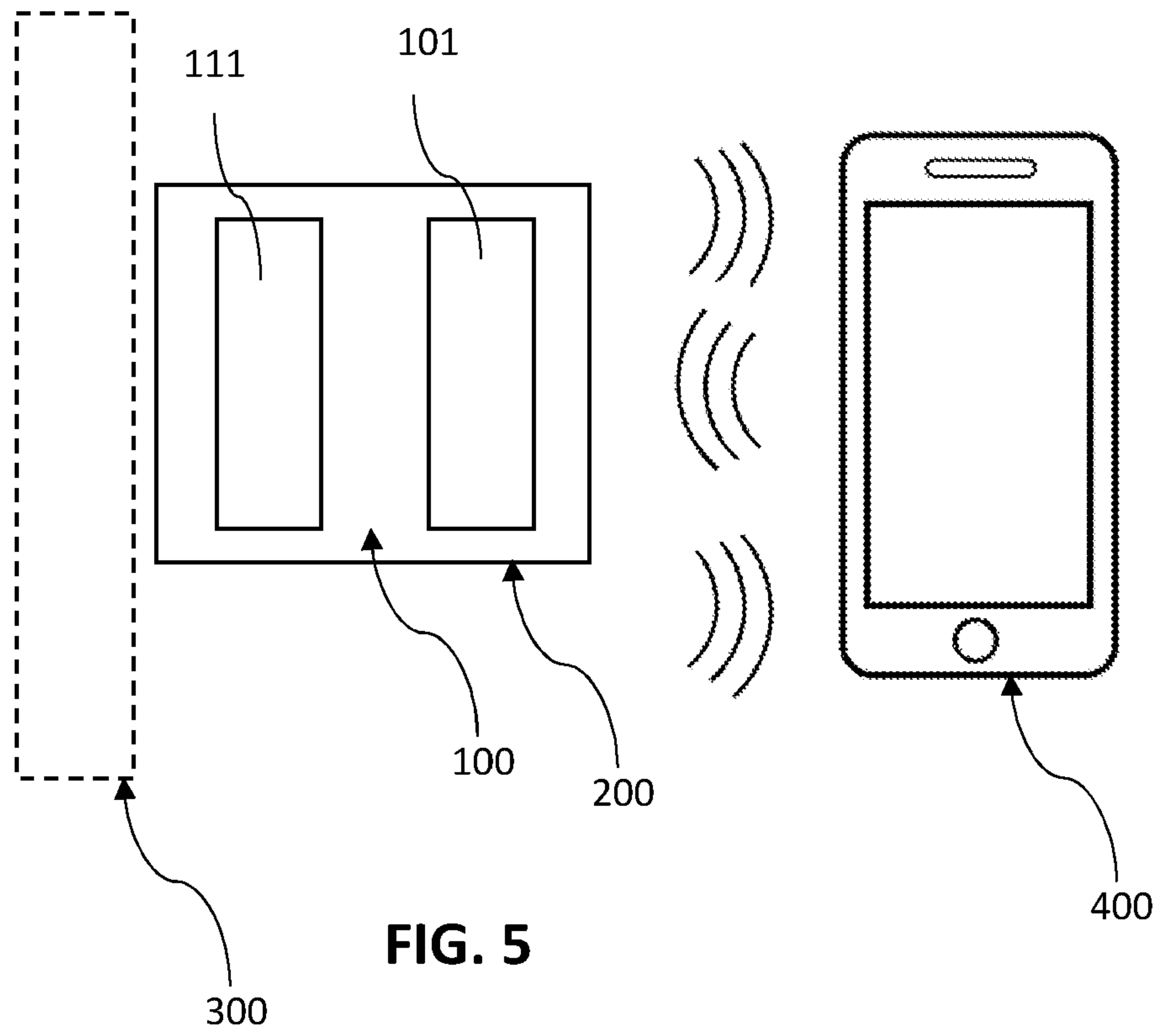


FIG. 5

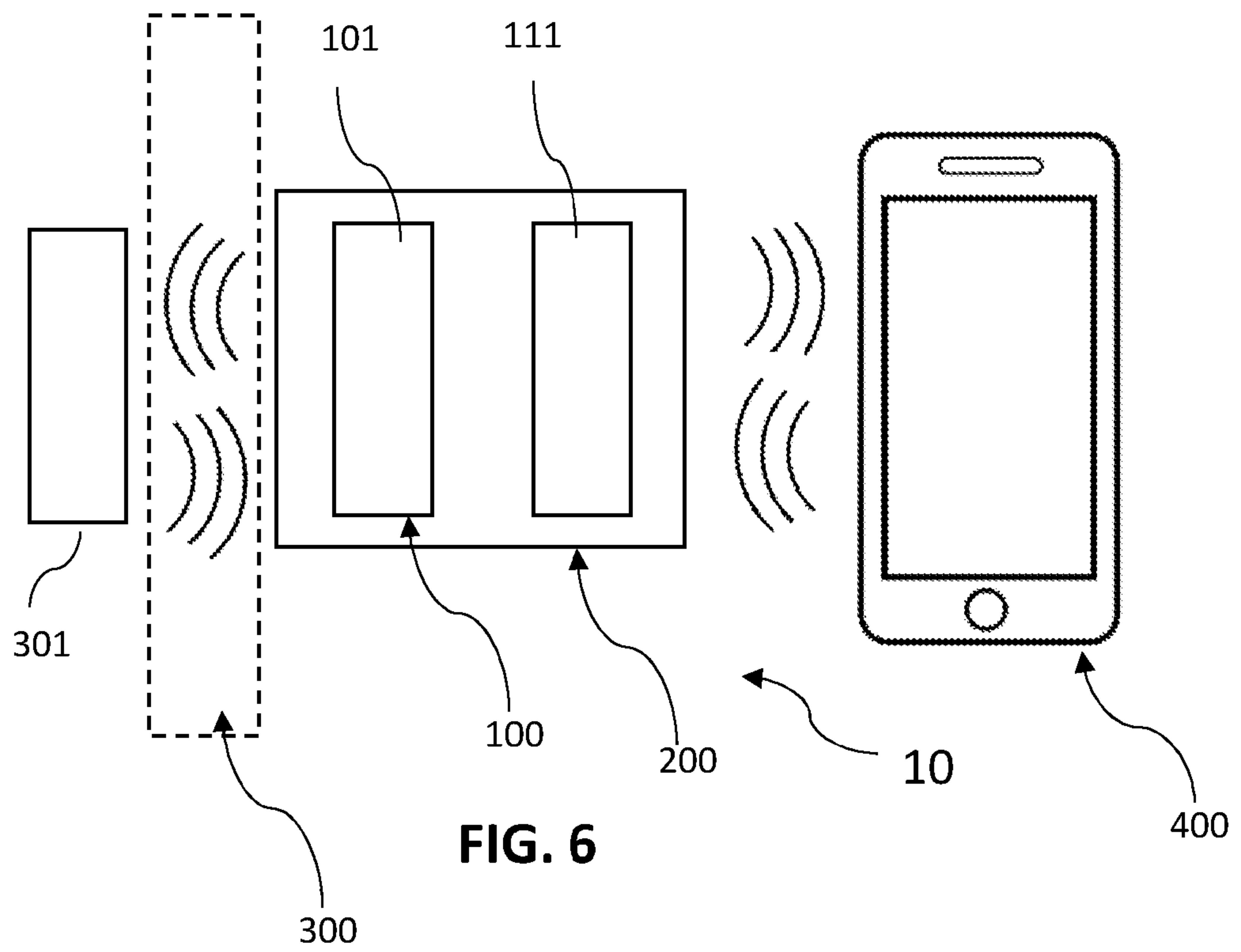


FIG. 6

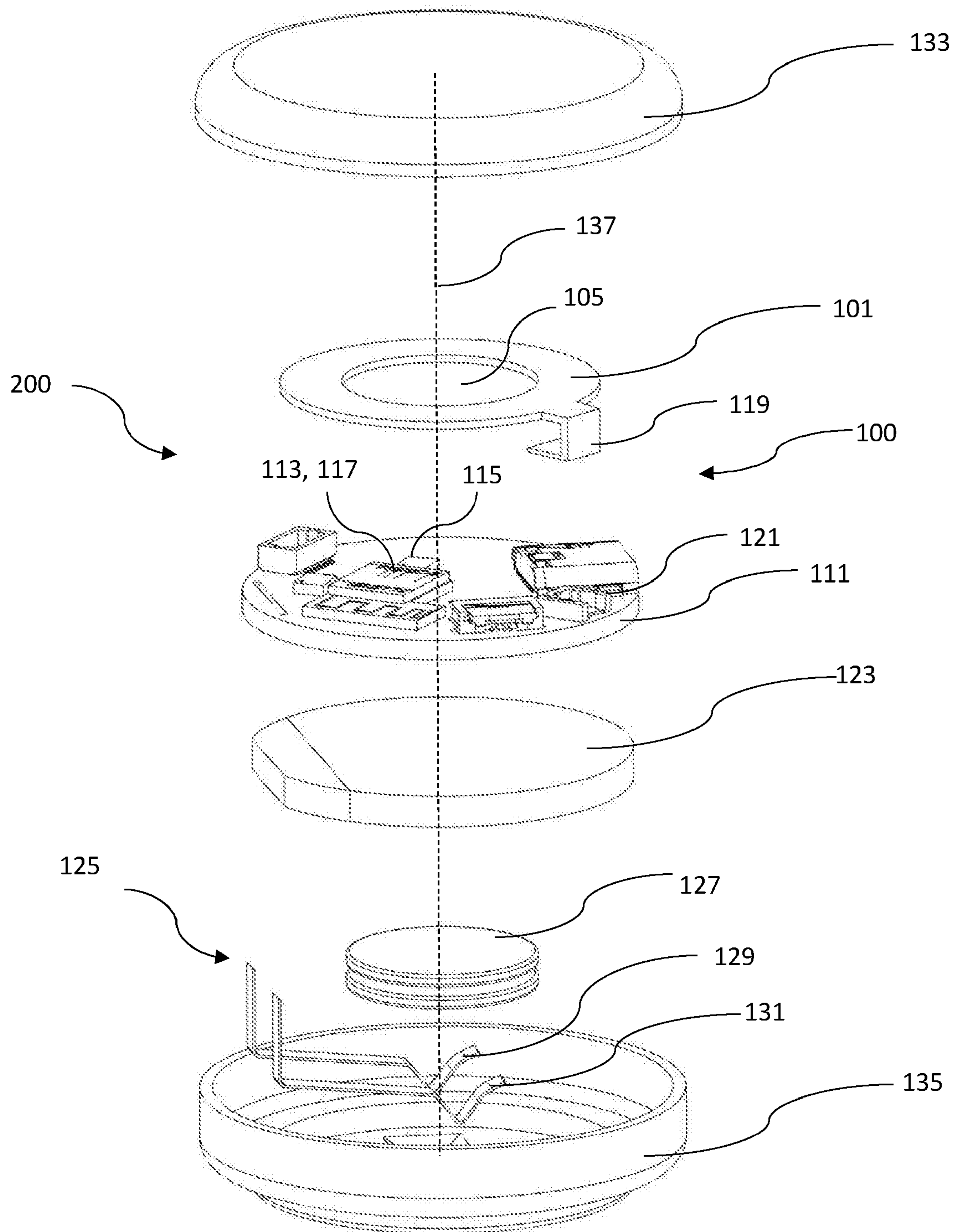


FIG. 7

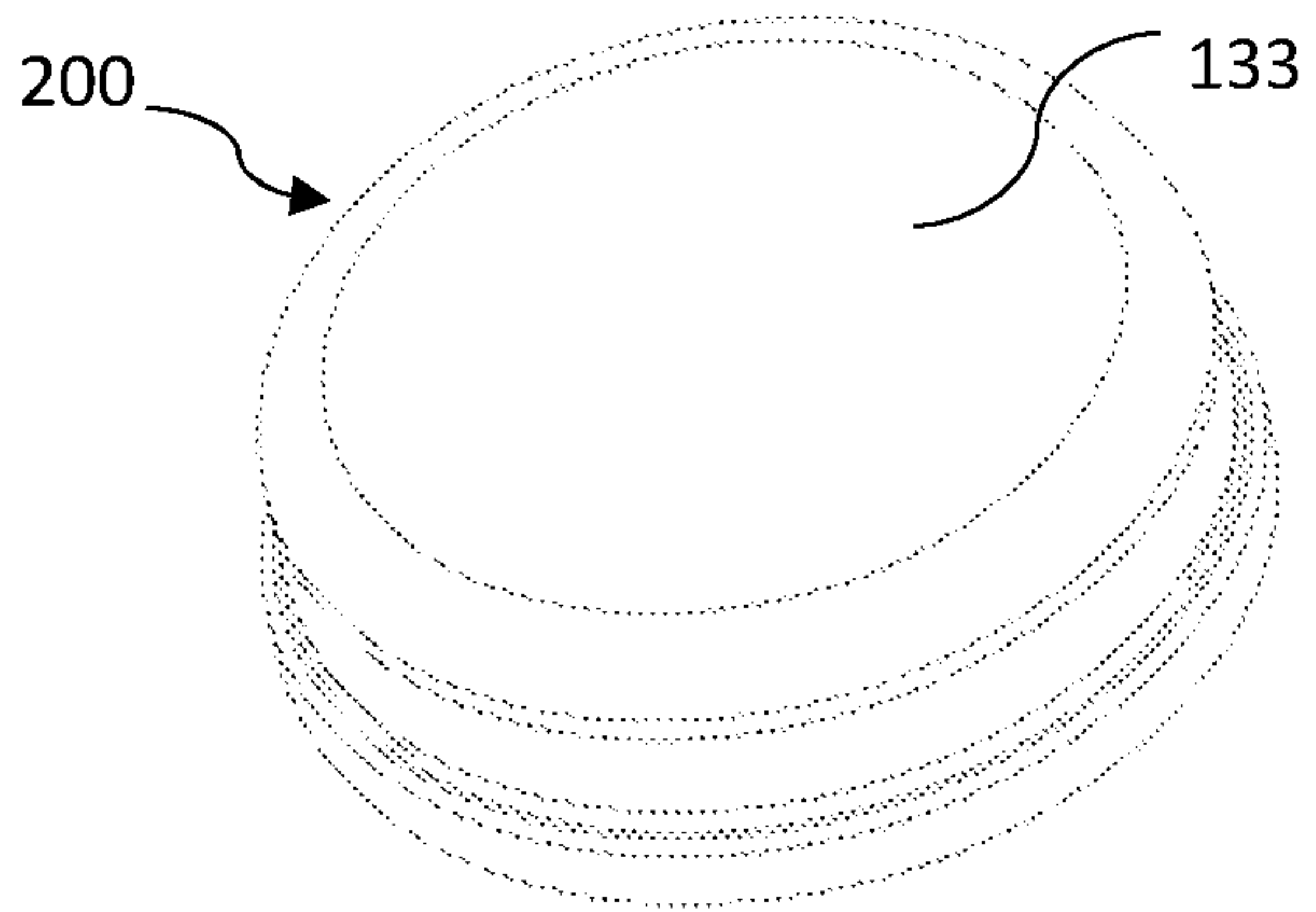


FIG. 8

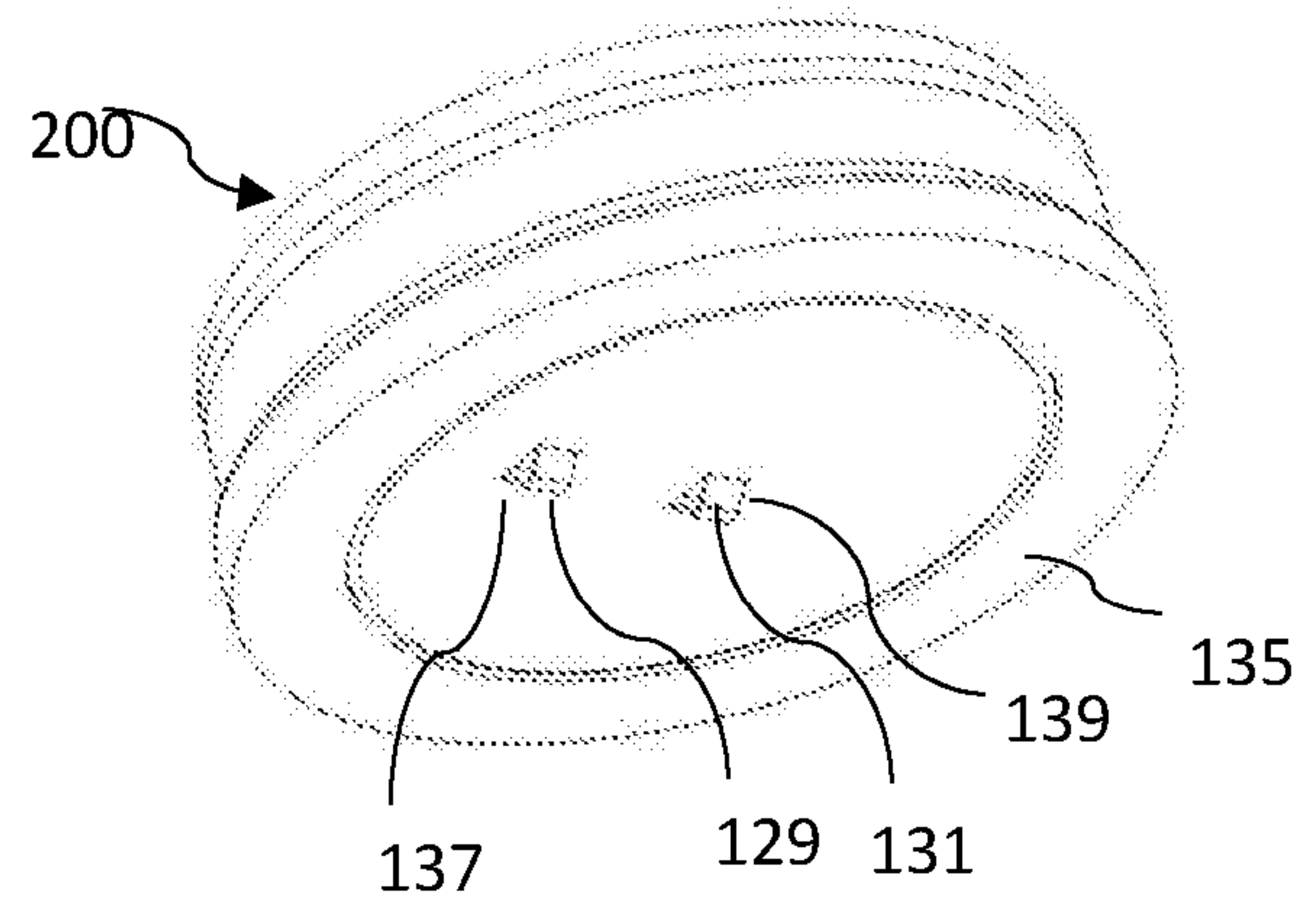


FIG. 9

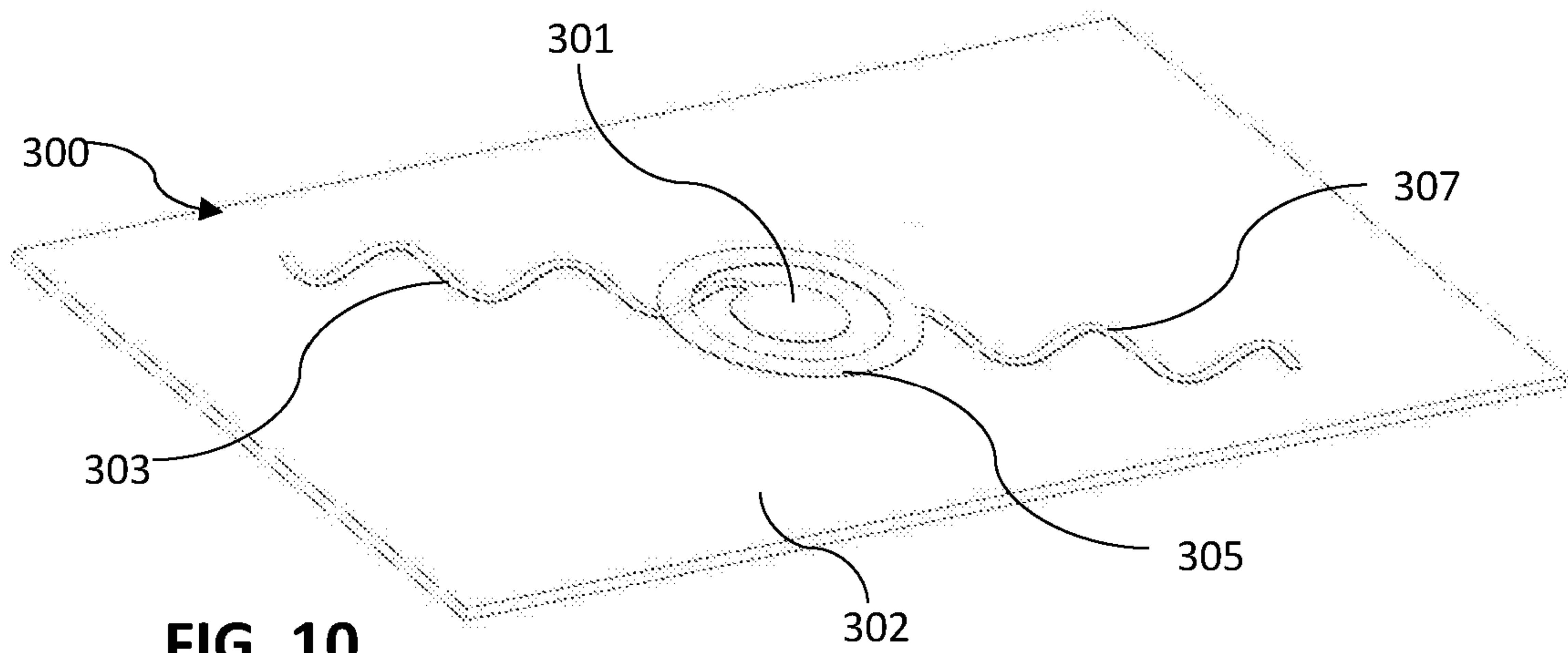


FIG. 10

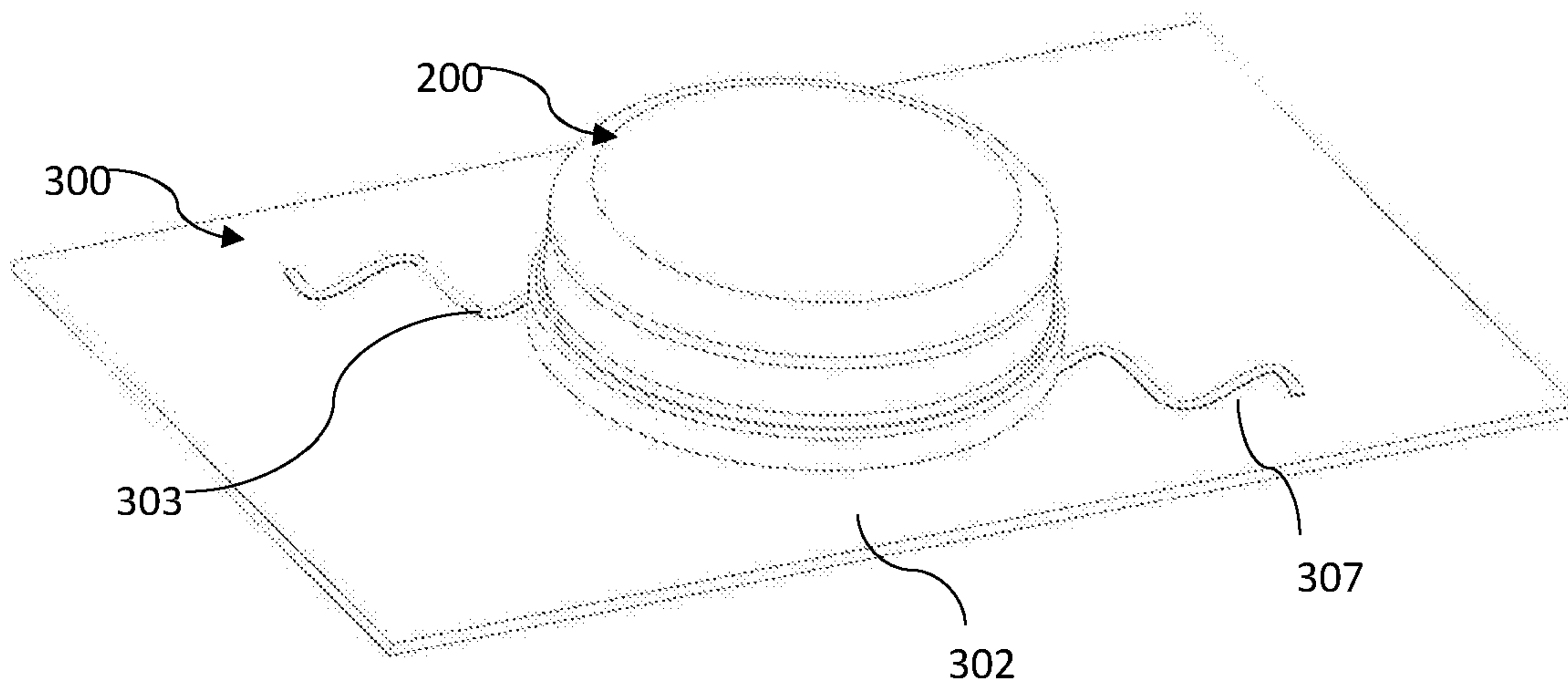


FIG. 11

PRINTED CIRCUIT BOARD STRUCTURE

The present invention is directed towards a printed circuit board structure, electronics module, and wearable article incorporating the printed circuit board structure. The printed circuit board
5 structure comprises first and second antennas.

Background

United States Patent Publication No. 2016/0126002 A1 discloses a wireless charging and near-field communications dual coil printed circuit board structure. It is desirable to provide an
10 improved or at least an alternative to this printed circuit board structure.

It is also desirable to provide an electronics module for a wearable article with a structure that facilitates the transfer of power and/or data between the electronics module and an external device.
15

Summary

According to the present disclosure there is provided printed circuit board structure, electronics module and wearable article as set forth in the appended claims. Other features of the invention
20 will be apparent from the dependent claims, and the description which follows.

According to a first aspect of the disclosure, there is provided a printed circuit board structure. The printed circuit board structure comprises a printed circuit board. The printed circuit board comprises a first region bounding an aperture extending through the printed circuit board. The
25 printed circuit board comprises a first antennal arranged in the first region of the printed circuit board. The printed circuit board comprises a second antenna arranged in the first region of the printed circuit board.

Significantly, the printed circuit board structure comprises (at least) two antennas and thus has
30 more functionality than a single antenna printed circuit board structure. Moreover, the aperture enables other components such as other antenna or light sources to have line-of-sight through the printed circuit board structure. This is particularly beneficial when the printed circuit board structure is provided in a housing with other electronics components. The present disclosure therefore provides a printed circuit board structure which has a reduced interference effect on
35 the signal transmission of other devices within the vicinity of the printed circuit board structure.

The first antenna may comprise an antenna coil. The second antenna may comprise an antenna coil. The antenna coil(s) may comprise spiral coil wires.

The aperture may be located in a central region of the printed circuit board.

5 The first region may comprise an outer region and an inner region. The inner region may be located between the outer region and the aperture. One of the first and second antennas may be arranged in the outer region. The other of the first and second antennas may be arranged in the inner region.

10 The first antenna may be interlaced with the second antenna.

The first antenna may be a communication antenna.

15 The first antenna may be a short-range communication antenna. The short-range communication antenna may be arranged to transmit and/or receive data over a communication range of up to 50 metres, optionally up to 30 metres, optionally up to 10 metres, and optionally up to 1 metre. The short-range communication antenna may comprises one or more of a near field communication, NFC, wireless body area network, BAN, and a wireless personal area network, PAN, communication antenna. The short-range communication antenna may comprise one or more of a NFC, Bluetooth®, Bluetooth® Low Energy, Bluetooth® Mesh, Bluetooth® 5, 20 Thread, Zigbee, IEEE 802.15.4, and Ant communication antenna.

25 The first antenna may be a medium-range communication antenna. The medium-range communication antenna may be arranged to transmit and/or receive data over a communication range of up to 200 metres, optionally up to 100 metres, optionally up to 50 metres, optionally up to 30 metres. The medium-range communication antenna may comprise one or more of a wireless near-me area network, NAN, a wireless local area network, WLAN, and a Wi-Fi communication antenna.

30 The first antenna may be a long-range communication antenna. The long-range communication antenna may be arranged to transmit and/or receive data over a communication range of over 200 metres, optionally over 100 metres, optionally over 50 metres. The long-range communication antenna may comprise one or more of a wireless metro-area network, WMAN, a wireless wide area network, WAN, a low power wide area network, LWAN, and a cellular antenna. The cellular antenna may be configured to transmit or receive data over one or more 35 of a fourth generation (4G) LTE, LTE Advanced (LTE-A), LTE Cat-M1, LTE Cat-M2, NB-IoT, fifth generation (5G), sixth generation (6G), and/or any other present or future developed cellular wireless network.

The second antenna may be a power receiving antenna.

The second antenna may be a communication antenna. The communication antenna may be any of the short-range, medium range, and long-range communication antennas as described above. The first antenna may be a short-range communication antenna and the second antenna
 5 may be a short-range communication antenna. The first and second antenna may use different communication protocols. The first antenna may be a short-range communication antenna and the second antenna may be a medium-range communication antenna or vice versa. The first antenna may be a short-range communication antenna and the second antenna may be a long-range communication antenna or vice versa. The first antenna may be a medium-range
 10 communication antenna and the second antenna may be a long-range communication antenna or vice versa.

The printed circuit board may be a flexible printed circuit board.

15 The printed circuit board is a rigid-flexible printed circuit board.

The printed circuit board structure may further comprise a controller communicatively coupled to at least one of the first antenna and the second antenna. The printed circuit board may be a first printed circuit board of the printed circuit board structure. The printed circuit board structure
 20 may further comprise a second printed circuit board. The controller may be provided on the second printed circuit board.

The first and second printed circuit boards may be arranged in a stacked configuration.

25 A conductor may extend from the first printed circuit board to the second printed circuit board to conductively connect the first printed circuit board to the second printed circuit board.

The printed circuit board structure may be a flex-rigid printed circuit board structure. The first and second printed circuit boards may be rigid components of the flex-rigid printed circuit board structure. The conductor may be a flexible component of the flex-rigid printed circuit board
 30 structure.

The second printed circuit board may comprise a third antenna. The third antenna may be arranged on the printed circuit board such that the antenna has line of sight through the aperture.
 35 The first antenna may be for communicating using a first wireless communication protocol. The third antenna may be for communicating using a second wireless communication protocol. The first wireless communication protocol may be near-field communication. The second wireless communication protocol may be Bluetooth ® or Bluetooth ® Low Energy. The present disclosure

is not limited to these examples. The third antenna may be any of the short-range, medium-range and long-range communication antennas described above.

5 The second printed circuit board may comprise a light source. The light source may be arranged on the printed circuit board such that the light source has line of sight through the aperture. The light source may comprise one or a plurality of light emitting diodes.

10 One or both of the first antenna and the second antenna may be in the form of a Global Navigation Satellite System, GNSS, receiver.

According to a second aspect of the disclosure, there is provided an electronics module for a wearable article. The electronics module comprises the printed circuit board structure of the first aspect of the disclosure.

15 The electronics module may further comprise an interface arranged to communicatively couple with an electronics arrangement of the wearable article so as to form a signal pathway between the electronics module and the electronics arrangement.

20 The electronics module may further comprise a power source, coupled to the printed circuit board structure and arranged to supply power to the printed circuit board structure.

25 The electronics module may further comprise a housing arranged to house the printed circuit board structure. The electronics module may further comprise a housing. The housing may comprise a top enclosure and a bottom enclosure. The bottom enclosure may be closest to the wearable article and/or the wearer of the wearable article in use. The top enclosure may be furthest from the wearable article and/or the wearer of the wearable article in use. A longitudinal axis extends from the top enclosure to the bottom enclosure. The printed circuit board comprising the first and second antennas may be proximate to the top enclosure. This is beneficial for near field communication with a mobile device as it minimises the communication distance between the antenna and the mobile device. The printed circuit board comprising the first and second antennas may be proximate to the bottom enclosure. This is beneficial for short-range communication with the wearable article as it minimises the communication distance between the antennas and the wearable article.

35 The electronics module may further comprise a sensor. The sensor may be arranged to detect a mobile device being brought into proximity with the electronics module. In response to the sensor detecting the mobile device being brought into proximity with the electronics module, the controller may be arranged to wake-up, control an antenna to transmit data or perform any other form of control operation. The sensor may be a motion sensor arranged to detect a displacement

of the electronics module caused by the mobile device being brought into proximity with the electronics module. That is, the sensor may be able to detect a “tap” input caused by the mobile device being tapped against the electronics module. The sensor is not required to be a motion sensor. Other forms of sensor such as capacitive sensors, optical sensors, and ultrasound sensors may be used to detect a mobile device being brought into proximity with the electronics module. One or both of the first and second antennas may function as the sensor. That is, a current induced in one or both of the first and second antennas may cause the controller to wake-up and control one or both of the antennas to transmit data or perform any other form of control operation.

10

According to a third aspect of the disclosure, there is provided a wearable article comprising the electronics module of the second aspect of the disclosure. The wearable article may be a garment.

15

The wearable article may comprise one or more sensing components. The sensing components may be biosensing components. The sensing components may comprise one or more components of a temperature sensor, a humidity sensor, a motion sensor, an electropotential sensor, an electroimpedance sensor, an optical sensor, an acoustic sensor. Here, “component” means that not all of the components of the sensor may be provided in the wearable article. The processing logic, power and other functionality may be provided in the electronics module. The wearable article may only comprise the minimal functionality to perform the sensing such as by only including sensing electrodes. The temperature sensor may be arranged to measure an ambient temperature, a skin temperature of a human or animal body, or a core temperature of a human or animal body. The humidity sensor may be arranged to measure humidity or skin-surface moisture levels for a human or animal body. The motion sensor may comprise one or more of an accelerometer, a gyroscope, and a magnetometer sensor. The motion sensor may comprise an inertial measurement unit. The electropotential sensor may be arranged to perform one or more bioelectrical measurements. The electropotential sensor may comprise one or more of electrocardiography (ECG) sensor modules, electrogastrography (EGG) sensor modules, electroencephalography (EEG) sensor modules, and electromyography (EMG) sensor modules. The electroimpedance sensor may be arranged to perform one or more bioimpedance measurements. Bioimpedance sensors can include one or more of plethysmography sensor modules (e.g., for respiration), body composition sensor modules (e.g., hydration, fat, etc.), and electroimpedance tomography (EIT) sensors. An optical sensor may comprise a photoplethysmography (PPG) sensor module or an orthopantomogram (OPG) sensor module.

35

According to a fourth aspect of the disclosure, there is provided an electronics module for a wearable article. The electronics module comprises a controller configured to process signals received from a sensing component. The sensing component may be part of the electronics

module and/or may be separate to the electronics module and incorporated into the wearable article. The electronics module comprises a power source, coupled to the controller, and arranged to supply power to the controller. The electronics module comprises an antenna unit comprising a first antenna and a second antenna. The electronics module comprises a housing
 5 arranged to house the controller, power source, and antenna unit.

The first antenna and the second antenna may be provided in the same plane.

The housing may comprise a top enclosure and a bottom enclosure, and a longitudinal axis
 10 extending from the bottom enclosure to the top enclosure. The antenna unit may be spaced apart from the power source and the controller along the longitudinal axis of the housing. The antenna unit may be provided proximate to the top enclosure. The antenna unit may be provided proximate to the bottom enclosure.

15 The electronics module may comprise the printed circuit board structure disclosed above in relation to the first aspect of the disclosure. The electronics module may comprise some or all of the features disclosed above in relation to the second aspect of the disclosure. The electronics module may be useable in the wearable article of the third aspect of the disclosure.

20 According to a fifth aspect of the disclosure, there is provided a printed circuit board structure. The printed circuit board structure comprises a printed circuit board, the printed circuit board comprises a first communication antenna for sending and/or receiving data over a first wireless communication protocol; and a second communication antenna for sending and/or receiving data over a second wireless communication protocol.

25 Significantly, the printed circuit board structure comprises (at least) a first and a second communication antenna has more functionality than a single antenna printed circuit board structure.

30 According to a sixth aspect of the disclosure, there is provided a printed circuit board structure. The printed circuit board structure comprises a printed circuit board, the printed circuit board comprises: a first, power receiving, antenna; and a second, communication, antenna for sending and/or receiving data over a wireless communication protocol. The wireless communication protocol may be a communication protocol other than near field communication.

35 Significantly, the printed circuit board structure comprises (at least) a power receiving antenna and communication antenna and thus has more functionality than a single antenna printed circuit board structure.

According to a seventh aspect of the disclosure, there is provided a printed circuit board structure comprising a printed circuit board. The printed circuit board comprises a first antenna in the form of a Global Navigation Satellite System, GNSS, receiver; and a second antenna.

- 5 Significantly, the printed circuit board structure comprises (at least) a GNSS receiver antenna and another antenna such as a power receiving or communication antenna and thus has more functionality than a single antenna printed circuit board structure.

10 The printed circuit board structures of the fifth, sixth, and seventh aspect of the disclosure may comprise any of the features of the printed circuit board structure of the first aspect of the disclosure and may be incorporated into the wearable article and electronics module of the second to fourth aspects of the present disclosure.

15 The present disclosure is not limited to wearable articles. The electronics modules disclosed herein may be incorporated into other forms of devices such as user electronic devices (e.g. mobile phones). In additions, they may be incorporated into any form of textile article. Textile articles may include upholstery, such as upholstery that may be positioned on pieces of furniture, vehicle seating, as wall or ceiling décor, among other examples.

20 **Brief Description of the Drawings**

Examples of the present disclosure will now be described with reference to the accompanying drawings, in which:

25 Figure 1 shows a perspective view of an example printed circuit board structure according to aspects of the present disclosure;

Figure 2 shows a cross-sectional view of another example printed circuit board structure according to aspects of the present disclosure;

Figure 3 shows a cross-sectional view of yet another example printed circuit board structure according to aspects of the present disclosure;

30 Figure 4 shows a schematic diagram of an example system according to aspects of the present disclosure;

Figure 5 shows a schematic diagram of another example system according to aspects of the present disclosure;

35 Figure 6 shows a schematic diagram of yet another example system according to aspects of the present disclosure;

Figure 7 shows an exploded view of an example electronics module according to aspects of the present disclosure;

Figures 8 and 9 show perspective views of the electronics module of Figure 7;

Figure 10 shows a perspective view of a component of a garment according to aspects of the present disclosure; and

Figure 11 shows a perspective view of the electronics module of Figures 8 and 9 mounted on the garment of Figure 10.

5

Detailed Description

The following description with reference to the accompanying drawings is provided to assist in a comprehensive understanding of various embodiments of the disclosure as defined by the claims and their equivalents. It includes various specific details to assist in that understanding but these are to be regarded as merely exemplary. Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the various embodiments described herein can be made without departing from the scope and spirit of the disclosure. In addition, descriptions of well-known functions and constructions may be omitted for clarity and conciseness.

15

The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used by the inventor to enable a clear and consistent understanding of the disclosure. Accordingly, it should be apparent to those skilled in the art that the following description of various embodiments of the disclosure is provided for illustration purpose only and not for the purpose of limiting the disclosure as defined by the appended claims and their equivalents.

20

It is to be understood that the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise.

25

“Wearable article” as referred to throughout the present disclosure may refer to any form of electronic device which may be worn by a user such as a smart watch, necklace, bracelet, or glasses. The wearable article may be a textile article. The wearable article may be a garment. The garment may refer to an item of clothing or apparel. The garment may be a top. The top may be a shirt, t-shirt, blouse, sweater, jacket/coat, or vest. The garment may be a dress, brassiere, shorts, pants, arm or leg sleeve, vest, jacket/coat, glove, armband, underwear, headband, hat/cap, collar, wristband, stocking, sock, or shoe, athletic clothing, swimwear, wetsuit or drysuit. The wearable article/garment may be constructed from a woven or a non-woven material. The wearable article/garment may be constructed from natural fibres, synthetic fibres, or a natural fibre blended with one or more other materials which can be natural or synthetic. The yarn may be cotton. The cotton may be blended with polyester and/or viscose and/or polyamide according to the particular application. Silk may also be used as the natural fibre. Cellulose, wool, hemp and jute are also natural fibres that may be used in the wearable

35

article/garment. Polyester, polycotton, nylon and viscose are synthetic fibres that may be used in the wearable article/garment. The garment may be a tight-fitting garment. Beneficially, a tight-fitting garment helps ensure that the sensor devices of the garment are held in contact with or in the proximity of a skin surface of the wearer. The garment may be a compression garment.

5 The garment may be an athletic garment such as an elastomeric athletic garment.

The following description refers to particular examples of the present disclosure where the wearable article is a garment. It will be appreciated that the present disclosure is not limited to garments and other forms of wearable article are within the scope of the present disclosure as outlined above.

Referring to Figure 1, there is shown a printed circuit board structure 100 according to aspects of the present disclosure. The structure 100 comprises a printed circuit board 101. The printed circuit board 101 comprises a first region 103 bounding an aperture extending through the printed circuit board 101. A first antenna in the form of first antenna coil 107 and a second antenna in the form of second antenna coil 109 are arranged in the first region 103 of the printed circuit board 101. The following examples refer to particular examples where the first and second antennas are antenna coils. This is not required in all aspects of the present disclosure and other antenna structures such as dipole antennas are within the scope of the present disclosure.

15 Significantly, the printed circuit board structure 100 comprises (at least) two antenna coils 107, 109 and thus has more functionality than a single antenna coil printed circuit board structure. Moreover, the aperture 105 enables other components such as other antenna or light sources to have line-of-sight through the printed circuit board structure 100. This is particularly beneficial when the printed circuit board structure 100 is provided in a housing with other electronics components.

The printed circuit board 101 may be a single-faced circuit board 101. The first antenna coil 107 and the second antenna coil 109 may be provided on a face of the single-faced circuit board.

30 The printed circuit board 101 has an annular shaped region. The aperture 105 is located in a central part of the annular shaped region of the printed circuit board 101 and has a circular shape. The first antenna coil 107 extends around the circular aperture 105 and contains one (as shown, several may be included) loops of coil. The second antenna coil 109 extends around the circular aperture and contains several (three are shown) loops of coil. The first antenna coil 107 is located inside of the second antenna coil 109. This means that the first region 103 of the printed circuit board 101 comprises an outer region and an inner region. The inner region is located between the outer region and the aperture 105. The first antenna coil 107 is arranged in the inner region. The second antenna coil 109 is arranged in the outer region. This arrangement

is not required in all implementations of the present disclosure and instead, for example, the first antenna coil may be interlaced with the second antenna coil.

5 The printed circuit board 101 has a connection region 104 that extends from the annular shaped region. The connection region 104 comprises contact points of the first and second antenna coils 107, 109 and allows the first and second antenna coils 107, 109 to be electrically connected to other components. The contact points may be provided as connection pads (not shown). The contact points may be provided on a different face of the printed circuit board 101.

10 The first antenna coil 107 may be a communication coil and is preferably a short-range communication coil such as a near-field communication coil.

The second antenna coil 109 may be a power receiving coil. The power receiving coil may be a wireless charging (WLC) coil operated with a one-way power transmission frequency. The power
15 receiving coil may be compatible with any or all of the Alliance for Wireless Power (A4WP), Power Matters Alliance (PMA), and Wireless Power Consortium (WPC) standard. The printed circuit board 101 may be arranged on a ferrite plate such that the printed circuit board can function as an induction-transmission plate for wireless charging.

20 In other examples, the first antenna coil 107 and the second antenna coil 109 may be any of a short-range, medium-range, and long-range communication coil, GNSS receiver coil, or power receiving coil.

Generally, if the first antenna coil 107 is a near-field communication coil and the second antenna
25 coil 109 is a power receiving coil for wireless charging, it will be expected that the two coils operate in different frequency bands. The NFC coil 107 will generally have a shorter length and will be operated with a two-way communication frequency. The power-receiving coil 109 will have a longer length than the NFC coil 107 and will operate with a one-way power transmission frequency. While Figure 1 shows that the power receiving coil 109 on the outside and the NFC
30 coil 107 on the inside it will be appreciated that the position of these coils may be swapped around.

The first and second antenna coils 107, 109 may be formed on the printed circuit board 101 by etching, coating, or electro-plating or by using other conventional methods known in the art.
35

Referring to Figure 2, there is shown a cross-sectional view of a printed circuit board structure 100 according to aspects of the present disclosure. The printed circuit board structure 100 comprises a first printed circuit board 101 which is the same as the printed circuit board 101 of Figure 1 and a second printed circuit board 111. The second printed circuit board 111 is provided

vertically below the first printed circuit board 101. In this way, the first printed circuit board 101 and the second printed circuit board 111 are provided in a stacked configuration. The second printed circuit board 111 comprises a third antenna coil 113 provided in a central region of the second printed circuit board 111. At least a component of the third antenna coil 113 is aligned with the aperture 105 of the first printed circuit board 101 such that the third antenna coil 113 has line of sight through the aperture 105. The third antenna coil 113 may be a communication antenna coil such as for Bluetooth®, Bluetooth® Low Energy, Bluetooth® Mesh, Bluetooth® 5, Thread, Zigbee, IEEE 802.15.4, or Ant, wireless wide area network (WWAN), wireless metroarea network (WMAN), wireless local area network (WLAN), wireless personal area network (WPAN), Global Navigation Satellite System (GNSS), or cellular communication for communicating over a cellular communication network. The cellular communication network may be a fourth generation (4G) LTE, LTE Advanced (LTE-A), LTE Cat-M1, LTE Cat-M2, NB-IoT, fifth generation (5G), sixth generation (6G), and/or any other present or future developed cellular wireless network.

Referring to Figure 3, there is shown a cross-sectional view of another printed circuit board structure 100 according to aspects of the present disclosure. The printed circuit board structure 100 comprises a first printed circuit board 101 which is the same as the printed circuit board 101 of Figure 1 and a second printed circuit board 111. The second printed circuit board 111 is provided vertically below the first printed circuit board. In this way, the first printed circuit board 101 and the second printed circuit board 111 are provided in a stacked configuration. The second printed circuit board 111 comprises a third antenna coil 113 provided in a central region of the second printed circuit board 111. At least a component of the third antenna coil 113 is aligned with the aperture 105 of the first printed circuit board 101 such that the third antenna coil 113 has line of sight through the aperture 105. The third antenna coil 113 may be a communication antenna coil such as for Bluetooth® or cellular communication. In addition, a light source 115 is provided in the central region of the second printed circuit board 111. The light source 115 is aligned with the aperture 105 of the first printed circuit board 101 such that the third antenna coil 113 has line of sight through the aperture 105. It will be appreciated that both the light source 115 and the third antenna coil 113 are not required to be provided on the second printed circuit board 111. Instead, one of the light source 115 and the third antenna coil 113 may be provided. The light source 115 may be one or a plurality light emitting diodes.

Referring to Figures 2 and 3, the second printed circuit board 111 further comprises a controller 117. The controller 117 is communicatively coupled to at least one of the first antenna coil 107 and the second antenna coil 109. The controller 117 may for example control the energization of the first antenna coil 107 to transmit data using a communication protocol such as NFC. The controller 117 may be communicatively coupled to the third antenna coil 113. The controller 117 may control the energization of the third antenna coil 113 to transmit data using a communication

protocol such as Bluetooth ® or a cellular communication protocol. The controller 117 may be communicatively coupled to the light source 115 for controlling the emission of light by the light source 115.

- 5 In some examples of the printed circuit board structures 100 of Figures 2 and 3, a conductor (not shown) extends from the first printed circuit board to the second printed circuit board to conductively connect the first printed circuit board to the second printed circuit board

10 In some examples of the printed circuit board structures 100 of Figures 2 and 3, the printed circuit boards structure 100 has a rigid-flexible structure. The first and second printed circuit boards 101, 111 are rigid components of the rigid-flexible structure. The conductor is a flexible component of the flex-rigid printed circuit board structure. In other examples, the printed circuit boards 101, 111 are flexible printed circuit boards. In other example, the printed circuit boards 101, 111 and the conductor are rigid components.

15

Referring to Figure 4, there is shown an example system 10 according to aspects of the present disclosure. The system 10 comprises an electronics module 200 comprising the printed circuit board structure 100 of any of Figures 1 to 3, a garment 300, and a mobile device 400. The garment 300 is worn by a user. The electronics module 200 is attached to the garment 300. The electronics module 200 is arranged to integrate with electronic components incorporated into the garment 300 so as to obtain signals from the electronic components. The electronics components may comprise components of sensors. The electronics components may comprise electrodes. The electronics module 200 is further arranged to wirelessly communicate data to the mobile device 400. Various protocols enable wireless communication between the electronics module 200 and the mobile device 400. Example communication protocols include Bluetooth ®, Bluetooth ® Low Energy, and near-field communication (NFC).

20 The electronics module 200 may be removable from the garment 300. The electronics module 200 may be configured to be releasably mechanically coupled to the garment 300. The mechanical coupling of the electronic module 200 to the garment 300 may be provided by a mechanical interface such as a clip, a plug and socket arrangement, etc. The mechanical coupling or mechanical interface may be configured to maintain the electronic module 200 in a particular orientation with respect to the garment 300 when the electronic module 200 is coupled to the garment 300. This may be beneficial in ensuring that the electronic module 100 is securely held in place with respect to the garment 300 and/or that any electronic coupling of the electronic module 200 and the garment 300 (or a component of the garment 300) can be optimized. The mechanical coupling may be maintained using friction or using a positively engaging mechanism, for example.

Beneficially, the removable electronic module 200 may contain all of the components required for data transmission and processing such that the garment 300 only comprises the sensor components and communication pathways. In this way, manufacture of the garment 300 may be simplified. In addition, it may be easier to clean a garment 300 which has fewer electronic components attached thereto or incorporated therein. Furthermore, the removable electronic module 200 may be easier to maintain and/or troubleshoot than embedded electronics. The electronic module 200 may comprise flexible electronics such as a flexible printed circuit (FPC). The electronic module 200 may be configured to be electrically coupled to the garment 300.

It may be desirable to avoid direct contact of the electronic module 200 with the wearer's skin while the garment 300 is being worn. It may be desirable to avoid the electronic module 200 coming into contact with sweat or moisture on the wearer's skin. The electronic module 200 may be provided with a waterproof coating or waterproof casing. For example, the electronic module 200 may be provided with a silicone casing. It may further be desirable to provide a pouch or pocket in the garment to contain the electronic module in order to prevent chafing or rubbing and thereby improve comfort for the wearer. The pouch or pocket may be provided with a waterproof lining in order to prevent the electronic module 200 from coming into contact with moisture.

Referring to Figure 5, there is shown a schematic diagram of an example system 10 according to aspects of the present disclosure. The system 10 comprises an electronics module 200 attached to a garment 300 and in communication with a mobile device 400. The electronics module 200 comprises a printed circuit board structure 100 such as the ones shown in any of Figures 1 to 3. The printed circuit board structure 100 comprises a first printed circuit board 101 and a second printed circuit board 111. The first printed circuit board 101 comprises a first antenna coil 107 (Figure 1) and a second antenna coil 109 (Figure 1). The first antenna coil 107 is an NFC communication coil 107. The second antenna coil 109 is a power receiving coil 109 arranged to wirelessly receive power for charging the electronics module 200. The second printed circuit board 111 comprises a third antenna coil 113 (Figure 2 or 3) and may comprise additional components such as a controller 117 (Figure 2 or 3) and a light source 115 (Figure 3). The third antenna coil 113 is a Bluetooth® communication coil 113. The first printed circuit board 101 is provided proximate to the top of the electronics module 200 such that the first printed circuit board 101 is closest to the mobile device 400 and furthest from the garment 300. Beneficially, this arrangement minimises the communication distance between the NFC communication coil 107 and the mobile device 400. Bluetooth® has a longer communication range than NFC so positioning the Bluetooth® 113 further from the mobile device 400 than the NFC coil 107 does not negatively affect the Bluetooth® communication.

Referring to Figure 6, there is shown a schematic diagram of an example system 10 according to aspects of the present disclosure. The system 10 comprises an electronics module 200

attached to a garment 300 and in communication with a mobile device 400. The electronics module 200 comprises a printed circuit board structure 100 such as the ones shown in any of Figures 1 to 3. The printed circuit board structure 100 comprises a first printed circuit board 101 and a second printed circuit board 111. The first printed circuit board 101 comprises a first antenna coil 107 (Figure 1) and a second antenna coil 109 (Figure 1). The first antenna coil 107 is an NFC communication coil 107. The second antenna coil 109 is a power receiving coil 109 arranged to wirelessly receive power for charging the electronics module 200. The second printed circuit board 111 comprises a third antenna coil 113 (Figure 2 or 3) and may comprise additional components such as a controller 117 (Figure 2 or 3) and a light source 115 (Figure 3). The third antenna coil 113 is a Bluetooth ® communication coil 113. The first printed circuit board 101 is provided proximate to the bottom of the electronics module 200 such that the first printed circuit board 101 is closest to the garment 300 and furthest from the mobile device 400. Beneficially, this arrangement minimises the communication distance between the NFC communication coil 107 and a communication coil 301 of the garment 300. This enables the electronics module 200 to communicate with electronics components of the garment 300 wirelessly without requiring a conductive connection to be formed. The Bluetooth ® communication coil 113 communicates with the mobile device 400. In this example, the first printed circuit board 101 is not required to have an aperture as it is not within the communication pathway of the third communication coil 113.

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Referring to Figure 7, there is shown an exploded view of an example electronics module 200 according to aspects of the present disclosure. The electronics module 200 comprises a printed circuit board 100 structure. The printed circuit board structure 100 comprises a first printed circuit board 101 and a second printed circuit board 111.

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The first printed circuit board 101 comprises a first antenna coil 107 (Figure 1) and a second antenna coil 109 (Figure 1). The first antenna coil 107 is an NFC communication coil 107. The second antenna coil 109 is a power receiving coil 109 arranged to wirelessly receive power for charging the electronics module 200.

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The printed circuit board structure 100 comprises a second printed circuit board 111. The second printed circuit board 111 comprises a controller 117 with an integral third antenna coil 113. A light source 115 is also provided on the second printed circuit board 111. The third antenna coil 113 and the light source 115 are positioned such that they have line of sight through an aperture 105 in the first printed circuit board 101. The first printed circuit board 101 is provided with an integral rigid conductor 119 that forms a mating arrangement with a receptacle 121 on the second printed circuit board 111. In this way, the first printed circuit board 101 is brought into conductive connection with the second printed circuit board 111.

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The electronics module 200 further comprises a power source 123. The power source 123 is coupled to the controller 117 and is arranged to supply power to the controller 117. The power source 123 may comprise a plurality of power sources. The power source 123 may be a battery. The battery may be a rechargeable battery. The battery may be a rechargeable battery adapted to be charged wirelessly such as by inductive charging. The power source 123 may comprise an energy harvesting device. The energy harvesting device may be configured to generate electric power signals in response to kinetic events such as kinetic events performed by a wearer of the garment. The kinetic event could include walking, running, exercising or respiration of the wearer. The energy harvesting material may comprise a piezoelectric material which generates electricity in response to mechanical deformation of the converter. The energy harvesting device may harvest energy from body heat of a wearer of the garment. The energy harvesting device may be a thermoelectric energy harvesting device. The power source may be a super capacitor, or an energy cell.

The electronics module 200 further comprises an interface 125. The interface 125 comprises a magnet 127, and two conductive prongs 129, 131. The interface 125 is arranged to communicatively couple with an electronics arrangement of the garment 300 (Figures 4 to 6) so as to receive a signal from the electronics arrangement. The controller 117 is communicatively coupled to the interface 125 and is arranged to receive the signals from the interface 125. The interface 125 is not required to use conductive prongs 129, 131. The interface 125 form a conductive coupling or a wireless (e.g. inductive) communication coupling with the electronics components of the wearable article.

The components of the electronics module 100 are provided within a housing formed of a top enclosure 133 and a bottom enclosure 135. A longitudinal axis 137 extends from the top enclosure 133 to the bottom enclosure 135. The first printed circuit board 101 is provided proximate to the top enclosure 133. The bottom enclosure 135 is closest to the body of the wearer in use and the top enclosure 119 is furthest away from the body of the wearer in use. Beneficially, providing the first antenna 107 proximate to the top enclosure 119 minimises the communication distance between the first antenna 107 and the mobile device. This is particularly beneficial when the first antenna 107 is a short-range communication antenna 107 such as an NFC antenna 107.

The first antenna coil 107 may be used to exchange information with the mobile device 400 over the first wireless communication protocol to facilitate pairing the electronics module 200 to the mobile device 400 over a second wireless communication protocol. This may enable the third antenna coil 113 to communicate with the mobile device 400 over the third wireless communication protocol. The first wireless communication protocol may be a near field communication (NFC) protocol. The second wireless communication protocol may be a

Bluetooth ® protocol or a Bluetooth ® Low Energy protocol. Outside of the field of electronics modules for wearable articles, it is known to use near-field communication technologies to enhance the user experience of applications that use Bluetooth ® technology. In particular, the publication “Bluetooth ® Secure Simple Pairing Using NFC” which was published by the Bluetooth ® Special Interest Group of the NFC forum on 9th January 2014 describes that NFC can be used to enhance at least the selection of Bluetooth ® devices, the secure connection of Bluetooth ® devices, and the initialisation of applications on Bluetooth ® devices. The disclosures of this document are hereby incorporated by reference.

10 The electronics module 200 may additionally comprise a sensor (not shown). The sensor 111 is arranged to detect the mobile device 400 being brought into proximity with the electronics module 200. In particular, the sensor may be a motion sensor that is arranged to detect a displacement of the electronics module 200 caused by the mobile device 400 being brought into proximity with the electronics module 200. These displacements of the electronics module 200 may be caused by the mobile device 400 being tapped against the electronics module 200. Physical contact between the mobile device 400 and the electronics module 200 is not required as the electronics module 200 may be in a pocket of the garment 300. This means that there may be a fabric (or other material) barrier between the electronics module 200 and the mobile device 400. In any event, the electronics module 200 being brought into contact with the fabric of the pocket will cause an impulse to be applied to the electronics module 200 which will be sensed by the sensor.

The motion sensor may be an inertial measurement unit. The inertial measurement unit may comprise an accelerometer and optionally one or both of a gyroscope and a magnetometer. A gyroscope/magnetometer is not required in all examples, and instead only an accelerometer may be provided or a gyroscope/magnetometer may be present but put into a low power state. A processor of the sensor may perform processing tasks to classify different types of detected motion. The processor of the sensor may in particular perform machine-learning functions so as to perform this classification. Performing the processing operations on the sensor rather than the controller 117 (Figures 2 or 3) is beneficial as it reduces power consumption, and leaves the controller 117 free to perform other tasks. In addition, it allows for motion events to be detected even when the controller 117 is operating in a low power mode. The sensor communicates with the controller 117 over a serial protocol such as the Serial Peripheral Interface (SPI), Inter-Integrated Circuit (I2C), I3C, Controller Area Network (CAN), and Recommended Standard 232 (RS-232). Other serial protocols are within the scope of the present disclosure. The sensor is also able to send interrupt signals to the controller 117 when required so as to transition the controller 117 from a low power model to a normal power mode when a motion event is detected. The interrupt signals may be transmitted via one or more dedicated interrupt pins.

The sensor detecting the mobile device 400 being brought into proximity with the electronics module 200 may cause, amongst other things, the controller 117 to wake-up, or any of the antenna coils 107, 109, 113 to be energised to transmit data to the mobile device 400. In addition to being used for triggering an antenna coil to transmit information, the motion (e.g. ‘tap’)

5 detection by the sensor can be used to control operations of the electronics module 200. In this way, the detected taps may replicate the basic function of a user button on existing electronics module 200. A physical button is therefore not required for the present example. A single tap may be used to wake up the electronics module or cycle through different modes of operation.

10 The electronics module 200 may comprise a Universal Integrated Circuit Card (UICC) that enables the electronics module 200 to access services provided by a mobile network operator (MNO) or virtual mobile network operator (VMNO). The UICC may include at least a read-only memory (ROM) configured to store an MNO/VMNO profile that the electronics module 200 can utilize to register and interact with an MNO/VMNO. The UICC may be in the form of a Subscriber

15 Identity Module (SIM) card. The electronics module 200 may have a receiving section arranged to receive the SIM card. In other examples, the UICC is embedded directly into a controller of the electronics module 200. That is, the UICC may be an electronic/embedded UICC (eUICC). A eUICC is beneficial as it removes the need to store a number of MNO profiles, i.e. electronic Subscriber Identity Modules (eSIMs). Moreover, eSIMs can be remotely provisioned to

20 electronics module 200. The electronics module 200 may comprise a secure element that represents an embedded Universal Integrated Circuit Card (eUICC).

Referring to Figures 8 and 9, there is shown an electronics module 200 according to aspects of the present disclosure. The electronics module 200 may be the same as any of the electronics

25 modules 200 as described above in relation to Figures 4 to 7. The electronics module 200 comprises a housing which contains the components of the electronics module 200. The housing comprises a top enclosure 133 and a bottom enclosure 135. The bottom enclosure 135 is closest to the body of the wearer in use and the top enclosure 133 is furthest away from the body of the wearer in use. First and second conductive prongs 129, 131 extend from openings 137, 139 in

30 the bottom enclosure 135. The first and second conductive prongs 129, 131 are able to electrically conductively connect with conductive elements provided on a textile so as to electrically conductively connect the electronics module 200 to the conductive elements of the textile. The use of conductive prongs 129, 131 to electrically conductively connect the electronics module 100 to the textile are not required in all aspects of the present disclosure. Other forms

35 of conductive connection may be provided such as via conductive studs or pins. In addition, a conductive connection may not be required as a wireless communication connection may be formed between the electronics module 200 and electronics components of the textile to allow for data exchange between the electronics module 200 and the electronics components of the textile. In one example, the electronics module 200 comprises an NFC coil proximate to the

bottom enclosure 135 and the textile material comprises a corresponding NFC coil. These NFC coils form a communicative coupling when the electronics module 100 is brought into proximity with the textile to allow for data exchange. Figure 6 shows an example of a wireless communication arrangement between the electronics module 200 and a garment 300.

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Referring to Figure 10, there is shown an example textile layer of a garment 300 according to aspects of the present disclosure. The garment 300 comprises a textile material 302 and conductive elements 301, 303, 305, 307 provided on the textile material 302. The conductive elements 301, 303, 305, 307 comprise a first terminal 301 and a first electrically conductive pathway 303 that extends from the first terminal 301 to a first electrode (not shown). The first electrically conductive pathway 303 therefore electrically connects the first terminal 301 to the first electrode. The conductive elements 301, 303, 305, 307 further comprise a second terminal 305 and a second electrically conductive pathway 307 that extends from the second terminal 305 to a second electrode (not shown). The second electrically conductive pathway 307 therefore electrically connects the second terminal 305 to the second electrode. The first and second electrodes may be used to measure electro potential signals such as electrocardiogram (ECG) signals. The first and second terminals 301, 305 are arranged as concentric circles. A portion of the first electrically conductive pathway 303 extends under the second terminal 305. An insulating layer (not shown) insulates the first electrically conductive pathway 303 from the second terminal 305. This is just one example arranged of electrically conductive pathways on a textile. Other arrangements such as different positioning of electrically conductive pathways, and the use of different materials are within the scope of the present disclosure. For example, the electrically conductive pathways may be formed from a conductive thread or wire. The electrically conductive pathway may be incorporated into the textile. The electrically conductive pathway may be an electrically conductive track or film. The electrically conductive pathway may be a conductive transfer. The conductive material may be formed from a fibre or yarn of the textile. This may mean that an electrically conductive materials are incorporated into the fibre/yarn. In some examples, the conductive pathways may be provided on the underside surface of the textile. In some examples, an aperture may be provided in the textile so as to allow the electronics module to conductively connect to the conductive pathways.

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Referring to Figure 11, there is shown the electronics module 200 of Figures 8 and 9 attached to the garment 300 of Figure 10. The first conductive prong 129 is brought into conductive electrical contact with the first terminal 201 and the second conductive prong 131 is brought into conductive electrical contact with the second terminal 205. A magnet 127 (Figure 7) may be provided in the electronics module 200 and on the underside of the garment 300 so as to maintain the electronics module 200 in releasable attachment with the garment 300.

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While the above examples refer to printed circuit board structures with apertures, it will be appreciated that this is not required for all aspects of the present disclosure.

5 In the present disclosure, the electronics module may also be referred to as an electronics device or unit. These terms may be used interchangeably.

At least some of the example embodiments described herein may be constructed, partially or wholly, using dedicated special-purpose hardware. Terms such as 'component', 'module' or 'unit' used herein may include, but are not limited to, a hardware device, such as circuitry in the form of discrete or integrated components, a Field Programmable Gate Array (FPGA) or Application Specific Integrated Circuit (ASIC), which performs certain tasks or provides the associated functionality. In some embodiments, the described elements may be configured to reside on a tangible, persistent, addressable storage medium and may be configured to execute on one or more processors. These functional elements may in some embodiments include, by way of example, components, such as software components, object-oriented software components, class components and task components, processes, functions, attributes, procedures, subroutines, segments of program code, drivers, firmware, microcode, circuitry, data, databases, data structures, tables, arrays, and variables. Although the example embodiments have been described with reference to the components, modules and units discussed herein, such functional elements may be combined into fewer elements or separated into additional elements. Various combinations of optional features have been described herein, and it will be appreciated that described features may be combined in any suitable combination. In particular, the features of any one example embodiment may be combined with features of any other embodiment, as appropriate, except where such combinations are mutually exclusive.

25 Throughout this specification, the term "comprising" or "comprises" means including the component(s) specified but not to the exclusion of the presence of others.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

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Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

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The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification

(including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. A printed circuit board structure, comprising:
5 a printed circuit board, the printed circuit board comprising a first region bounding
 an aperture extending through the printed circuit board;
 a first antenna arranged in the first region of the printed circuit board; and
 a second antenna arranged in the first region of the printed circuit board.
- 10 2. A printed circuit board structure as claimed in claim 1, wherein the first antenna and the
 second antenna comprise antenna coils, and optionally comprise spiral coil wires.
3. A printed circuit board structure as claimed in claim 1 or 2, wherein the aperture is
 located in a central region of the printed circuit board.
- 15 4. A printed circuit board structure as claimed in any preceding claim, wherein the first
 region comprises an outer region and an inner region, wherein the inner region is located
 between the outer region and the aperture, and wherein one of the first and second
 antennas is arranged in the outer region, and wherein the other of the first and second
20 antennas is arranged in the inner region.
5. A printed circuit board structure as claimed in any of claims 1 to 3, wherein the first
 antenna is interlaced with the second antenna.
- 25 6. A printed circuit board structure as claimed in any preceding claim, wherein the second
 antenna is a power receiving antenna.
7. A printed circuit board structure as claimed in any preceding claim, wherein the first
 antenna is a communication antenna.
- 30 8. A printed circuit board structure as claimed in claim 7, wherein the first antenna is a
 short-range communication antenna.
9. A printed circuit board structure as claimed in claim 8, wherein the first antenna coil is a
 near-field communication antenna.
- 35 10. A printed circuit board structure as claimed in any preceding claim, wherein the printed
 circuit board is a flexible printed circuit board.
- 40 11. A printed circuit board structure as claimed in any preceding claim, wherein the printed
 circuit board is a rigid-flexible printed circuit board.

12. A printed circuit board structure as claimed in any preceding claim, further comprising a controller communicatively coupled to at least one of the first antenna and the second antenna.
- 5
13. A printed circuit board structure as claimed in claim 12, wherein the printed circuit board is a first printed circuit board of the printed circuit board structure, and wherein the printed circuit board structure further comprises a second printed circuit board, and wherein the controller is provided on the second printed circuit board.
- 10
14. A printed circuit board structure as claimed in claim 12 or 13, wherein the first and second printed circuit board are arranged in a stacked configuration.
- 15
15. A printed circuit board structure as claimed in claim 13 or 14, wherein a conductor extends from the first printed circuit board to the second printed circuit board to conductively connect the first printed circuit board to the second printed circuit board.
- 20
16. A printed circuit board structure as claimed in claim 15, wherein the printed circuit board structure is a flex-rigid printed circuit board structure, and wherein the first and second printed circuit boards are rigid components of the flex-rigid printed circuit board structure, and wherein the conductor is a flexible component of the flex-rigid printed circuit board structure.
- 25
17. A printed circuit board structure as claimed in any of claims 13 to 16, wherein the second printed circuit board comprises an antenna, and wherein the antenna is arranged on the printed circuit board such that the antenna has line of sight through the aperture.
- 30
18. A printed circuit board structure as claimed in any of claims 13 to 17, wherein the second printed circuit board comprises a light source, and wherein the light source is arranged on the printed circuit board such that the light source has line of sight through the aperture.
- 35
19. A printed circuit board structure as claimed in claim 18, wherein the light source comprises a light emitting diode.
20. An electronics module for a wearable article, the electronics module comprising the printed circuit board structure as claimed in any preceding claim.

21. An electronics module as claimed in claim 20, further comprising an interface arranged to communicatively couple with an electronics arrangement of the wearable article so as to form a signal pathway between the electronics module and the electronics arrangement.
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22. An electronics module as claimed in claim 20 or 21, further comprising a power source, coupled to the printed circuit board structure and arranged to supply power to the printed circuit board structure.
- 10
23. An electronics module as claimed in any of claims 20 to 22, further comprising a housing arranged to house the printed circuit board structure.
24. A wearable article comprising the electronics module as claimed in any of claims 20 to 23.
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25. A wearable article as claimed in claim 24, wherein the wearable article is a garment.



Application No: GB2000863.7

Examiner: Mr John Watt

Claims searched: 1 - 25

Date of search: 9 July 2020

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1 - 25	EP 1450438 A1 (NIPPON ANTENNA) see figs.10 & 31 and paragraphs [0031] - [0033] and [0056].
X	1 - 25	EP 0547563 A1 (SIEMENS) see figs.2 & 3 and col.5, line 54 to col.6, line 2.
A	-	JP 2008027015 A (DAINIPPON PRINTING) see fig.2 and abstract.
A	-	US 2016/0126002 A1 (CHIEN ET AL) see whole document, especially figs.3 - 6 and paragraphs [0012] and [0013].
A	-	CN 103199333 A (SHANGHAI AMPHENOL AIRWAVE) see whole document.
A	-	GB 2438292 A (NEC) see fig.16 and page 10, lines 15 - 28.
A	-	US 2009/0231211 A1 (ZWEERS) see figs.3 & 4 and abstract.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

H01Q

The following online and other databases have been used in the preparation of this search report



WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
H01Q	0001/38	01/01/2006
H01Q	0001/27	01/01/2006
H01Q	0005/00	01/01/2015
H01Q	0007/00	01/01/2006