(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 454 411 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**13.03.2019 Bulletin 2019/11**

(21) Application number: **17189735.8**

(22) Date of filing: **07.09.2017**

(51) Int Cl.:
***H01Q 1/24*** *(2006.01)* ***H01Q 1/27*** *(2006.01)*
***H01Q 1/44*** *(2006.01)* ***H01Q 7/00*** *(2006.01)*

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**
Designated Validation States:
**MA MD**

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(54) **ANTENNA ARRANGEMENT FOR WEARABLE DEVICE**

(57) This document discloses an antenna arrangement for a wearable apparatus, comprising: an electronic circuitry (110) comprising at least an antenna matching circuitry (116); a metallic chassis (100) enclosing the electronic circuitry (110); at least one grounding electrode (120, 122) coupled to the metallic chassis; and at least one feed electrode (124,126) coupling the antenna matching circuitry to the chassis. The wearable apparatus may be a wrist computer with wireless communication capabilities, for example.

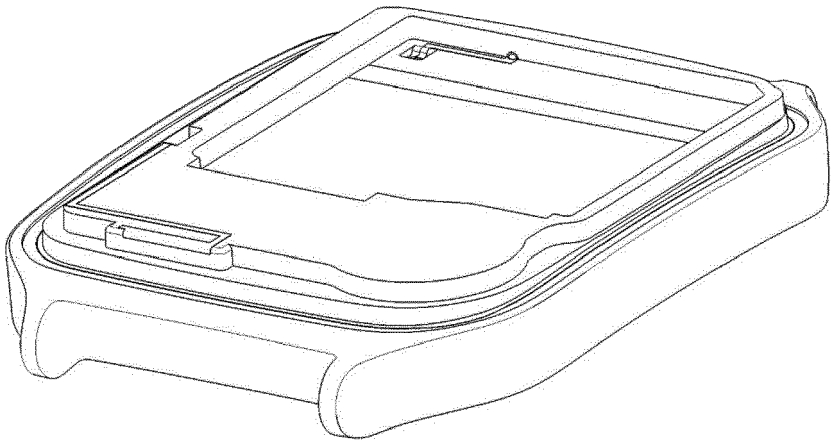

Fig 5B

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## Description

### TECHNICAL FIELD

**[0001]** The invention relates to radio frequency antennas and wearable devices and, in particular to an antenna arrangement in a wearable device.

### TECHNICAL BACKGROUND

**[0002]** Most of the smart watches and other wearable devices manufactured today are provided with a wireless modem capable of communicating according to one or more wireless communication protocols, e.g. Long-Term Evolution (LTE) protocols, IEEE 802.11 protocols, Bluetooth® protocols, satellite navigation system protocols, and other radio protocols. A single wearable device may support even dozens of radio protocols. This may pose a challenge in implementing antennas that would support all the protocols in such manner that the communication performance is at acceptable level.

### BRIEF DESCRIPTION

**[0003]** The invention is defined by the independent claim. Embodiments are defined in the dependent claims.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0004]** In the following the invention will be described in greater detail by means of preferred embodiments with reference to the accompanying drawings, in which

Figure 1 illustrates a simplified view of a chassis and electronics of a wearable device;
Figure 2 illustrates an antenna arrangement according to an embodiment of the invention;
Figure 3 illustrates an effect of the antenna arrangement of Figure 2;
Figure 4 illustrates an antenna arrangement according to another embodiment of the invention; and
Figures 5A and 5B illustrate an antenna arrangement according to another aspect.

### DETAILED DESCRIPTION OF THE INVENTION

**[0005]** The following embodiments are examples. Although the specification may refer to "an", "one", or "some" embodiment(s) in several locations, this does not necessarily mean that each such reference is referring to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments. Furthermore, words "comprising" and "including" should be understood as not limiting the described embodiments to consist of only those features that have been mentioned and such embodiments may contain also features/structures that have not been specifically mentioned.

**[0006]** Figure 1 illustrates a simplified structure of a housing for a wearable device. The wearable device may be a smart watch, a wrist computer, or any device attachable to a human body. The wearable device typically comprises the housing comprising a chassis 100 and one or more electronic circuitries 110 enclosed by the chassis 100. The wearable device may further comprise an attachment structure suitable for attaching the housing to the human body. The attachment structure may comprise a strap for attaching the housing to an arm, wrist, torso, waist, head, neck, foot, and/or leg. The attachment structure may comprise an earlobe attachment structure, or it may comprise a frame of glasses or goggles.

**[0007]** In some embodiments of the invention, the chassis 100 is metallic, or it may be formed of another material suitable for providing the chassis 100 with capabilities of operating as an antenna. In the embodiments, the chassis 100 itself is arranged to function as one or more antennas which distinguishes the embodiments from solutions where an antenna is formed or attached to the chassis. The chassis 100 may be made of one integral piece of metallic material such as aluminium or steel. The chassis 100 may be arranged to have a circumferential shape, and the actual shape may be designed according to implementation. For example, the circumferential chassis 100 may take the form of an annulus or a hollow rectangle, as illustrated in Figure 2. The actual shape of the chassis may be affected by the design of the wearable device, e.g. the otherwise regular shape of the chassis may be broken by positioning of buttons or other mechanical objects of the wearable device.

**[0008]** Figure 2 illustrates an embodiment of an antenna arrangement for the wearable device. Referring to Figures 1 and 2, the antenna arrangement comprises: an electronic circuitry 110 comprising at least an antenna matching circuitry 116; a metallic chassis 100 enclosing the electronic circuitry 110; at least one grounding electrode 120, 122 coupled to the metallic chassis 100; and at least one feed electrode 124, 126 coupling the antenna matching circuitry 116 to the chassis 100.

**[0009]** Referring to Figure 2, the wearable device may comprise an application processor 112 executing one or more computer program applications in the wearable device. For example, the application processor 112 may execute a measurement application employing one or more sensors of the wearable device or connected to the wearable device. As another example, the application processor 112 may execute a calendar application or an e-mail application. At least some of the applications executed by the application processor may require a communication connection over a radio interface. For that purpose, the application processor 112 may configure a wireless modem 114 to establish a radio connection. The wireless modem 114 may support one or more radio communication protocols, e.g. one or more of the protocols described in the Background. The wireless modem may comprise hardware and software required to generate

and/or receive radio signals according to the one or more radio communication protocols. An output of block 114 may be coupled to the antenna matching circuitry 116 configured to provide impedance matching to the antenna or antennas formed by the chassis 100. The antenna matching circuitry may comprise a dedicated matching circuitry for each antenna feed electrode 124, 126.

**[0010]** In an embodiment, the chassis 100 is configured to form one or more antennas for signals transmitted and/or received according to a cellular communication protocol such as a 3G, 4G, or 5G cellular communication protocol. An example of the 3G protocol is Wideband Code Division Multiple Access (W-CDMA) standardized within the 3rd Generation Partnership Project (3GPP). An example of the 4G protocol is the LTE or LTE-Advanced standardized also within the 3GPP. Standardization of the 5G is currently under way within the 3GPP. Other cellular protocols exist, such as WiMAX (Worldwide Interoperability for Microwave Access).

**[0011]** The coupling between the feed electrodes 124, 126 and the chassis 100 may be galvanic or capacitive.

**[0012]** Figure 3 illustrates the arrangement of Figure 2 in a planar view from above the chassis. In the embodiment of Figures 2 and 3, there exists a first grounding electrode 120 and a second grounding electrode 122. Additionally, there exists a first feed electrode 124 and a second feed electrode 126. The first feed electrode 124 and the second feed electrode 126 are coupled to the chassis on opposite sides of the first grounding electrode 120 along a circumference of the chassis 100. In a similar manner, the first feed electrode 124 and the second feed electrode 126 are coupled to the chassis on opposite sides of the second grounding electrode 122 along the circumference of the chassis 100. As illustrated in Figures 1 and 2, the first feed electrode 124 is disposed at a location clockwise from the second grounding electrode 122 while the second feed electrode 126 is disposed at a location counter clockwise from the second grounding electrode 122. In a similar manner, the first feed electrode 124 is disposed at a location counter clockwise from the first grounding electrode 122 while the second feed electrode 126 is disposed at a location clockwise from the first grounding electrode 120. In this manner, a number of radiators with different radiation characteristics are formed.

**[0013]** As illustrated in Figure 3, radiating surfaces are formed between the feed electrodes 124, 126 and the grounding electrodes 120, 122. A first radiating surface is formed in the chassis 100 between the first feed electrode 124 and the second grounding electrode 122. As illustrated by the dashed line between the first feed electrode 124 and the second grounding electrode 122, this surface forms an L-shaped antenna. The locations of the first feed electrode 124 and the second grounding electrode 122 may be selected such that they are provided on different edges of the chassis to form the L-shape and such that the distance between the first feed electrode 124 and the second grounding electrode 122 is proportional to a desired wavelength $\lambda$ of radiated or absorbed radio signal, e.g. half of the wavelength $\lambda/2$.

**[0014]** A second radiating surface is formed in the chassis 100 between the second feed electrode 126 and the second grounding electrode 122. As illustrated by the dashed line between the second feed electrode 126 and the second grounding electrode 122, this surface also forms an L-shaped antenna. The locations of the second feed electrode 124 and the second grounding electrode 122 may be selected such that they are provided on different edges of the chassis to form the L-shape and such that the distance between the first feed electrode 124 and the second grounding electrode 122 is proportional to the desired wavelength $\lambda$ of radiated or absorbed radio signal, e.g. quarter of the wavelength $\lambda/4$. The desired wavelengths of the first and second radiating surfaces may be different to support multiple resonance frequencies, e.g. one resonance frequency below 1000 Megahertz (MHz) and another resonance frequency above 1 500 MHz.

**[0015]** Further radiating surfaces may be formed between the feed electrodes 124, 126 and the grounding electrodes 120, 122, as illustrated in Figure 3. By using two feed electrodes and two grounding electrodes, up to four radiating surfaces may be formed, and each radiating surface may be configured to provide different radiation characteristics such as different resonance frequencies by suitable positioning of the electrodes. Further radiating surfaces may be arranged by increasing the number of grounding electrodes and feed electrodes coupling the chassis with the antenna matching circuitry 116.

**[0016]** In an embodiment, only one feed electrode and only one grounding electrode is coupled to the chassis. In such an embodiment the chassis may form one or two radiating surfaces with different or even the same radiation characteristics.

**[0017]** Figure 4 illustrates an embodiment where the antenna arrangement comprises further antennas disposed on top of the chassis 100. Referring to Figure 4, two further antennas 300, 302 are coupled to the electronic circuitry 110. The antenna matching circuitry 116 may provide different antenna matching configurations to antenna(s) formed by the chassis and the further antenna(s) attached to the chassis 100. The further antennas 300, 302 may be attached to the chassis by using any state-of-the-art methods such as laser direct-structuring (LDS). Each of the further antennas 300, 302 may be a strip-line antenna, a patch antenna, or an inverted F-antenna (IFA), for example.

**[0018]** In the embodiment of Figure 4, a first antenna 302 is disposed on top of the grounding electrode 122 coupled to the metallic chassis 100. The first antenna 302 may be configured to form an antenna providing a resonance frequency on a frequency band of a wireless local area network (WLAN) complying with IEEE 802.11 technology. Providing the antenna on top of the grounding electrode 122 improves the isolation and reduces in-

terference between the WLAN and the cellular communications operated in the wearable device.

**[0019]** A second antenna 300 is disposed on top of the chassis and configured to provide a resonance frequency on a frequency band of a satellite positioning system. The second antenna 300 may be disposed such that the second antenna does not extend over any grounding electrode 120, 122 coupled to the metallic chassis. In such a case, a notch filter 304 may be provided between the at least one feed electrode 124, 126 coupling the antenna matching circuitry 116 to the chassis 100. The notch filter 304 may be configured to suppress a satellite positioning system frequency from a transmission/reception signal of the cellular antenna system, thus improving the isolation between the satellite positioning system antenna 300 and the cellular antenna(s).

**[0020]** The first and the second antenna 300, 302 may be arranged to have no galvanic contact with the chassis. For example, dielectric material may be disposed between the chassis and the antenna 300, 302.

**[0021]** In general, an antenna of any narrowband communication system may be provided at a location that is not on top of a grounding electrode coupled to the chassis, because the notch filter may then be employed to improve the isolation. An antenna of a wideband communication system may be provided on top of the grounding electrode to provide for better isolation without additional filtering.

**[0022]** Figures 5A and 5B illustrate an embodiment according to another aspect. Referring to Figure 5A, the antenna arrangement of any embodiment described above may be implemented in a frame 510 that is configured to be attached to the chassis 100 of the wearable device. In Figure 5A, the chassis 100 is denoted by 502 and an outer shape of the frame is designed to conform to an internal shape of the chassis such that the frame can be attached inside the circumference of the chassis, as illustrated in Figure 5B. The frame 510 may be made of any dielectric material. The antennas may be formed on the frame by using laser direct-structuring (LDS), adhesion, or any other solution for attaching metallic components on a non-metallic surface. In the embodiment of Figure 5A and 5B, the antennas 300 and 302 are now formed on the frame according to the above-described principles.

**[0023]** In the above-described embodiments, the chassis 100 forms the cellular antenna. In the embodiment of Figures 5A and 5B, the cellular antenna 500 is formed on the frame. The cellular antenna may be formed on an outer circumference of the frame and it may extend along in a plurality of directions along the outer perimeter, as illustrated in Figure 5A. In another embodiment, the cellular antenna may be disposed on another surface of the frame, e.g. top surface on which a display screen is provided to enable radiation in a direction perpendicular to a plane of the display screen. The cellular antenna may be provided such that it extends in parallel with one or both of the antennas 300 and 302.

**[0024]** According to these principles, even a higher number of additional antennas may be attached to the wearable device. It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

## Claims

1. An antenna arrangement for a wearable apparatus, comprising:

   an electronic circuitry (110) comprising at least an antenna matching circuitry (116);
   a metallic chassis (100) enclosing the electronic circuitry (110);
   at least one grounding electrode (120,122) coupled to the metallic chassis; and
   at least one feed electrode (124, 126) coupling the antenna matching circuitry to the chassis.

2. The antenna arrangement of claim 1, wherein the metallic chassis is circumferential.

3. The antenna arrangement of claim 2, comprising at least a first grounding electrode (120) and a second grounding electrode (122) coupled to the metallic chassis, wherein the at least one feed electrode (124) is coupled to the chassis between the first and second grounding electrode, wherein a distance between the at least one grounding electrode and the at least one feed electrode along the circumferential chassis is configured according to desired resonance frequency characteristics.

4. The antenna arrangement of claim 3, wherein the distance is one half or one fourth of a desired wavelength of a radio signal emitted or absorbed by the chassis.

5. The antenna arrangement of claim 3 or 4, comprising at least a first feed electrode (124) and a second feed electrode (126) coupling the antenna matching circuitry to the chassis, wherein the first feed electrode and the second feed electrode are coupled to the chassis on opposite sides of the first grounding electrode along a circumference of the chassis.

6. The antenna arrangement of claim 5, wherein a first radiating surface of the chassis between the first feed electrode and the first grounding electrode provides for different resonance frequency characteristics than a second radiating surface of the chassis between the second feed electrode and the first grounding electrode.

7. The antenna arrangement of any preceding claim, further comprising at least one further antenna (300, 302) attached to the chassis, wherein the at least one further antenna is coupled to the antenna matching circuitry with at least one further feed electrode, wherein the antenna matching circuitry provides different antenna matching configurations to an antenna or antennas formed by the chassis and to said at least one further antenna.

8. The antenna arrangement of claim 7, wherein the at least one further antenna comprises a first antenna (302) disposed on top of the grounding electrode coupled to the metallic chassis.

9. The antenna arrangement of claim 8, wherein the antenna is configured to form an antenna providing a resonance frequency on a frequency band of a wireless local area network.

10. The antenna arrangement of any preceding claim 7 to 9, wherein the at least one further antenna comprises a second antenna (300) disposed on top of the chassis and configured to provide a resonance frequency on a frequency band of a satellite positioning system.

11. The antenna arrangement of claim 10, wherein the second antenna is disposed such that the second antenna does not extend over any grounding electrode coupled to the metallic chassis.

12. The antenna arrangement of claim 10 or 11, further comprising a notch filter (304) between the at least one feed electrode coupling the antenna matching circuitry to the chassis, wherein the notch filter is configured to suppress a transmission frequency of the satellite positioning system.

13. The antenna arrangement of any preceding claim 7 to 12, wherein the at least one further antenna is coupled to the at least one further feed electrode via capacitive coupling.

14. A wearable device comprising the antenna arrangement of any preceding claim.

15. A wrist computer comprising the antenna arrangement of any preceding claim 1 to 13.

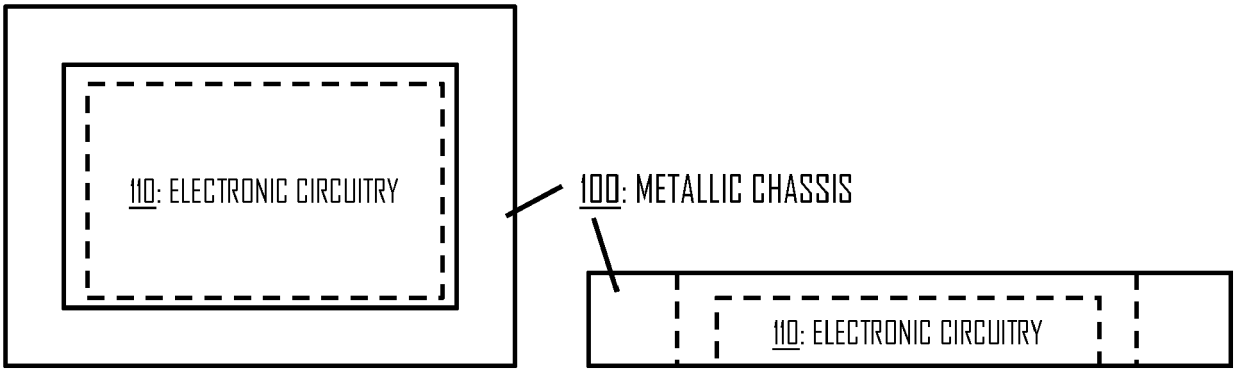


Fig 1

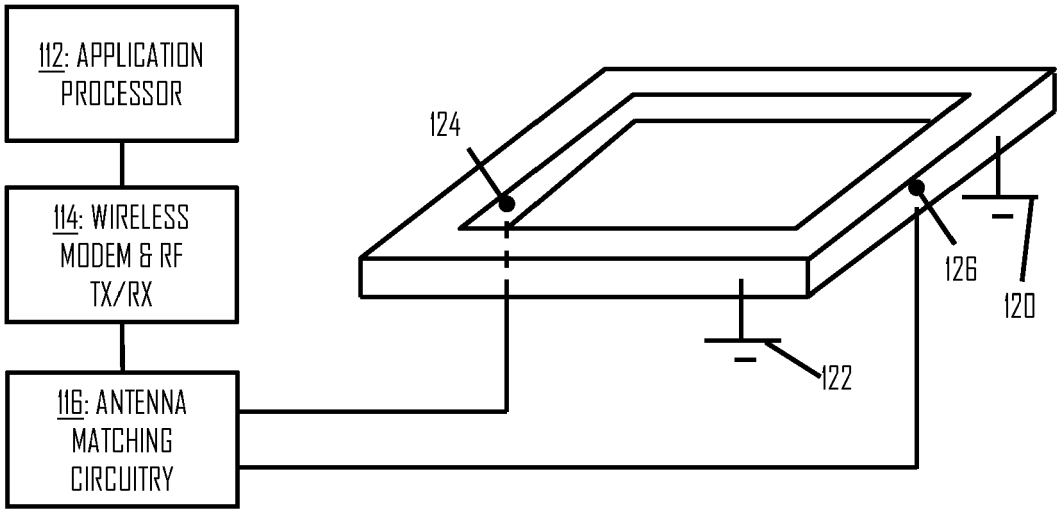


Fig 2

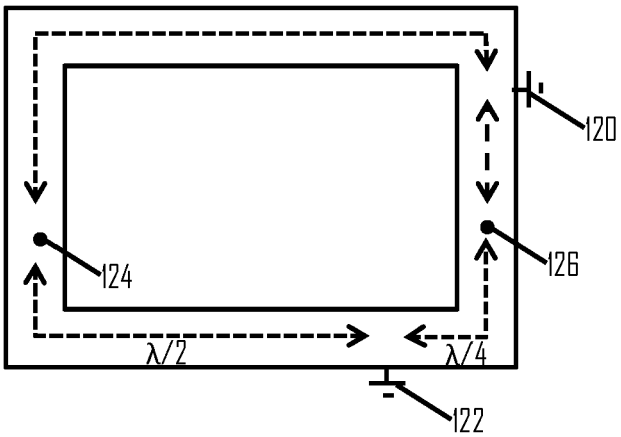


Fig 3

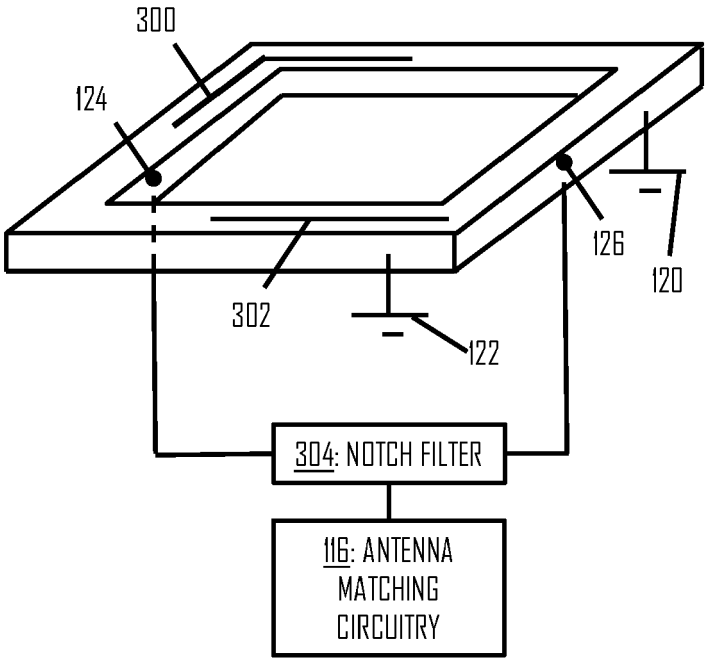
300
124
126
120
302
122
304: NOTCH FILTER
116: ANTENNA MATCHING CIRCUITRY

Fig 4

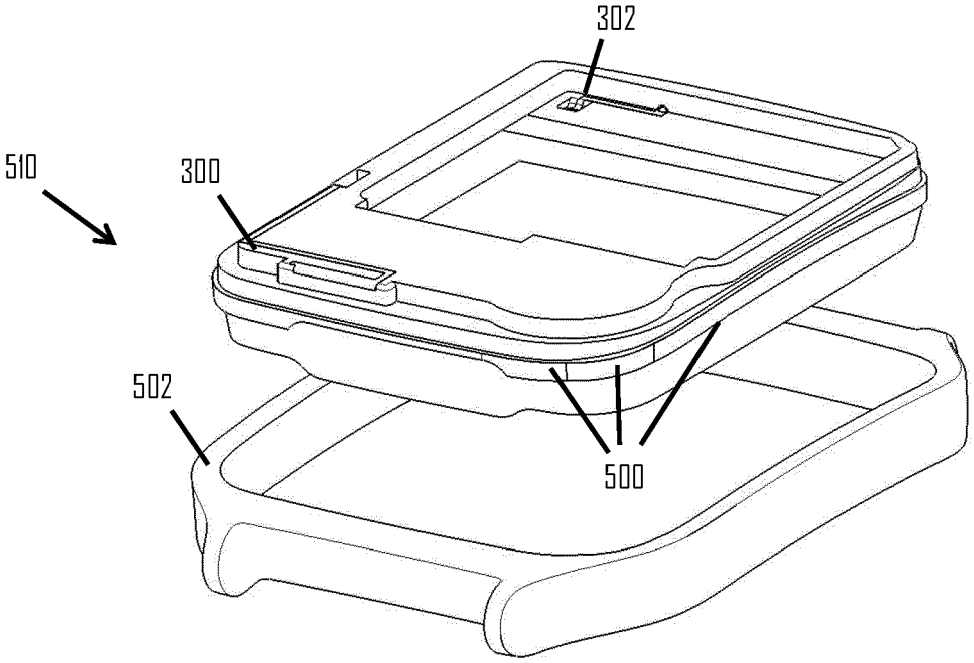
302
510
300
502
500

Fig 5A

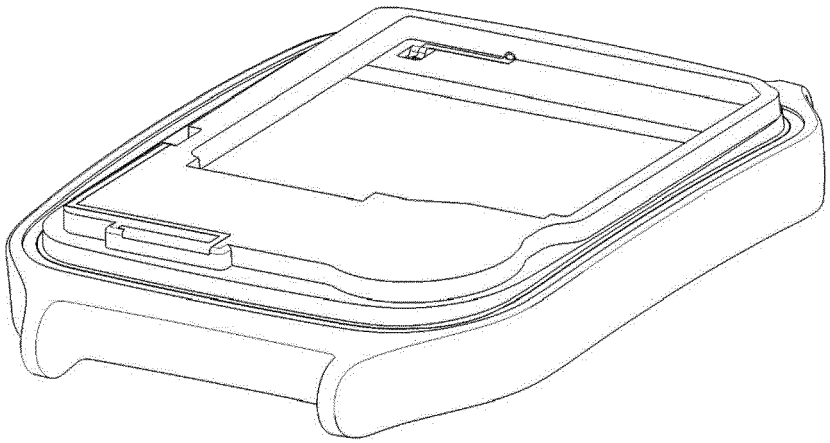

Fig 5B

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# EUROPEAN SEARCH REPORT

Application Number
EP 17 18 9735

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X<br>Y | US 2015/048979 A1 (ASRANI VIJAY L [US] ET AL) 19 February 2015 (2015-02-19)<br>* paragraph [0020] *<br>* paragraph [0025] *<br>* paragraph [0027] *<br>* paragraph [0028] *<br>* paragraph [0043] *<br>* figures 1-3 * | 1-6,14, 15<br>7-13 | INV.<br>H01Q1/24<br>H01Q1/27<br>H01Q1/44<br>H01Q7/00 |
| Y | US 2015/309533 A1 (MAJAVA VILLE [FI] ET AL) 29 October 2015 (2015-10-29)<br>* abstract *<br>* paragraph [0019] *<br>* figure 1 * | 7-13 | |
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TECHNICAL FIELDS SEARCHED (IPC)
H01Q

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 20 February 2018 | Mitchell-Thomas, R |

CATEGORY OF CITED DOCUMENTS

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 18 9735

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20-02-2018

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