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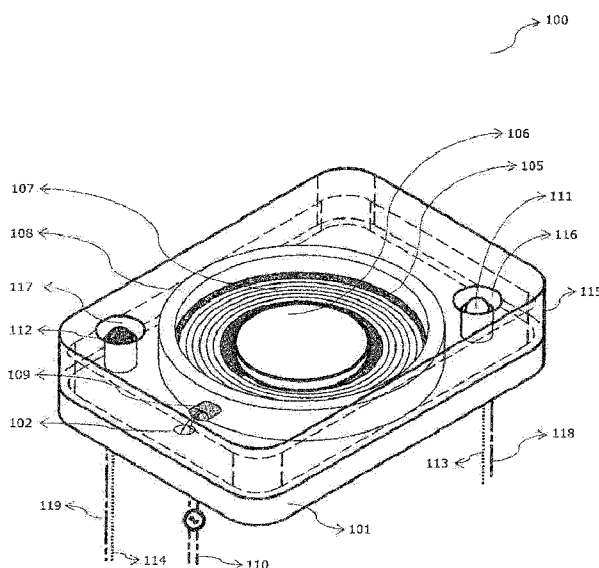


FIG.1

(57) Abstract: An integrated electromagnetic and optical device for a wireless transfer of power and transmission of data, with a light emitter (111), a light receiver (112) and a magnetic flux directing member (108) are disposed on a base member (101). An electromagnetic inductive interface (107) is coupled to a magnetic flux amplifier (106) and disposed within the magnetic flux directing member (108). A sealing member (115) with optical apertures (116, 117) to expose the light emitter (111) and the light receiver (112) and to form a sealing enclosure. A pair of integrated electromagnetic and optical devices (200a, 200b) are disposed to be coupled electromagnetically and optically and to be configured for a wireless transfer of power and transmission of data between them. An occupant restraint system (300) for an automotive vehicle with a buckle assembly and a tongue assembly for a wireless transfer of transfer of power and transmission of data.

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INTEGRATED ELECTROMAGNETIC AND OPTICAL DEVICE FOR WIRELESS TRANSFER OF POWER AND DATA COMMUNICATION

Technical Field

[001] This invention relates to a wireless energy transfer and data communication, particularly to an integrated electromagnetic and optical device to enable a wireless transfer of power and transmission of data, across electromagnetically and optically coupled systems. The present invention also relates to an occupant restraint system for a vehicle that is equipped with the integrated electromagnetic and optical device of the present invention, for a wireless transfer of power and data communication between a buckle and a webbing of the occupant restraint system.

Background of the invention

[002] Energy or power may be transferred wirelessly using electromagnetic devices. Similarly, data and information can be communicated using optical networking technologies, such as Li-Fi, which use light-emitting diodes, which can be a visible light diode or infra-red diode for data transmission.

[003] However, the power transfer and data communication are performed, by means of adoption of independent structural arrangements viz., electromagnetic and optical networking devices, to transfer power and transmit data separately. Such separate arrangements may require independent hardware systems thereby increasing size of the devices and the complexity in configuration of the respective electromagnetic and optical components.

[004] In automobile safety systems, seat belt system plays a pivotal role in securing occupants, to their seats, particularly in the event of abnormal situations, due to an impact or otherwise, resulting

in rapid displacement of the seated occupants from their normal positions. The seat belt system generally includes an arrangement of belt webbing reel that is stored in a retractor and connected to a sliding tongue. A buckle is attached to a structural component of vehicle like seat base and is positioned to receive and lock the sliding tongue, so that the seat belt webbing secures the occupants to their seats, in the event of an impact.

[005] The seatbelt systems are also provided with means to transfer power from a power source of a vehicle to the seat belt webbing through the buckle and tongue. There are also means available to transfer data from one part of a vehicle to the seat belt system, through the buckle and the tongue.

[006] US 2016/0355157 discloses a seat belt system where an electromagnetic coupling between a primary and a secondary coil is used to transfer power/data from one conducting member (buckle as a transmission member) that is connected to the primary coil to another conducting member (tongue as a receiving member) that is connected to the secondary coil, when the primary and secondary coils are placed in proximity to each other and not physically connected. In this arrangement, the electromagnetic coils are arranged to be in close proximity to the locking zone of the buckle and tongue of the seat belt system and the electromagnetic coils are used for both power transfer and data communication.

Objects of the present invention

[007] A primary object of the present invention is to provide an integrated electromagnetic and optical device, to enable a wireless transfer of power and communication of data, across electromagnetically and optically coupled systems.

[008] An object of the present invention is to provide an

integrated electromagnetic and optical device pair, which are coupled electromagnetically and optically, to enable a wireless transfer of power and communication of data, across electromagnetically and optically coupled systems.

[009] Another object of the present invention is to provide an occupant restraint system with the integrated electromagnetic and optical device pair of the present invention, for wireless transfer of power and communication of data, through an electromagnetic and optical coupling of a buckle and a tongue of the occupant restraint system.

[010] Yet another object of the present invention is to provide an occupant restraint system with the integrated electromagnetic and optical device pair of the present invention, for a wireless transfer of power and communication of data to a seat belt webbing, for actuating at least an alert member.

[011] It is also an object of the present invention is to provide an occupant restraint system with the integrated electromagnetic and optical device pair of the present invention, where electromagnetic interfaces and data transceivers are disposed in buckle and tongue extension housings and not in close proximity to the locking zones of the tongue and the buckle assemblies.

Brief description of the drawings

[012] **FIG.1** is an illustrated perspective view of the integrated electromagnetic and optical device, to enable a wireless transfer of power and communication of data, where the data transceivers are spaced apart.

[013] **FIG.2** is an illustrated exploded view of the device as shown in **FIG 1**.

[014] **FIG.3** is an illustrated top perspective view of the device

of the device as shown in FIG 1.

[015] **FIG.4** is an illustrated side perspective view of the device as shown in **FIG 1**.

[016] **FIG.5** is an illustrated perspective view of the integrated electromagnetic and optical device for a wireless transfer of power and communication of data, where data transceivers are arranged in a close spatial configuration.

[017] **FIG.6** is an illustrated exploded view of the device as shown in **FIG 5**.

[018] **FIG.7** is an illustrated top perspective view of the device of the device as shown in **FIG 5**.

[019] **FIG.8** is an illustrated side view of the device as shown in **FIG 5**.

[020] **FIG.9** is a schematic side view of paired integrated electromagnetic and optical device for a wireless power transfer and data transmission.

[021] **FIG.10** is a side perspective illustrating magnetic flux lines from an electromagnetic interface, when the paired integrated electromagnetic and optical devices, as shown in **FIG.9** are electromagnetically and optically coupled.

[022] **FIG.11** is a side perspective illustrating magnetic flux lines from an electromagnetic interface and a magnetic flux amplifier, when the paired integrated electromagnetic and optical devices, as shown in **FIG.9** are electromagnetically and optically coupled.

[023] **FIG.12** is a side perspective illustrating magnetic flux lines from an electromagnetic interface and a magnetic flux amplifier, along with a magnetic flux directing member, when the paired integrated electromagnetic and optical devices, as shown in **FIG.9** are

electromagnetically and optically coupled.

[024] **FIG. 13** is a schematic front view, illustrating an occupant restrained by a seat belt with alert members, where a tongue plate and a buckle of the seat belt are shown in locked condition.

[025] **FIG.14** is an illustrated perspective view of tongue plate and buckle assemblies of the occupant restraint system in locked condition, depicting an arrangement of pair of integrated electromagnetic and optical devices of the present invention, for a wireless transfer of power and transmission of data.

[026] **FIG.15** is a perspective view of the tongue assembly of the occupant restraint system, illustrating the arrangement of the integrated electromagnetic and optical device of the present invention.

[027] **FIG.16** is a perspective view of the tongue assembly illustrating the arrangement of the integrated electromagnetic and optical device of the present invention, along with the alert member that is disposed in the seat belt webbing.

[028] **FIG.17** is a partial magnified view of the integrated electromagnetic and optical device of the present invention as shown in **FIG.16**.

[029] **FIG.18** is a perspective view of the buckle assembly illustrating the arrangement of the integrated electromagnetic and optical device of the present invention, along with the alert member that is disposed in the seat belt webbing.

[030] **FIG.19** is a partial magnified view of the integrated electromagnetic and optical device of the present invention as shown in **FIG.18**.

[031] **FIG.20** is a partial perspective view of the tongue and buckle assemblies of the occupant restraint system, shown in a latched

condition, along with the arrangement of pair of integrated electromagnetic and optical devices.

[032] **FIG.21** is a partial magnified view of **FIG.20**, illustrating the arrangement of paired integrated electromagnetic and optical devices.

[033] **FIG.22** is a broad schematic drawing of the system with the integrated electromagnetic and optical devices of the present invention.

[034] **FIG.23** is a perspective view of the tongue and buckle assemblies of the occupant restraint system, illustrating the arrangement of plurality of the integrated electromagnetic and optical devices.

[035] **FIG.24** is a partial magnified view of **FIG.23**, illustrating the arrangement of the integrated electromagnetic and optical devices.

Summary of the present invention

[036] The present invention provides an integrated electromagnetic and optical device for a wireless transfer of power and transmission of data. The device is provided with a light emitter and a light receiver that are disposed on a base member. A magnetic flux directing member is mounted on the base member. An electromagnetic inductive interface that is coupled to a magnetic flux amplifier is disposed in the magnetic flux directing member and on an insulating substrate of the base member. A sealing member with optical apertures is connected to base member, to form a sealing enclosure. The light emitter and the light receiver are disposed to be configured for data communication and the electromagnetic inductive interface and the magnetic flux amplifier are disposed to be configured for power transfer. The present invention also provides a paired device and an occupant restraint system for an automotive vehicle with the paired

device.

Detailed description of the invention

[037] This disclosure provides an integrated electromagnetic and optical device, to enable a wireless transfer of power and communication of data, across electromagnetically and optically coupled systems. In the present disclosure, one of the exemplary applications of the device is described in the form of an occupant restraint system of an automotive vehicle, where the power is transferred from a seat belt buckle assembly to a seat belt webbing, through a tongue assembly. Concurrently, data/information are transmitted from the seat belt buckle assembly to the seat belt webbing via tongue assembly. Further, data communication is also performed from the seat belt webbing to the seat belt assembly through the tongue assembly, as a feed back and other useful information which need to be communicated.

[038] It is therefore, to be understood here that the use device of the present invention is not restricted to particular example(s) or application(s) as described and illustrated in this disclosure but may be used for driving a wide variety of applications, such as a heart rate monitor, a microphone and a heating system for a seat belt webbing of the occupant restraint system. The device of the present invention can also be used at various locations of a vehicle, for instance under a vehicle seat, where the corresponding seat electronics can be powered along with data communication. The device of the present invention can also find applications in power and data transmission at vehicle maintenance platforms or charging stations. The device of the present invention can also be used in domestic, commercial and industrial environments such as smart homes, offices and manufacturing establishments, wherever there is a need for a wireless transfer of power and communication of data between electromagnetically and

optically coupled systems.

[039] Initially, the preferred embodiments of the integrated electromagnetic and optical device, to enable a wireless power transfer and data communication, across electromagnetically and optically coupled systems. In this disclosure, the term electromagnetically and optically coupled systems encompass contrivances, which are configured to receive and transfer power along with data transmission, where the data include set of instructions. The power and data are used to power and actuate the desired functional attributes of the electronic, mechanical and electro-mechanical elements of the contrivances.

[040] As shown initially shown in **FIGs.1-4**, the integrated electromagnetic and optical device **100** includes a base member **101**, where the base member **101** is configured to act as a platform for the integration of other elements of the electromagnetic and optical elements of the device **100**, to form a single unit. The formation of the single unit enables a concurrent or independent transfer of power and communication of data, across the electromagnetically and optically coupled systems. In this exemplary aspect, the base member **101** is shown as a rectangular structure, which is not limited to that particular configuration, since other suitable shapes such as square, circle etc., can also be suitably adapted for use as the base member **101**. A flux directing member opening **109** is preferably arranged on the central portion of the base member **101**. Base member openings **102**, **103**, **104** on the base member **101**, which are positioned outside the flux directing member opening **109** and in the peripheral areas of the base member **101**. A flux directing member opening **109** is provided on the base member **101**. The base member **101** is preferably made of material that acts as a magnetic flux barrier, which can damp or attenuate the inductive magnetic flux that is generated in the device **100**. Accordingly, materials such as acrylic, polystyrene, brass,

copper, aluminum, steel, iron, paper, stainless steel etc.

[041] Now, the preferred embodiments of the data transceiver assembly are now described. The data transceiver assembly includes a light emitter **111**, that is arranged on the peripheral portion of the base member **101**, through the base member opening **104** (as particularly shown in **FIGs.1** and **2**). The light emitter **111** in this arrangement is advantageously a Li-Fi device, using a visible light spectrato act as data carrier for data communication. In the present exemplary embodiment, a light-emitting diode (LED), is the light emitter **111**, that is configured to receive power from a source through a power cable **118** for generating light pulses or flashes. The light emitter **111** is equipped to connect with a suitable Li-Fi system having an integrated circuit package through light emitter cable **113** with a data conversion module that is configured to convert data such as voice, text, video etc., into 1"s and 0"s, so that they can be represented as digital signals. The digital signals are fed as input data to the light emitter **111** (LED) through the light emitter data cable **113**, by the integrated circuit package. The Li-Fi system is preferably provided with an operating frequency in the range of $4 \times 10^{14} \sim 8 \times 10^{14}$. The data processing unit is also provided with a transmitter module, which is configured to generate corresponding on-off patterns for the LED, using suitable Li-Fi techniques such as, single-carrier modulation schemes, for instance, an on-off keying (OOK), to transmit the digital signals in the form of light pulses or flashes of light, with time intervals between each bit. If preferred, a multi-carrier modulation scheme can also be suitably adapted for use for high-speed optical wireless communication. In this exemplary aspect, a single light emitter **111** is shown as an optical light emitter. However, it is understood here that an array of light emitters can also be suitably adapted for use. It is also within purview of this invention to use colour shift keying (CSK), where signals are

encoded into colour intensities emitted by red, green and blue (RGB) LEDs. In the alternate, the light emitter **111** can also be a diode that emits infrared (IR) rays as data carrier. A digital camera can also be used to view the emitted IR in order to verify the functioning of the device. Therefore, the light emitter **111**, which is broadly based on Li-Fi system, the input data first get converted to binary through an ADC (digital signals) and the digital signals are then fed into a LED driver circuit, which is controlled by the integrated signal circuit. The LED driver works with On-Off Keying modulation at high speeds and transmits the data as optical pulses from the light emitter **111**.

[042] A light or photo receiver **112**, is arranged, in this exemplary aspect, on the peripheral portion of the base member **101**, through the opening **102** (as shown in **FIG.1**). The light receiver **112** is configured to receive power from the source through a power cable **119**. The light receiver **112** is positioned, advantageously, in a line-of-sight configuration with the light emitter **111** and is spatially separated, so as to prevent any possible optical interference between them. In this exemplary aspect, the light receiver **112** is a silicon photodiode (*p-i-n* photodiodes), which is connected to an integrated circuit package, that is dedicated for the light receiver **112** through the light receiver data cable **114** and is configured to receive the optical pulses from the light emitter **111** that are incident on its surface. The light receiver **112** interprets the optical pulses into electrical signals, which are amplified by a transimpedance amplifier and then converted back to a binary data (digital signals) by using a comparator. In this exemplary aspect, a single light receiver **112** is shown. However, it is understood here that an array of light receivers can also be suitably adapted for use, in a reciprocal arrangement with an array of light emitters.

[043] In another aspect of the present invention, the light

receiver **112** is also configured to receive data from the light emitter **111** (for instance from a light emitter of a paired data transceiver assembly), where the data can be in the form of a feed back or any other data and audio communications.

[044] Therefore, the arrangement of the light transmitter **111** and the light receiver **112**, constitutes the data transceiver assembly, which can be configured to either transmit or receive data in a wireless mode.

[045] The data transceiver assembly (light emitter and receiver) of the present invention are in compliance with prevailing standards such as IrDA (Infrared Data Association) and IEEE 802.11, IEC, ANSI standards preferably those devices that render focused and narrow beam for data transmission. The data transceiver assembly of the present invention can also suitably adapted for a long range (greater than 10 m) data communications, by providing infrared links that are based on line-of-sight systems, to minimize the path loss.

[046] Hitherto, the constructional elements pertaining to optical transmission of data are described. Now, the preferred embodiments of the transfer of power, electromagnetically using the device **100** of the present invention are described, by referring to **FIGs.1-4**. A magnetic flux directing member **108** is connected to the base member **101**, through the flux directing member opening **109** and is positioned in between the light emitter **111** and the light receiver **112**, as particularly shown in **FIG.2**. In this exemplary aspect, the magnetic flux directing member **108** is provided with a hollow structural section and preferably with a cylindrical shape. Other suitable hollow structural sections, such as rectangular, square etc., can be suitably adapted for the magnetic flux directing member **108**. The magnetic flux directing member **108** is configured to act as a magnetic flux guide or a magnetic flux concentrator, by directing the magnetic flux that is

generated inductively by the device **100**. The magnetic flux directing member **108** can also be constructed with different layers of suitable materials. In an exemplary aspect, the magnetic flux directing member **108** is preferably made of ferrite material containing predominantly oxides iron that are blended with other metals such as barium, strontium, manganese, nickel, zinc, lithium and cadmium.

[047] An insulating substrate **105** is adhered to the bottom portion of the magnetic flux directing member **108** and is made of an epoxy insulating resin or at least one material selected from materials such as acrylic polymer, phenol-based polymer, polyimide polymer or the like.

[048] An electromagnetic interface **107**, which is capable of producing a desired electromagnetic field, on the application an electrical energy, is mounted on the insulating substrate **105**. In this exemplary aspect, the electromagnetic interface **107** is an induction coil. The electromagnetic inductive interface **107** is coupled to the electrical source, to receive the electrical energy from a pre-designated power system, via a power supply transformer or any other suitable power conversion device. It is understood and appreciated, that the electromagnetic interface **107** may be large enough to power the connected devices. For instance, the electromagnetic interface **107** is a copper coil attached to a AC Signal generator circuit, which generates AC signals in the range of about 80-300 kHz. The copper coil then converts this alternating current into time-varying electromagnetic field.

[049] Inductive interface power cable **110**, which are connected to the terminal ends of the the electromagnetic inductive interface **107** on one side are permitted to pass through the flux directing member opening **109** and through the base member opening **103**, for establishing an electrical connection with the electrical source. The

passage area of the flux directing member opening **109** that permits the inductive interface power cable **110**, is sealed with a suitable material like adhesives, silicone sealants, rubber or polymer sealants etc., so as to prevent any possible leakage of magnetic flux through the flux directing member opening **109**. The required strength of the magnetic field for the electromagnetic interface **107** is varied as a function of the amplitude of a drive current as obtained from the electrical source. In an exemplary aspect, the AC drive current that is provided to the electromagnetic inductive interface **105**, is typically in the order of 10 to 2000(milli) amps at 5 to 12 volts, with a frequency in the range of 80to 300 kHz.

[050] A magnetic flux amplifier **106** is mounted on the insulating substrate **105** and arranged in central open area of the electromagnetic interface **107** as particularly shown in **FIG.3**. In this arrangement, the magnetic flux amplifier **106** is coupled electromagnetically to the electromagnetic interface **107**. The magnetic flux amplifier **106**, in the present embodiment is used to enhance the flux density of the electromagnetic interface **107**, by directing, concentrating and focusing the flux generated by the electromagnetic interface **107**. The magnetic flux amplifier **106** is advantageously a ferro or ferri magnet. Other exemplary magnetic flux focusing elements that can be suitably adapted for use, include Neodymium or Neo Rare Earth magnets (NdFeB), Samarium Cobalt (SmCo), Hard Ferrites or Ceramic magnets such as (SrFe₂O₃) Alnico magnets (Al-Ni-Co). The magnetic flux amplifier **106** thus generates a constant magnetic flux that is attributed to a permanent magnet.

[051] Accordingly, the electromagnetic interface **107** along with the magnetic flux amplifier **106** is enclosed inside the magnetic flux directing member **108**. Accordingly, on application of power the electromagnetic interface **107** generates a varying magnetic flux,

inductively and whereas the magnetic flux amplifier **106** generates a substantially constant magnetic flux. Therefore, the generation of the magnetic flux by the magnetic flux amplifier **106**, amplifies the varying magnetic flux that is generated by the electromagnetic interface **107**, resulting in an efficient transfer of magnetic flux from the electromagnetic interface **107**.

[052] In the arrangement as described above, where the magnetic flux lines that are generated from the electromagnetic interface **107** and the magnetic flux enhancer **106**, take different loops around the electromagnetic interface **107** the magnetic flux enhancer **106** respectively. In this process, some of the magnetic flux lines depart from the stated path and broadcast into surroundings, thereby enhancing magnetic reluctance paths or magnetic resistance for the magnetic flux lines. The magnetic flux directing member **108** that is mounted on the base member **101**, controls the departing magnetic flux lines by shielding and directing them so as to enhance paths of least resistance for the magnetic flux lines. Therefore, the preferred geometry of magnetic flux directing member **108** is selected so that it reduces, substantially the magnetic reluctance paths and prevents the broadcast of magnetic flux lines into undesired surroundings.

[053] Therefore, the combined arrangement of the electromagnetic interface **107**, the magnetic flux enhancer **106** and the magnetic flux directing member **108**, not only results in an enhanced flux density but also assists in directing the magnetic flux lines to have reduced magnetic reluctance paths and increase efficiency.

[054] A sealing member **115** is used to cover the base member **101** and the constituent elements of the device **100** of present invention. The shape of the sealing member **115** is reciprocal to the base member **101** and acts as a lid to contain and hermetically seal

the constituent elements of the device **100** that are mounted on the base member **101**. The upper portion of the sealing member **115** is also provided with optical apertures **116** and **117**, to expose the terminal ends of the light emitter **111** and the light receiver **112**, respectively. The material for the sealing member **115** is selected from materials that exhibit magnetic flux permeability. Accordingly, the sealing member **115**, is made of suitable materials, that can permit the propagation of magnetic flux lines that are originating from the electromagnetic inductive interface **107** and the magnetic flux enhancer **106**, through them, which include but are not limited to glass, teflon etc.

[055] In yet another aspect of the present invention, the magnetic flux directing member **108** can also be extended vertically to connected with the upper portion of the sealing member **115**.

[056] Therefore, the integrated electromagnetic and optical device **100** to enable a wireless transfer of power and data communication, across electromagnetically and optically coupled systems, of the present invention, is an integrated combination of electromagnetic and optical elements that are arranged on a single base member **101**. The integrated electromagnetic and optical device **100** can be configured not only to receive and transfer power but also to receive and transmit data.

[057] Accordingly, as shown in **FIGs.1-4** the integrated electromagnetic and optical device **100** for a wireless transfer of power and transmission of data, is formed by an assembly where the light emitter **111** and the light receiver **112** constituting data transceivers, are optically coupled and disposed on the base member **101**. The magnetic flux directing member **108** is mounted on the base member **101** and disposed in between the light emitter **111** and the light receiver **112**. The electromagnetic inductive interface **107** that is

coupled to the magnetic flux amplifier **106**, is disposed in the magnetic flux directing member **108** and on the insulating substrate **105** of the base member **101**. The sealing member **115** acting as lid and an enclosure for the constituent elements of the device **100**. The sealing member **115** is also provided with optical apertures **116**, **117**, to expose the light emitter **111** and the light receiver **112**.

[058] In another aspect of the present invention, as shown in **FIGs.5-8**, the integrated electromagnetic and optical device **100**, comprises a data transceiver assembly, with the light emitter **111** and the light receiver **112**, which are arranged adjacent to each other on the magnetic flux amplifier **106**, as particularly shown in **FIG.5**. This arrangement of the transceiver assembly can be used in applications where a compact integrated electromagnetic and optical device **100** is preferred. The arrangement of the other constituent elements of the integrated electromagnetic and optical device **100**, are as described above, while referring to **FIGs.1-4**. In view of the proximal arrangement of the light emitter **111** and the light receiver **112**, a screen or a partition member that is made of suitable opaque material, can be placed in between the light emitter **111** and the light receiver **112**, so as prevent optical interference between the light emitter **111** and the light receiver **112**.

[059] In yet another aspect of present invention, the preferred embodiments of the electromagnetically and optically coupled device pair **200a**, **200b**, for power transfer and data transmission, are described by particularly referring to **FIG.9**. The electromagnetic and optical device pair **200a**, **200b** is constituted by an electromagnetic and optical coupling of the integrated electromagnetic and optical device **100** as described above. The coupled integrated electromagnetic and optical devices are designated as **200a**, **200b**, as shown in **FIG.9**. The integrated electromagnetic and optical device pair

200a, 200b for a wireless transfer of power and transmission of data, comprises the integrated electromagnetic and optical devices **200a, 200b** that are configured to be coupled electromagnetically and optically, for wireless transfer of power and transmission of data, include light emitters and light receivers **211a, 211b, 212a, 212b** respectively of the integrated electromagnetic and optical devices **200a, 200b**, constituting data transceivers, which are optically coupled *inter se* and disposed on the peripheral ends of base members **201a, 201b**. Magnetic flux directing members **208a, 208b** with hollow structural sections are mounted on the respective base members **201a, 201b** and positioned in between the light emitters and receivers **211a, 211b** and **212a, 212b** respectively. Electromagnetic inductive interfaces **207a, 207b** that are coupled to magnetic flux amplifiers **206a, 206b** are arranged in the magnetic flux directing members **208a, 208b** and on insulating substrates **205a, 205b** of the base members **201a, 201b**. Sealing members **215a, 215b** with optical apertures **216a, 217b** to expose the light emitters and receivers **211a, 211b, 212a, 212b**, are disposed on the base members **201a, 201b**, respectively.

[060] In this arrangement, the electromagnetic inductive interface **207a** of the integrated electromagnetic and optical device **200b**, acting as a power transfer cum data transmission device, is configured to receive power by from a desired electrical source to generate the corresponding oscillating magnetic flux, which is amplified by the magnetic flux amplifier **206a**. The generated oscillating magnetic flux is thus transferred to the electromagnetic inductive interface **207b**, which converts this oscillating magnetic flux to a constant DC power, as particularly shown in **FIG.9**.

[061] The electromagnetically and optically coupled device pair **200a, 200b** that is provided with magnetic flux directing members

208a and **208b**, is as shown in **FIG.10**. The magnetic flux directing members **208a** and **208b** that are mounted on the base member **201a** and **201b**, control the departing magnetic flux lines by shielding and directing them so as to enhance paths of least resistance for the magnetic flux lines.

[062] The integrated electromagnetic and optical device **200a** is also configured to receive and transmit data, through the data transceivers(light emitters and light receivers) **211a, 212a**, where the light receiver **212a** receives data (from a designated source) and the data are transmitted by the light emitter **211a**, to the optically coupled light receiver **212b**, in the form of light energy and received light energy is converted into the corresponding electrical signals and these electrical signals are amplified to generated the desired output. In other words, the data from the light emitter **211a** is converted into an intermediate data representation i.e., byte format and then converted into light signals which are emitted by the light emitter **211a** as shown in **FIG.9**. The light signals, which are received by the light receiver **211b**, where the process is reversed to retrieve the data from the received light signals.

[063] The integrated electromagnetic and optical device pair **200a, 200b** of the present invention, can be suitably adapted for use for transfer of power and data communication, in electromagnetically and optically connected systems.

[064] The electromagnetically and optically coupled device pair **200a, 200b** of the present invention can be configured to be implemented in diverse systems, wherever there is a requirement of wireless transfer of power and data communication between the electromagnetically and optically coupled entities. The transfer of power and data communication between the electromagnetically and optically coupled device pair **200a, 200b** can be performed by using

suitable data processors and communication protocols.

[065] The preferred embodiments of the electromagnetically and optically coupled device pair **200a, 200b**, to illustrate the functional aspects of the magnetic flux directing members **208a, 208b** in regulating the flow of magnetic flux are described, by particularly referring to **FIGs.10-12**. The magnetic flux directing members **208a** and **208b** that are mounted on the base members **201a, 201b**, control the departing magnetic flux lines by shielding and directing them so as to enhance paths of least resistance for the magnetic flux lines. In addition, the combined arrangement of the electromagnetic interfaces **207a, 207b**, the magnetic flux enhancers **206a, 206b** and the magnetic flux directing members **208a, 208b**, not only results in an enhanced flux density but also assists in directing the magnetic flux lines to have reduced magnetic reluctance paths and so increasing the power transfer efficiency.

[066] In the present invention, as an exemplary embodiment, actuation of alert members, such as haptic actuators, which are arranged on the webbing of an occupant restraint system of an automotive vehicle, where the wireless transfer of power is performed from a buckle assembly to a tongue assembly for further onward transfer. Whereas, the data communication is also performed from the buckle assembly to the tongue assembly and vice versa, in a wireless mode. The transfer of power and data communication are used to actuate the actuators (visual and aural) including haptic actuators of seat belt webbing, based on the alerts that are generated by an electronic control unit (ECU), of the automotive vehicle, to the haptic actuators, through buckle and tongue assemblies. It is understood by a person of ordinary skill in the art that the power and data transfer using the integrated electromagnetic and optical devices of the present invention are not limited to transfer of power data communication in

the occupant restraint system, as exemplarily shown here but the wireless transfer of power and transmission of data can be suitably implemented for other on-board systems of the automotive vehicle and also between the automotive vehicle and other external devices that can be wirelessly connected.

[067] Now, the preferred embodiments of the occupant restraint system **300** of the automotive vehicle, to demonstrate in an exemplary manner, the implementation of the integrated electromagnetic and optical devices of the present invention, particularly the paired integrated electromagnetic and optical devices, for a wireless transfer of power and communication of data, primarily, between the buckle and tongue assemblies and for actuating alert members (haptic actuators) that are provided in the seat belt webbing.

[068] The exemplary embodiments of the occupant restraint system **300** that is incorporated with the integrated electromagnetic and optical device pair of the present invention are described by particularly referring to **FIGs.13-24**. The coupled integrated electromagnetic and optical devices are designated as **300a** for a buckle assembly and **300b** for a tongue assembly of the occupant restraint system **300**.

[069] The exemplary occupant restraint system **300**, as illustrated in **FIG.13**, is used, during the course of operation of an automotive vehicle, by an occupant **325**, who is positioned on a vehicle seat **326** and wears the seat belt **327** having a seat belt webbing **328**. The seat belt webbing **328**, when worn by the occupant **325**, is arranged to extend about the occupant **325**. One end of the seat belt webbing **328** is anchored to the vehicle body **329** through an anchor plate **330** that is located on one side of the vehicle seat **326** as shown in **FIG.13**. The other end of the seat belt webbing **328** is connected to a retractor (not shown in **FIG.13**), as fixed to the vehicle

body **329** on the same side of the vehicle seat **326**.

[070] The seat belt webbing **328** is also permitted to pass through a tongue assembly **331b**, as shown in **FIG.14** and the tongue assembly **331b** is slidably mounted on the seat belt webbing **328**. The seat belt webbing **328** is provided with the alert members (haptic actuators) **342**, which in turn are connected to the integrate circuit package **341b** of the tongue assembly **331b** through the power and data cables **318b**, **319b** as shown in particularly shown in **FIGs.15**, **16**.

[071] The tongue assembly **331b**, as particularly shown in **FIG.15** comprises a slidable tongue plate **332b** that includes generally a narrower end portion with an opening **333b**. The narrower end portion with an opening **333b** is used to lock the tongue assembly **331b** with a buckle assembly **337a** as shown in **FIG.11**, when the seat belt **327** is worn by the occupant **325**. Accordingly, the narrow portion of the slidable tongue plate **332b** forms the locking zone of the tongue assembly **331b**. The tongue assembly **331b** also includes a tongue body **334b** that is generally with a plastic overmold **335b** having a webbing opening through which the tongue assembly **331b** is slidably mounted on the seat belt webbing **328**. A tongue extension housing **336T** is formed, as a hollow member, by extending the plastic overmold **335b** of the tongue body **334b**. To engage the seat belt webbing **328**, the tongue assembly **331b** is held and pulled across the lap and torso of the occupant **325** sitting on the vehicle seat **326**. As the tongue assembly **331b** is pulled across the lap and torso of the occupant **325**, the tongue assembly **331b** moves along the seatbelt webbing **328** and the belt webbing **328** is unwound from the retractor, when the seatbelt webbing **328** is pulled across the torso and lap and of the occupant **325**. The occupant **325** buckles the tongue assembly **331** into the buckle assembly **337a** to make the seat belt

327 act as a restraint. When the seat belt webbing **328** is thus in buckled position, the length of seat belt webbing **328** extends over a torso portion of the vehicle occupant **325** and a lap portion extends across the lap of the vehicle occupant **325**. When the seatbelt **327** is not in use, the seat belt webbing **328** is wound on the retractor. The buckle assembly **337a** is connected to the vehicle body **329** and is arranged on the side of the vehicle seat **326** opposite to the anchor plate **330**.

[072] Now the preferred embodiments of the integrated electromagnetic and optical device **300b**, corresponding to the tongue assembly **331b** are described. The integrated electromagnetic and optical device **300b** is fitted inside the tongue extension housing **336b**, as shown in **FIG.15** and **FIG.16**. An integrated circuit package **341b** for the tongue assembly **331b** is arranged inside the plastic overmold **335b** and is electrically connected to the integrated electromagnetic and optical device **300b** of the tongue assembly **331b** through a suitable wiring (for data and power) arrangement. The connectivity of the integrated circuit package **341b** is further extended through the seat belt webbing **328** through the wiring arrangement. The extended wiring arrangement is connected to the haptic actuator sensor assemblies including, but not limited to assemblies of the haptic actuator **349**. The integrated circuit package **341b** is also connected to an electrical unit **348** of the and ECU **349** vehicle to receive data and instructions pertaining to sensing of an incident that requires triggering of an alert member (haptic actuator) **347** of the seat belt webbing **328**. The haptic actuator **347b** is arranged in the seat belt webbing **328** and connected to the integrated circuit package **341b**, through the required data and power cables as shown in **FIGs.15,16,17**.

[073] The buckle assembly **337a**, includes a buckle housing

338a in which a latch member (not shown in the figure) is arranged to lock the slidable tongue plate **332b** of the tongue assembly **331b**. Accordingly, the latch member of the buckle assembly **337b** forms a latching zone of the buckle assembly **337a**. The seat belt **327** can be taken off by pushing a release button **339** of the buckle assembly **337a**. A buckle extension housing **340a** is formed, as a hollow member, on the lateral side of the buckle housing **338**. An integrated circuit package **344a** is connected to the power source of the vehicle **347** and the electronic control unit (ECU) **348** of the vehicle to receive power and data pertaining to sensing of an incident that requires triggering of the haptic actuator **342**.

[074] When the seat belt **327** is buckled by the occupant **325**, through the latching of the tongue and buckle assemblies **331a, 337b**, the latching zones physically mesh with each other to provide the locking arrangement. Such a locking arrangement is therefore, a frictional locking arrangement, that causes friction of the mating parts the tongue and buckle assemblies **331a, 337b**, in the locking zone. Accordingly, any arrangement of electronic or electromagnetic components, in proximity to the locking zone are exposed to a possible risk of frictional wear and tear due to frequent buckling and unbuckling of the seat belt.

[075] Accordingly, the occupant restraint system **300** with the integrated electromagnetic and optical device pair **300a, 300b** of the present invention, where the integrated electromagnetic and optical device pair **300a, 300b** are disposed on the buckle and the tongue respectively and at locations that are not in proximity or nearer to the locking zone of the tongue with the buckle assemblies **331a, 337b**, where frequent latching and de-latching of the seatbelt buckle does not interfere with the functioning of the integrated electromagnetic and optical device pair **300a, 300b**.

[076] Now, the arrangement of the shown in **FIG.20** and **FIG.16** the integrated electromagnetic and optical device **300** corresponding to the buckle assembly **331a**, is arranged in the buckle extension housing **340a**. An integrated circuit package **344a** for the buckle assembly **331a** is arranged inside the buckle extension housing **340a** and is electrically connected to the integrated electromagnetic and optical device **300** of the buckle assembly **331a** through a suitable wiring arrangement.

[077] Now the preferred embodiments of the system **300** of the present invention, when the buckle and tongue and assemblies **331a**, **337b** are in locked condition are described. In the locked condition, the tongue extension housing **336b** and buckle extension housing **340a** are arranged co-axial and close proximity to each other, as shown in **FIG.21**. The integrated electromagnetic and optical device **300b**, corresponding to the tongue assembly **331b** and the integrated electromagnetic and optical device **300a**, corresponding to the buckle assembly **337a** are also arranged co-axial to each other with an intervening gap between them as shown in **FIG.21**. In other words, when tongue and buckle assemblies **331a**, **337b** are in locked condition and in close proximity to each other, these assemblies are coupled electromagnetically, such that the wireless transfer of power transfer, through the generation and transfer of magnetic flux between the electromagnetic interfaces **307a**, **307b** can be performed from the buckle assembly **331a** to the tongue assembly **337b**. Concurrently, in the locked arrangement, an optical coupling is also established between the tongue and buckle assemblies **331a**, **337b** to perform data transmission between light emitters and light receivers **311a**, **311b**, **312a**, **312b** of the buckle and tongue assemblies **331a**, **337b**, in the form light pulses or flashes, as particularly shown in **FIG.21**.

[078] Now, the broad system architecture of the coupled devices,

with a specific reference to their arrangement in an occupant restraint system, is now described by referring to **FIG.24**. While the present invention is described with respect to the system for the actuation of haptic actuators, the present invention may be adapted to be used in other control and communication systems or the like. In the following description, various operating parameters and components are described for one exemplary embodiment. Therefore, these specific parameters and components are included as examples and are not meant to be limiting.

[079] The system of the present invention is primarily composed of the following primary segments viz., a vehicle control and power segment **349**, a buckle segment **350**, a tongue segment **351** and a haptic actuator segment **352**.

[080] The vehicle control and power segment **349** includes a vehicle power source **347** that caters to the power requirements of the on-board electrical, electronic and mechanical devices, of the vehicle. The vehicle power source **347**, which is generally a unit comprising elements such as a battery, a starter, an alternator etc., provides a required DC power.

[081] The buckle segment **350** includes a power regulator **353**, which is connected to vehicle power source **347**, to regulate the input DC power and to protect the various components of the system. A power transmitter controller **354** is connected to the power regulator **353**, to control the amount of power that is to be transmitted to an electromagnetic interface driver **355** (buckle segment), depending on the required power. The electromagnetic interface driver **355** is provided with oscillators, AC/DC power converters, to generate an alternating current (AC) power corresponding to the input DC power. This alternating current power is then allowed to pass through an electromagnetic interface **307a**, of the buckle segment **350**, to

generate the corresponding time-varying magnetic flux.

[082] Whereas, the tongue segment **351** includes an electromagnetic interface **307b**, which is configured to receive the magnetic flux from the electromagnetic interface **307a** and convert the magnetic flux into a corresponding power. An electromagnetic interface driver (tongue) **356** is connected to the electromagnetic interface **307b** and includes rectifiers, AC/DC power converters, to convert the provided AC source to required DC power. This DC power is then allowed to pass through a power receiver controller **357** to control or modulate the amount of power considering the end use requirements. For instance, in the present case, the power that is required to actuate the haptic actuators of the seat belt webbing. A power regulator **358** is connected to the power receiver controller **357** of the tongue segment **351**, so that a constant DC power is supplied to the other components, including integrated circuit package of the tongue segment **351** and to the alert members **342** of the seat belt webbing. The power receiver controller also communicates its power requirement and amount of power received to the power transmitter controller, by using the existing optical communication system. This helps the power transmitter to take required actions to increase power efficiency, by doing so unwanted system heating and interference due to metal objects can be avoided.

[083] The vehicle control and power segment **349** further includes an electronic control unit (ECU) **348**. The term ECU as indicated here shall also mean to include a group of ECU's catering to various functionalities of the vehicle. Accordingly, the ECU **348** can be any embedded systems in automotive electronics, which control one or more of the electrical and electronic systems, subsystems in a vehicle. For instance, automotive ECUs that are connected to devices such as image processing modules, sensors and camera, support a

number of advanced driver assistance systems (ADAS) like adaptive cruise control, driver drowsiness detection, lane departure warning, forward collision alert, pedestrian detection and more, based on which suitable actions and alerts are prompted and executed in the vehicle, either automatically or through the occupants of the vehicle. The ECU **348** includes a microprocessor, an application specific integrated circuit (ASIC) or any other custom designed device, with a required memory slots. The ECU is generally embedded with a firm ware corresponding to various functionalities of the automotive vehicle. The ECUs are also provided with ADC's, DAC's, capabilities to generate high-level digital outputs, signal conditioners, communication chips to implement in-car communication standards such as controller-area networking (CAN). The ECU **348** may be the central computer for the vehicle and, therefore, be capable of controlling the operations of other vehicle components and accessories. The ECU **348**, in the present exemplary embodiment is configured to execute, *inter alia*, routines for receiving alerts from advanced driver assistance systems (ADAS), in conjunction with on-board event capturing members (devices/sensors), such as charge-coupled devices (CCDs), Radar, Lidar, infrared sensors, oxygen sensors, image capturing and processing devices, wheel speed sensor, etc. The alerts that are received by the ECU **348** are processed and communicated to an integrated circuit package **344a**, which is arranged in the buckle segment **350**, through communication protocols such as CAN, FlexRay or Ethernet.

[084] The integrated circuit package **344a** of the buckle segment is advantageously a PCB with a central processor, input/output and memory controllers, interface connectors, memory and other components integrated for the required purpose and applications. The subsystems of the PCB are configured to use communication protocols

such as serial peripheral interface (SPI), inter-integrated circuit (I2C) for internal communication. The integrated circuit package **344a** processes the received information from the ECU **348** into a compatible format for transmission to a driver **359** of the light emitter of the buckle segment **350**. For instance, in the present case, the processed information relates to the actuation of the haptic actuators of the seat belt webbing. The driver **359** is configured to convert the information received from the integrated circuit package **344a**, into pulsed voltage signals of desired pulse width and frequency, which are sent to the light emitter **311a**. The light emitter **311a**, which is a Li-Fi device, uses a visible light spectra to act as data carrier for data communication. In the present exemplary embodiment, the light emitter **311a** that is connected to the integrated circuit package **344a** of the buckle segment **350** is provided with a data conversion module or a routine that is configured to convert data such as voice, text, video etc., into 1"s and 0"s, so that they can be represented as digital signals. These digital signals are fed as input data to the light emitter **311a**. The Li-Fi device is preferably configured to operate with an operating frequency in the range of $4 \times 10^{14} \sim 8 \times 10^{14}$. The integrated circuit package **344a** is also provided with a transmitter module or a routine, which is configured to generate corresponding on-off patterns for the light emitter **311a**, using suitable Li-Fi techniques such as, single-carrier modulation schemes, for instance, an on-off keying (OOK), to transmit the digital signals in the form of light pulses or flashes of light, with time intervals between each bit. If preferred, a multi-carrier modulation scheme can also be suitably adapted for use for high-speed optical wireless communication. It is also within purview of this invention to use colour shift keying (CSK), where signals are encoded into colour intensities emitted by red, green and blue (RGB) LEDs. In the alternate, the light emitter can also be a diode that emits infrared (IR) rays as data carrier. A digital camera can also be used to view the

emitted IR in order to verify the functioning of the device. Therefore, the light emitter **311a**, which is broadly based on Li-Fi system, firstly, the input data get converted to through an ADC (to obtain digital signals) and the digital signals are then fed into a LED driver circuit (light emitter), which is controlled by a signal processor. The LED driver works with On-Off Keying modulation at high speeds and transmits the data and/or processed information, as optical pulses from the light emitter **311a**.

[085] The tongue segment **351**, which is coupled optically and electromagnetically to the buckle segment **350**, is provided with light receiver **312b** is optically coupled to the light emitter **311a** to receive the pulsed optical signals carrying the data through wireless mode. A driver **360** (tongue) is connected to the light receiver **312b** of the tongue segment **351** and is configured to convert the pulsed signals into a suitable format, for further processing by an integrated circuit package **341b** of the tongue segment **351**. The configuration of integrated circuit package **341b** is similar to the integrated circuit package **344a**. The integrated circuit package **341b** is configured to communicate with alert members **542** of the seat belt webbing are coupled to integrated circuit package **341b** for actuation. Accordingly, the system of the present invention, facilitates a wireless transfer of power and data communication between the buckle and tongue assemblies and to the end use devices such as haptic actuators.

[086] In the arrangement of the system of the present invention, the integrated circuit package **341b** is also connected to the driver **360** and the light emitter **312b** of the tongue segment **351**, to provide a feedback once the tongue and buckle assemblies are coupled. The feedback is communicated from the light emitter **312b** to the light receiver **312a** of the buckle segment **350**, which is turn is communicated to the integrated package circuit **343a** through the

driver **362**. The feedback information channel can be used to determine events such as the optical and electromagnetic coupling of the paired devices, transmission errors etc.

[087] In yet another aspect of the present invention, as shown in **FIGs.23** and **24**, an occupant restraint system **400** with a plurality of the integrated electromagnetic and optical devices **400a1**, **400b1**, **400a2**, **400b2** are arranged on either side of respective buckle **437a**, and tongue assemblies **431b** and inside the buckle extension housings **440a1**, **440a2** and tongue extension housings **436b1**, **436b2**, where an electromagnetic and optical coupling is established between the tongue and buckle assemblies **400a1**, **400b1**, **400a2**, **400b2**.

We claim:

1. An integrated electromagnetic and optical device **100** for a wireless transfer of power and transmission of data, comprising:
a light emitter **111** and a light receiver **112** constituting data transceivers are disposed on a base member **101**,
a magnetic flux directing member **108** is mounted on the base member **101** and disposed in between the light emitter **111** and the light receiver **112**;
an electromagnetic inductive interface **107** that is coupled to a magnetic flux amplifier **106** is disposed in the magnetic flux directing member **108** and on an insulating substrate **105** of the base member **101**;
a sealing member **115** with optical apertures **116**, **117** to expose the light emitter **111** and the light receiver **112**, is connected to base member **101** and to form a sealing enclosure; and
the light emitter **111** and the light receiver **112** are disposed to be configured for data communication and the electromagnetic inductive interface **107** and the magnetic flux amplifier **106** are disposed to be configured for power transfer.
2. The integrated electromagnetic and optical device **100** as claimed in claim 1, wherein a pair of the integrated electromagnetic and optical devices **200a**, **200b** are disposed to be coupled electromagnetically and optically and to be configured for a wireless transfer of power and transmission of data between them.

3. The integrated electromagnetic and optical device **100** as claimed in claim 1, wherein the electromagnetic inductive interface **107** is an electromagnetic coil.
4. The integrated electromagnetic and optical device **100** as claimed in claim 1, wherein the material for magnetic flux directing member **108** is a ferrite material.
5. The integrated electromagnetic and optical device **100** as claimed in claim 1, wherein the magnetic flux directing member **108** is connected to upper portion of the sealing member **115**.
6. The integrated electromagnetic and optical device **100** as claimed in claim 1, wherein the light emitter **111** and the light receiver **112** are disposed on the peripheral ends of adjacent to each other or on the magnetic flux amplifier **106**.
7. The integrated electromagnetic and optical device **100** as claimed in claim 1, wherein an array of light emitters and the light receivers are disposed on the base member **(101)**.
8. The integrated electromagnetic and optical device **100** as claimed in claim 1, wherein the light emitter **111** is a white LED or an IR light-emitting diode and the light receiver **112** is a silicon photodiode.
9. The integrated electromagnetic and optical device **100** as claimed in claim 7, wherein the array of light emitters are white LEDs, red, green and blue (RGB) LEDs or IR light-emitting diodes and the array of light receivers are silicon photodiodes.
10. An occupant restraint system of a vehicle with a buckle assembly and a tongue assembly for wireless transfer of power and data communication between the buckle and tongue assemblies, when the tongue assembly is latched with the buckle assembly, comprising:

a webbing **328** of a seat belt **327** with at least an alert member **342**, is slidably connected to the tongue assembly **331b** and fastened to an occupant **325**, a vehicle power source **347** and an ECU **348** of the vehicle are connected to the buckle assembly **337a**; characterized in that

integrated electromagnetic and optical devices **300a**, **300b** are disposed in buckle and tongue extension housings **336a**, **340b** and are configured to be coupled electromagnetically and optically, for wireless transfer of power and transmission of data, the integrated electromagnetic and optical devices **300a**, **300** include

light emitters **311a**, **311b** and light receivers **312a**, **312b** constituting data transceivers, are disposed on the base members **301a**, **301b**;

magnetic flux directing members **308a**, **308b**, are mounted on the base members **301a**, **301b** and disposed in between the light emitters **311a**, **311b** and the light receivers **312a**, **312b**;

electromagnetic inductive interfaces **307a**, **307b** that are coupled to magnetic flux amplifiers **306a**, **306b** of the buckle and tongue assemblies **337a**, **331b**, are disposed in the magnetic flux directing members **308a**, **308b** and on insulating substrates **305a**, **305b** of the base members **301a**, **301b**;

sealing members **315a**, **315b** with optical apertures **316a**, **317b**, to expose the light emitters **311a**, **311b** and the light receivers **312a**, **312b**, are connected to the base members **301a**, **301b** and to form sealing enclosures; and

integrated circuit packages **343a**, **341b** are disposed in the buckle and tongue assemblies **337a**, **331b** and are operably

connected to vehicle power source **347**, the ECU **348**, and the integrated electromagnetic and optical devices **300a**, **300b** to transfer power of the vehicle source **347** as magnetic flux from the electromagnetic inductive interface **307a** to the electromagnetic inductive interface **307b**, and to supply power to the alert member **342** from the electromagnetic inductive interface **307b**; and

the integrated circuit packages **343a**, **341b** and the ECU **348** are also configured to perform data communication from the ECU **348** to the alert member **342**, through the data transceivers **311a**, **311b**.

11. The occupant restraint system as claimed in claim 10, wherein a pair of the integrated electromagnetic and optical devices **300a**, **300b** are disposed to be coupled electromagnetically and optically for a wireless transfer of power and transmission of data.
12. The occupant restraint system as claimed in claim 10, wherein the electromagnetic inductive interfaces **307a**, **307b** are electromagnetic coils.
13. The occupant restraint system as claimed in claim 10, wherein the material for magnetic flux directing members **308a**, **308b** is a ferrite material.
14. The occupant restraint system as claimed in claim 10, wherein the magnetic flux directing members **308a**, **308b** are connected to upper portions of the sealing members **315a**, **315b**.
15. The occupant restraint system as claimed in claim 10, wherein light emitters **311a**, **311b** and light receivers **312a**, **312b** are

disposed on the peripheral ends of adjacent to each other or on the magnetic flux amplifiers **306a, 306b**.

16. The occupant restraint system as claimed in claim 10, wherein an array of light emitters and the light receivers are disposed on the base members **301a, 310b**.
17. The occupant restraint system as claimed in claim 10, wherein the light emitters **311a, 311b** are white LEDs or IR light-emitting diodes and the light receivers **312a, 312b** are silicon photodiodes.
18. The occupant restraint system as claimed in claim 16, wherein the array of light emitters are white LEDs, red, green and blue (RGB) LEDs or IR light-emitting diodes and the array of light receivers are silicon photodiodes.

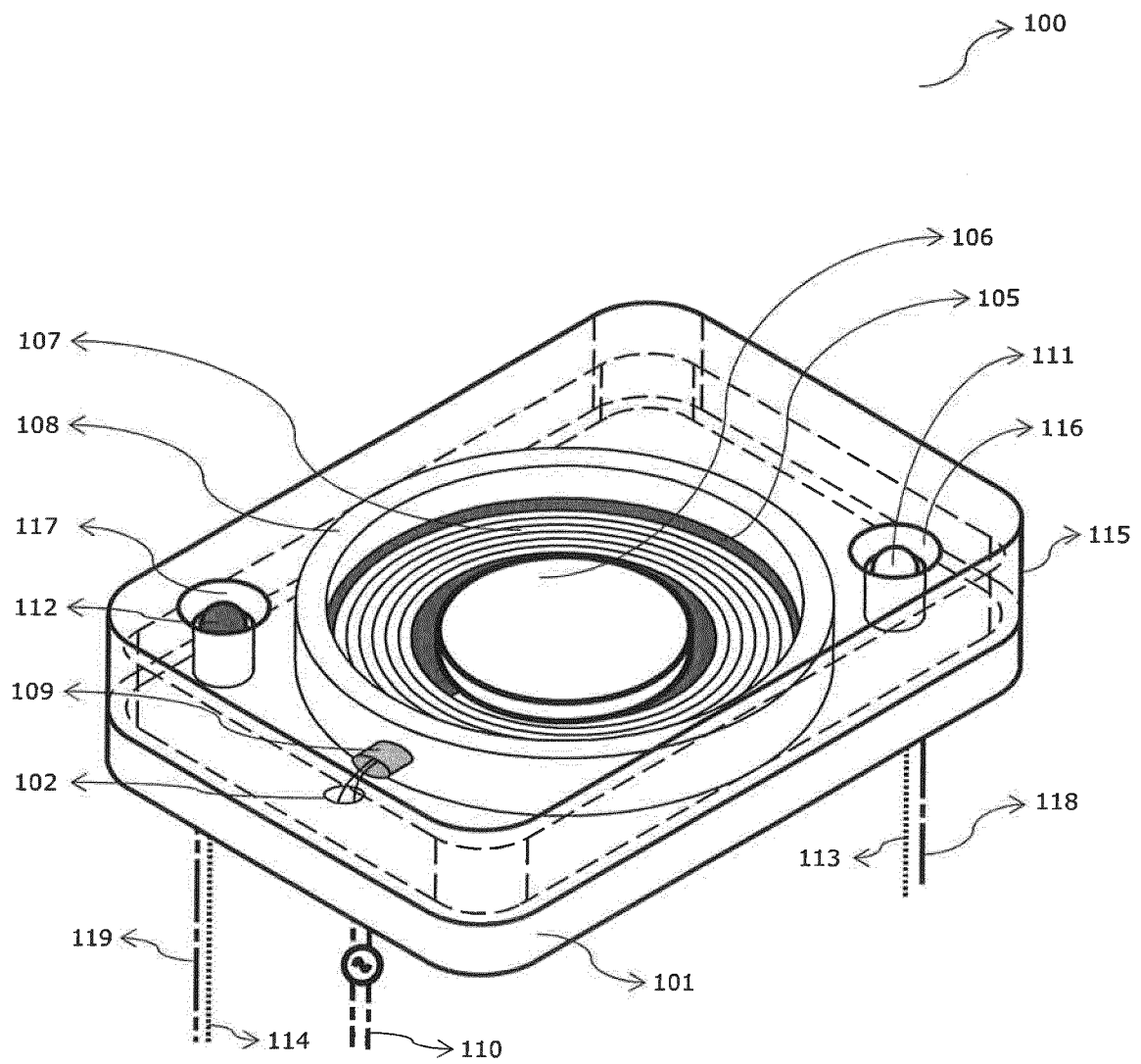


FIG.1

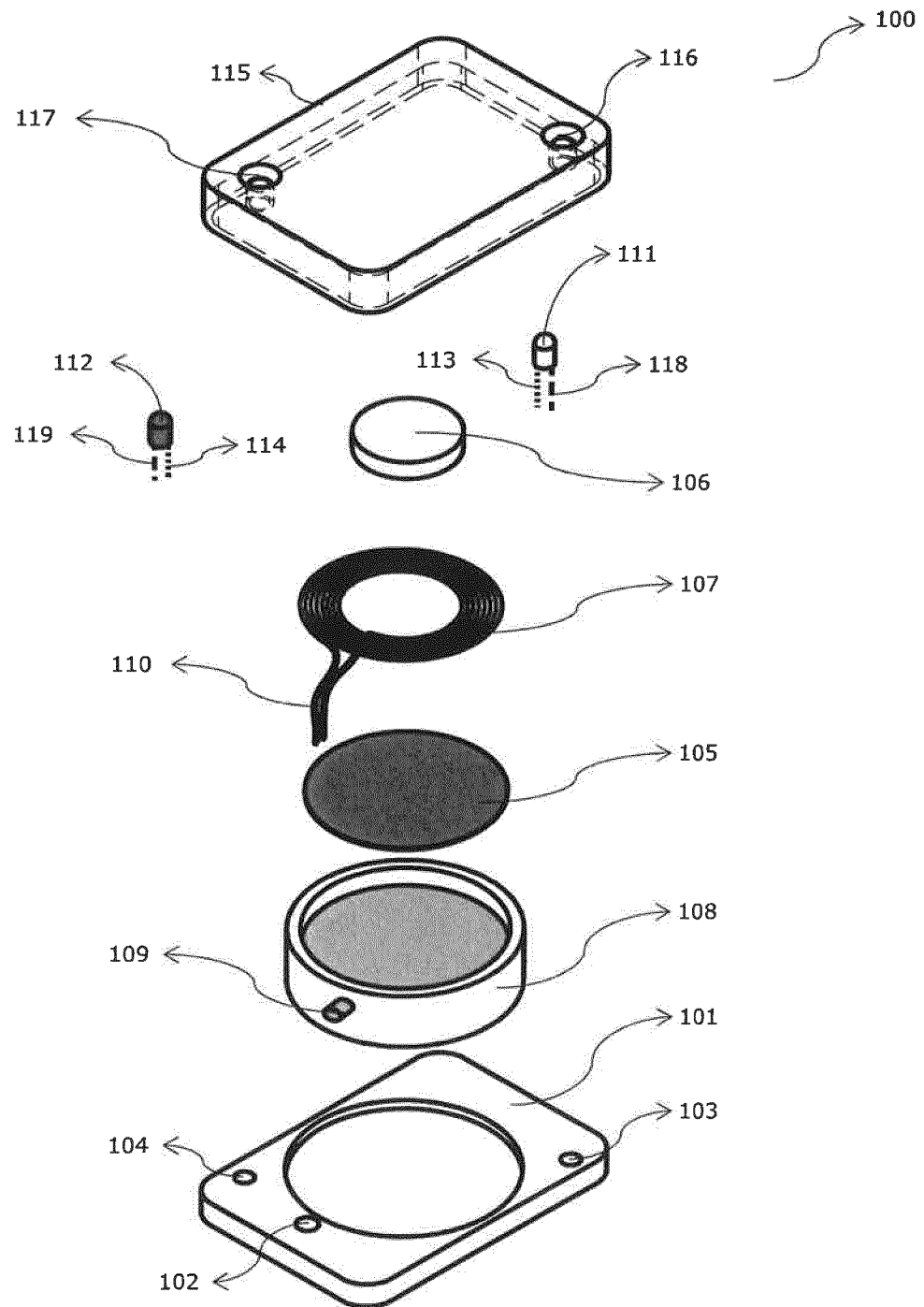


FIG.2

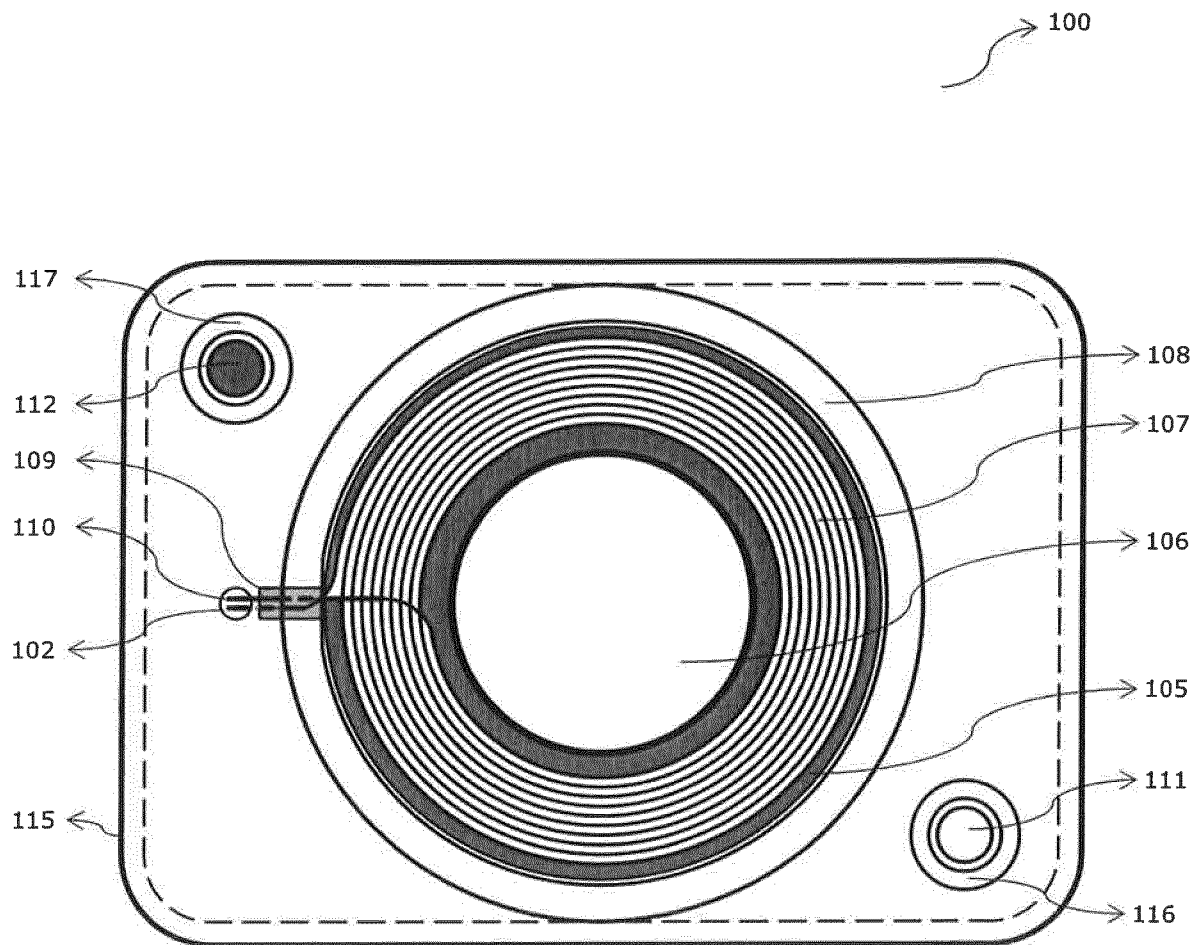


FIG.3

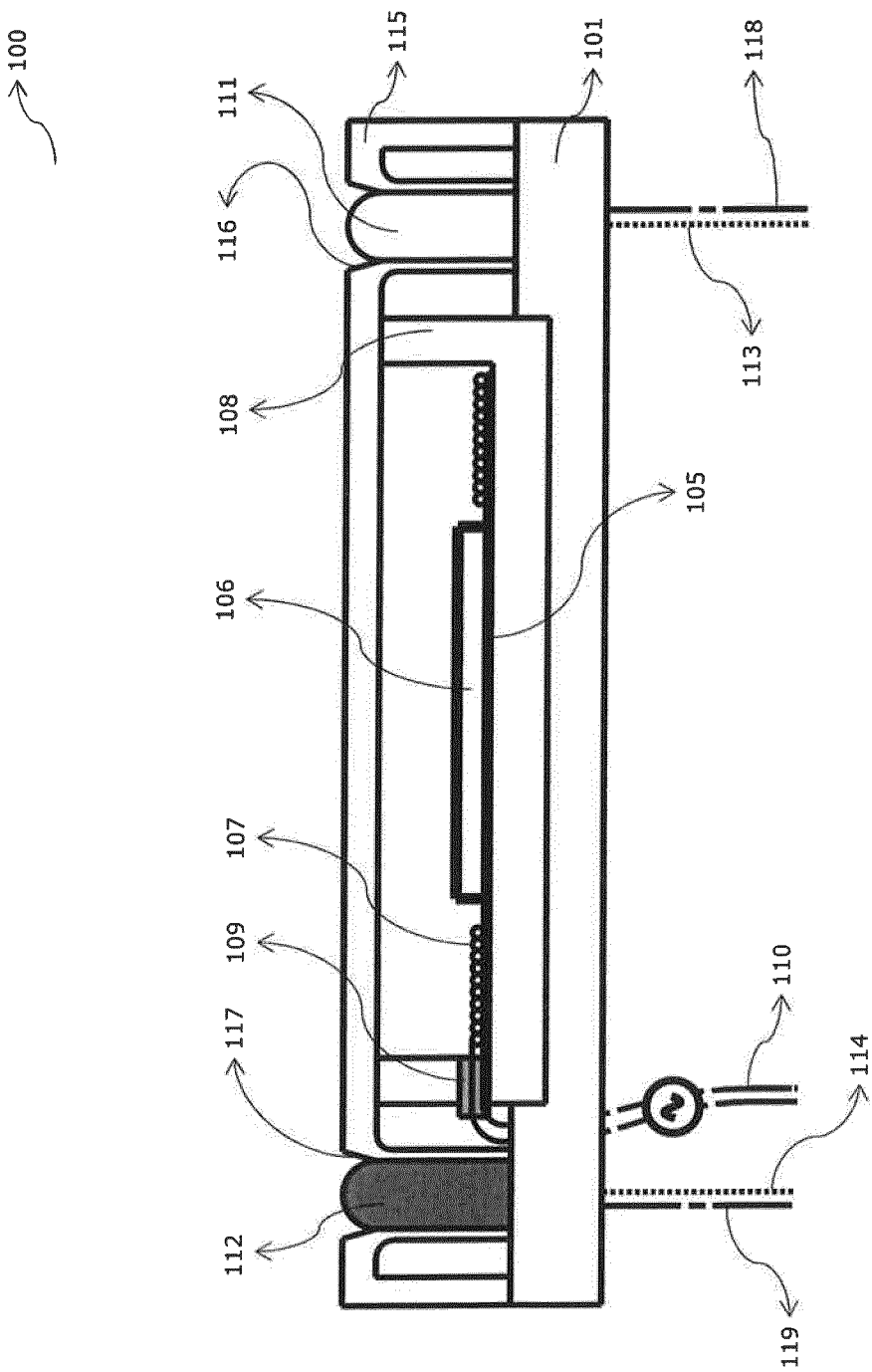


FIG.4

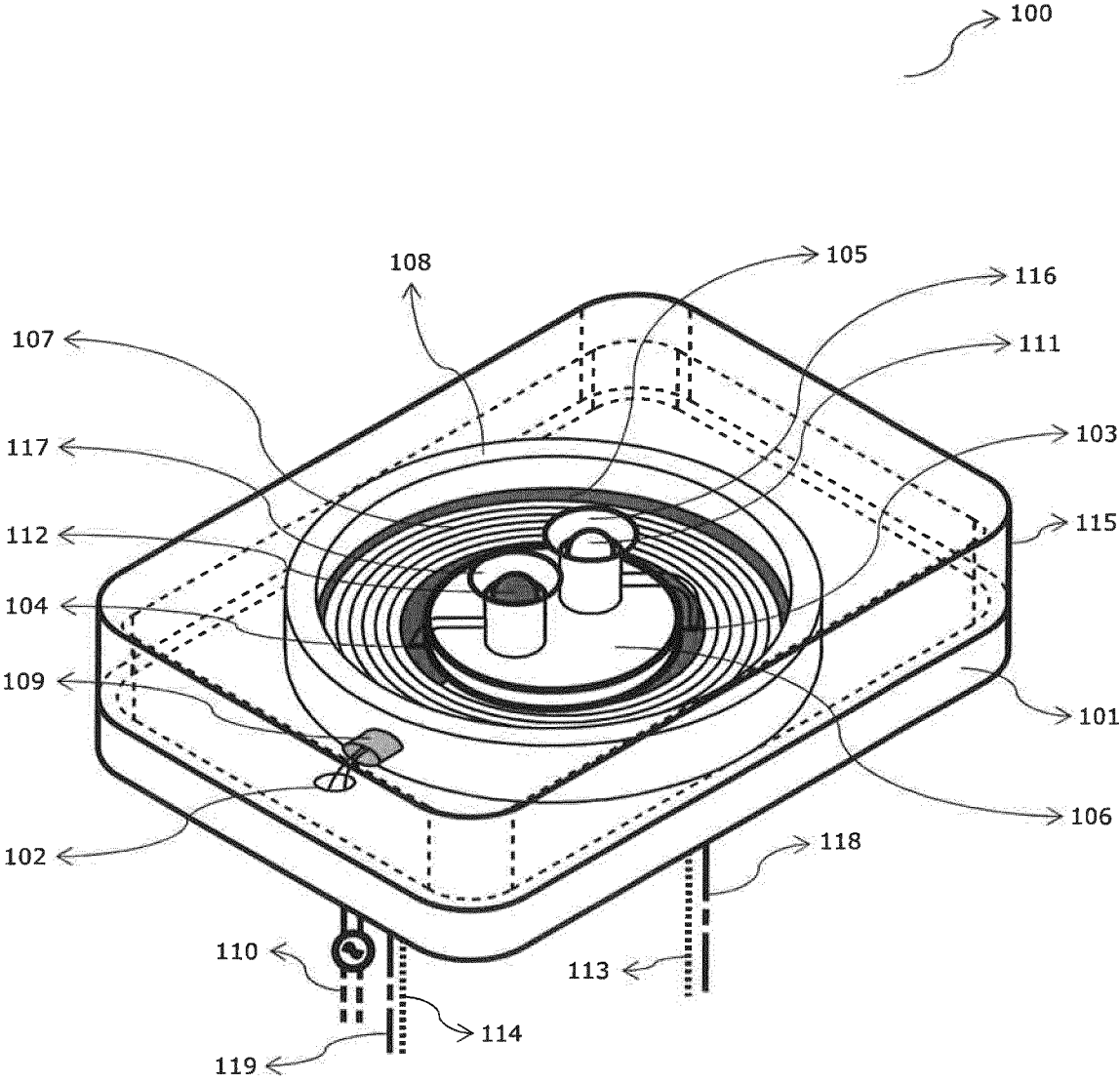
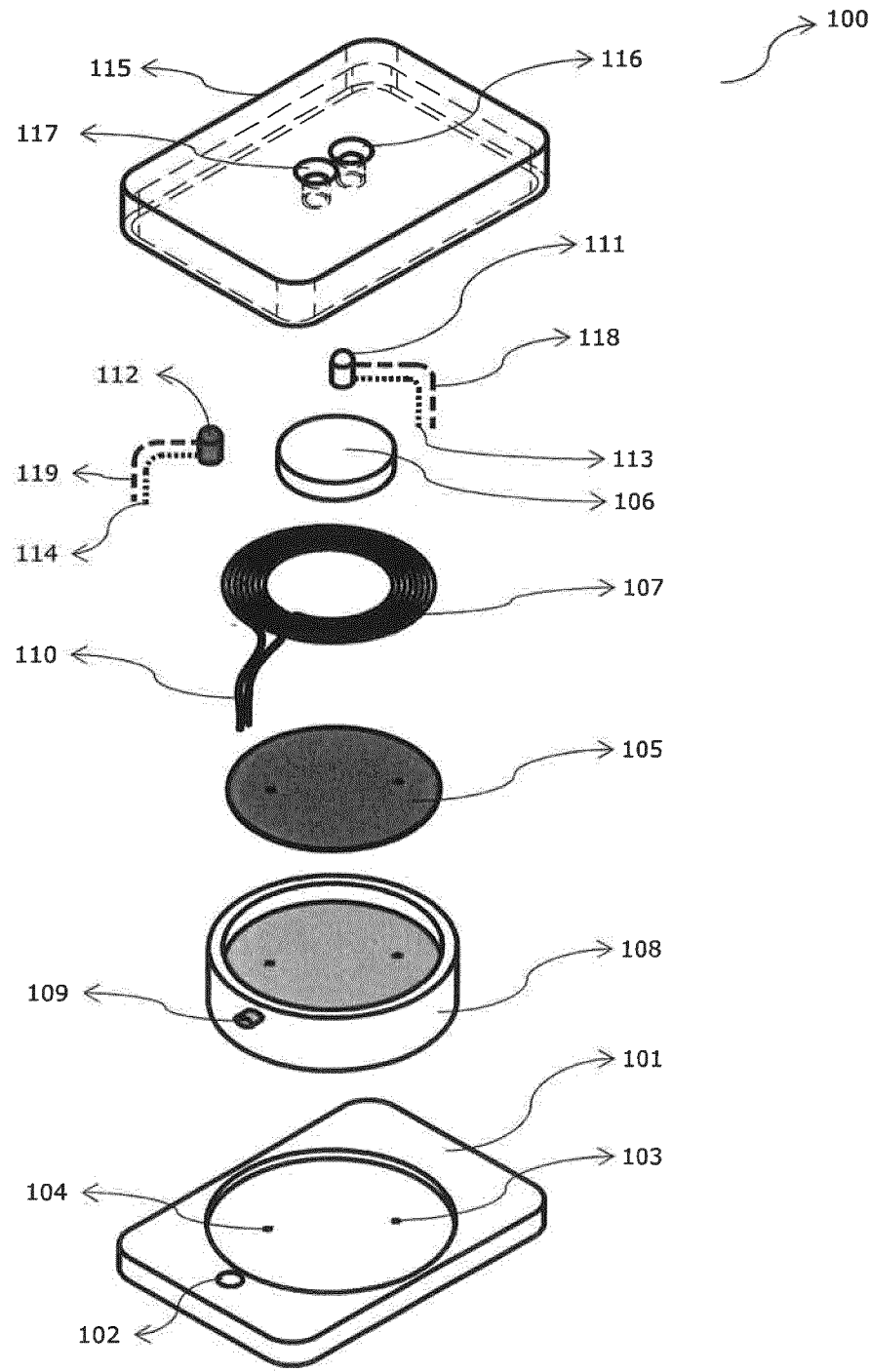


FIG.5



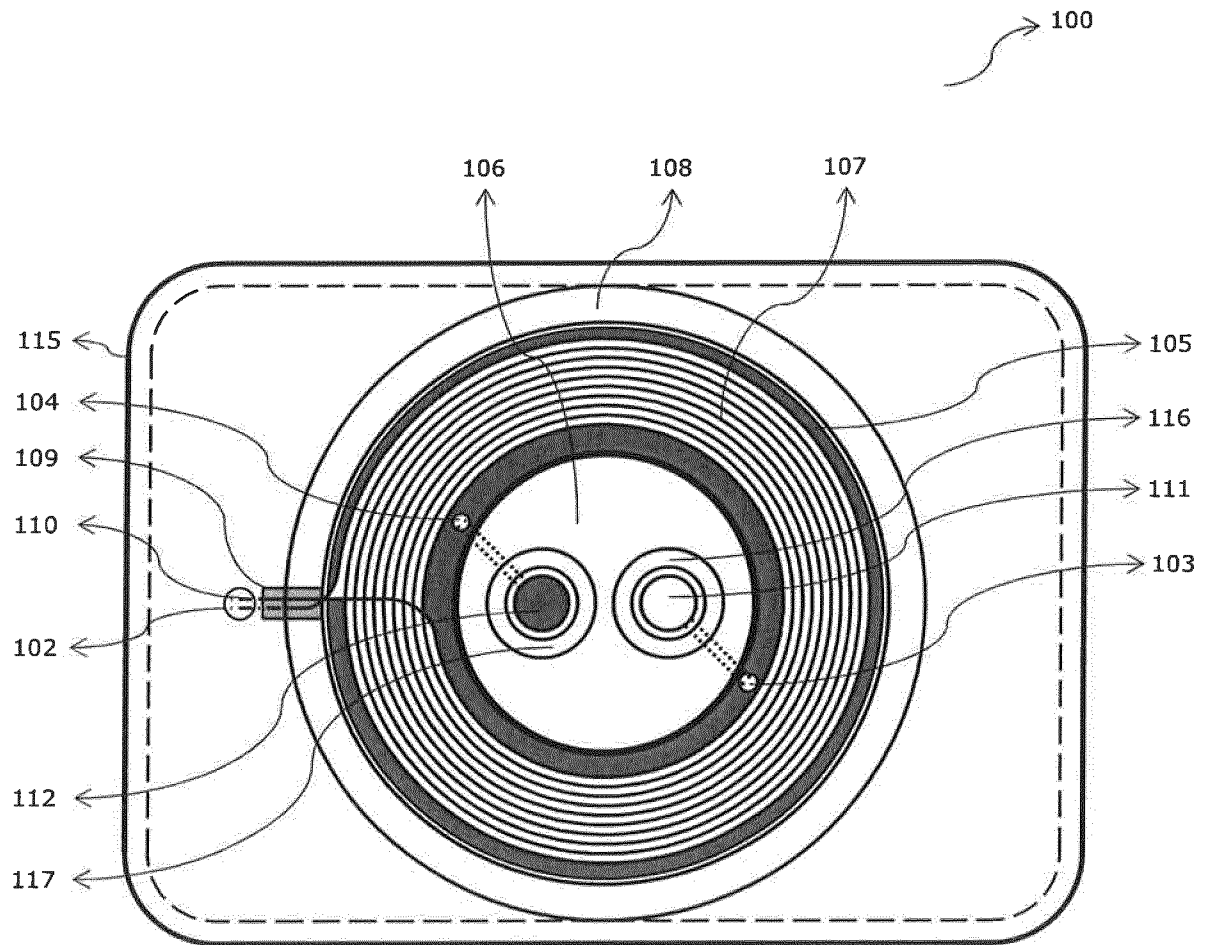


FIG. 7

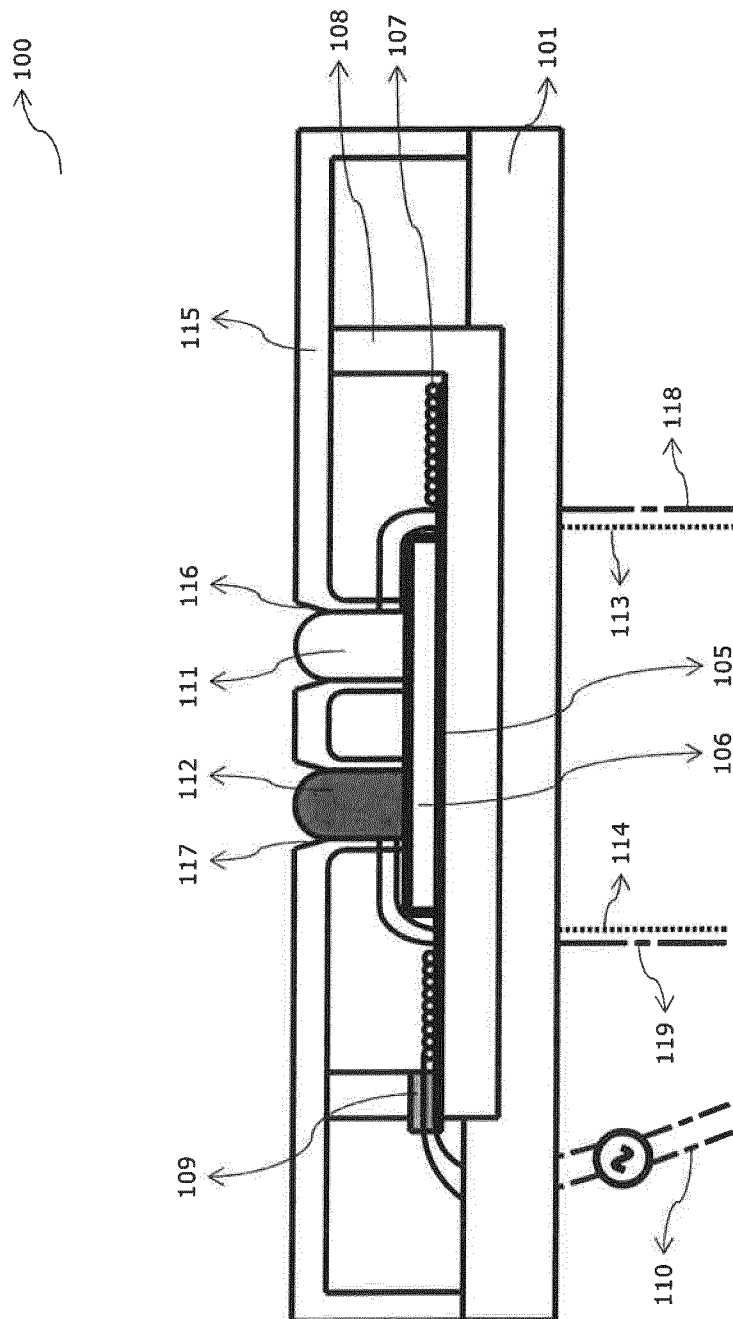


FIG. 8.

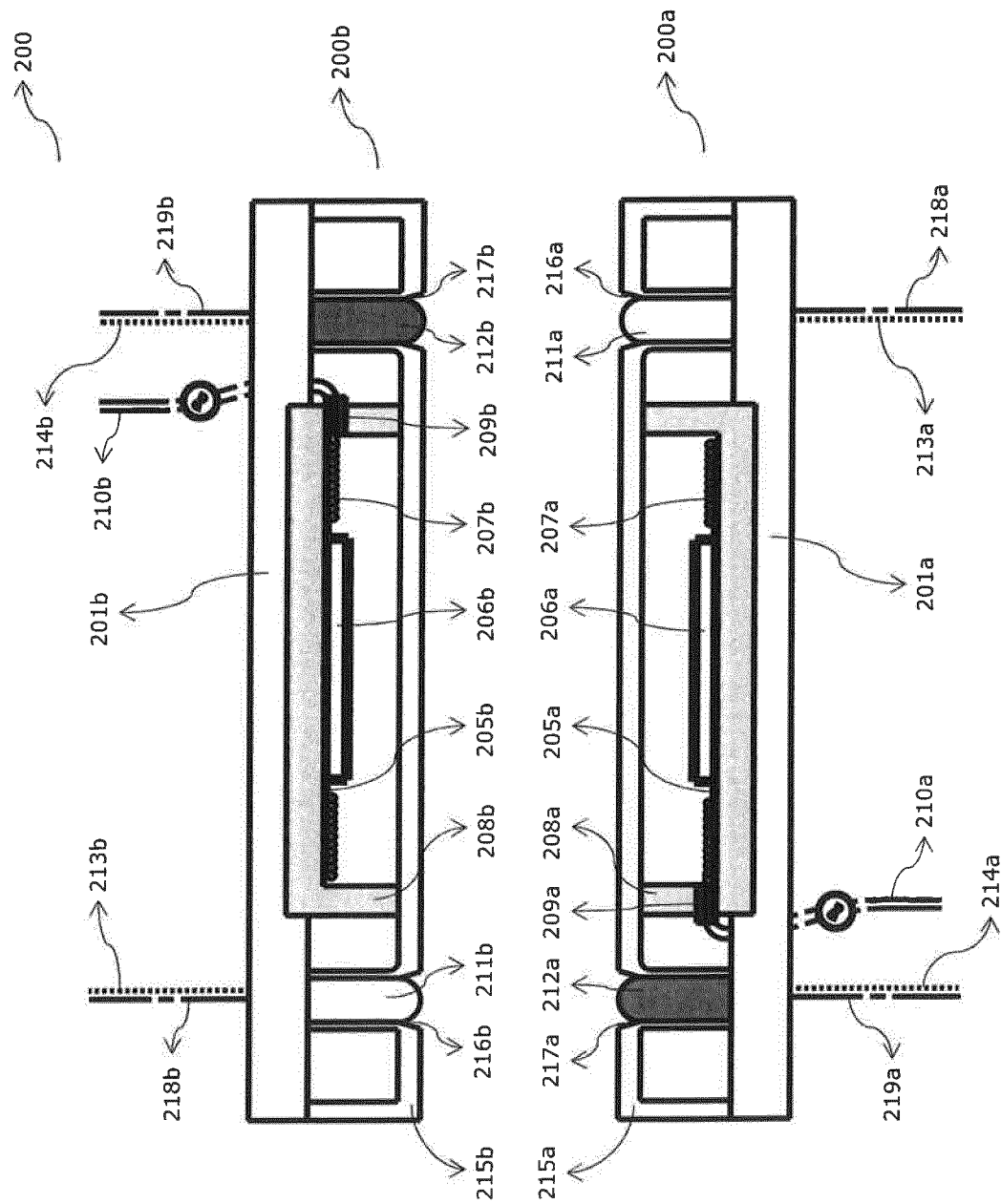


FIG.9

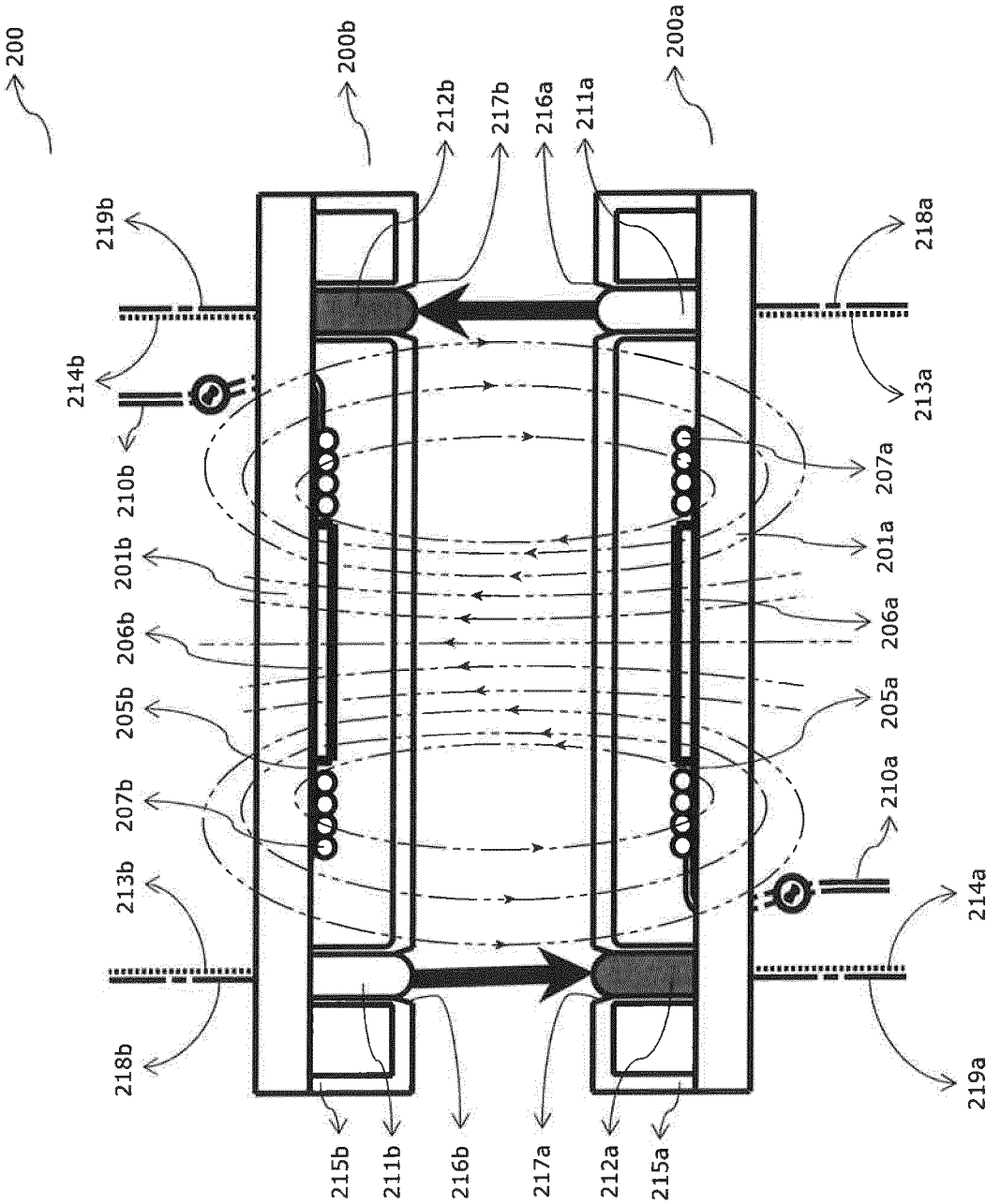


FIG. 11

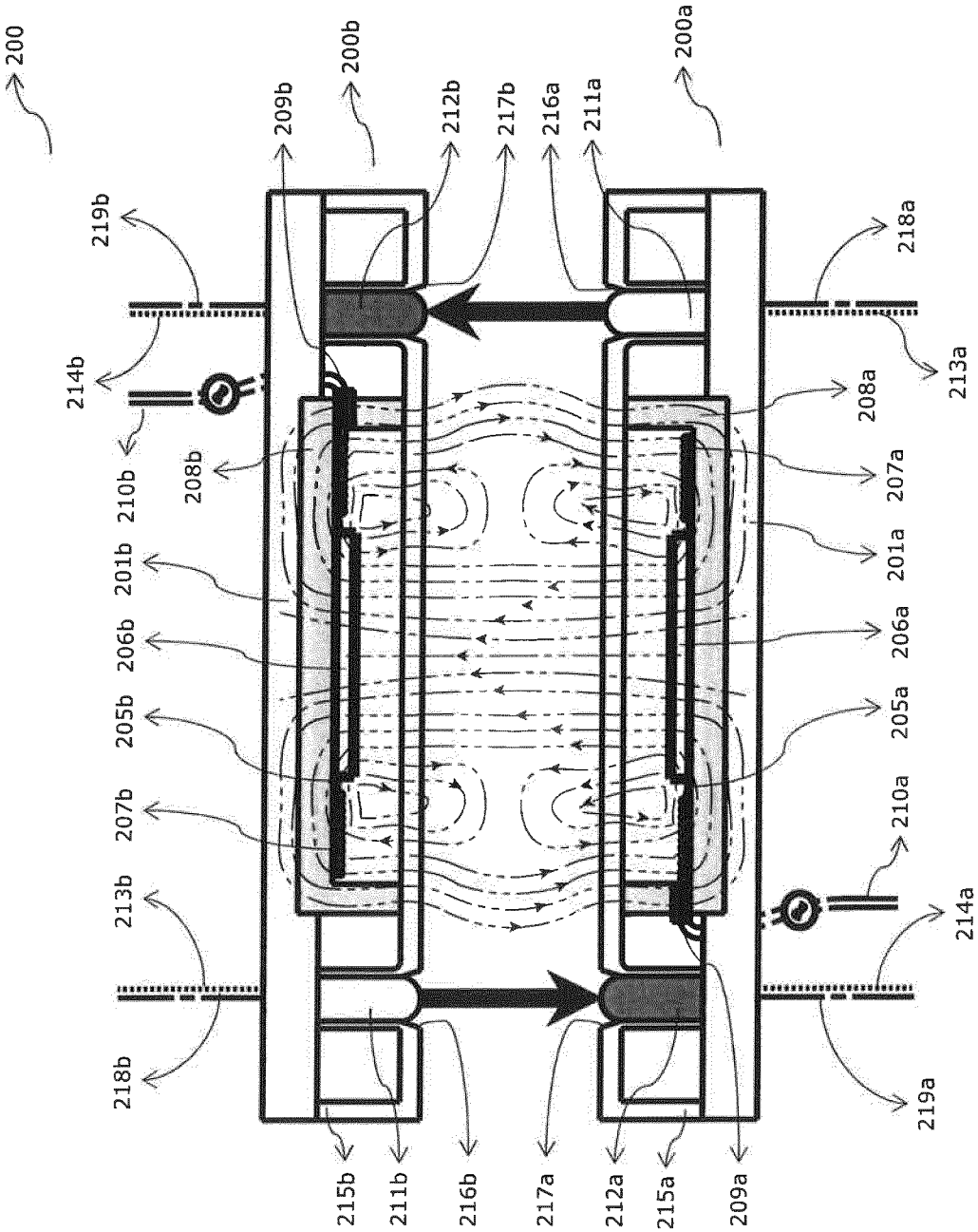


FIG. 12

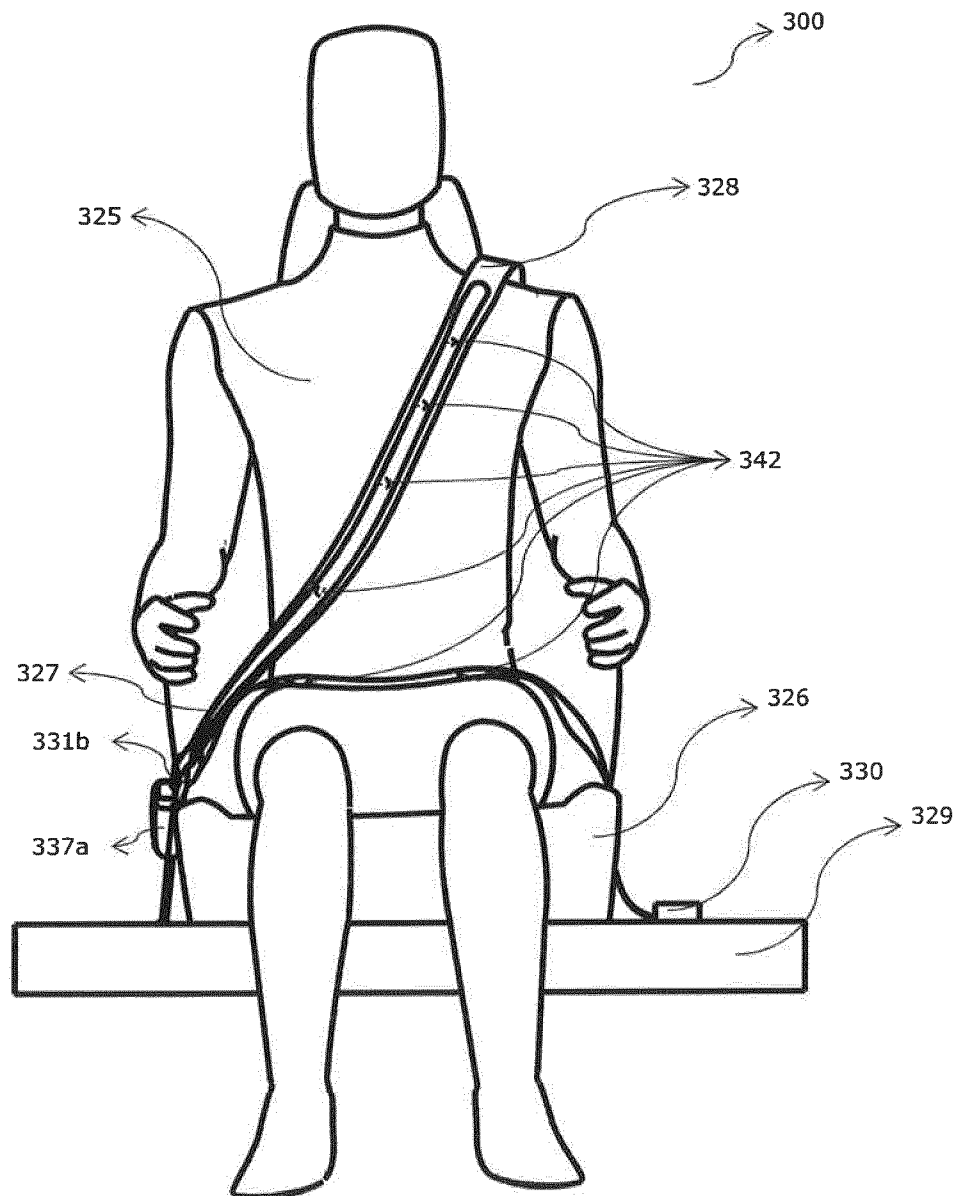


FIG.13

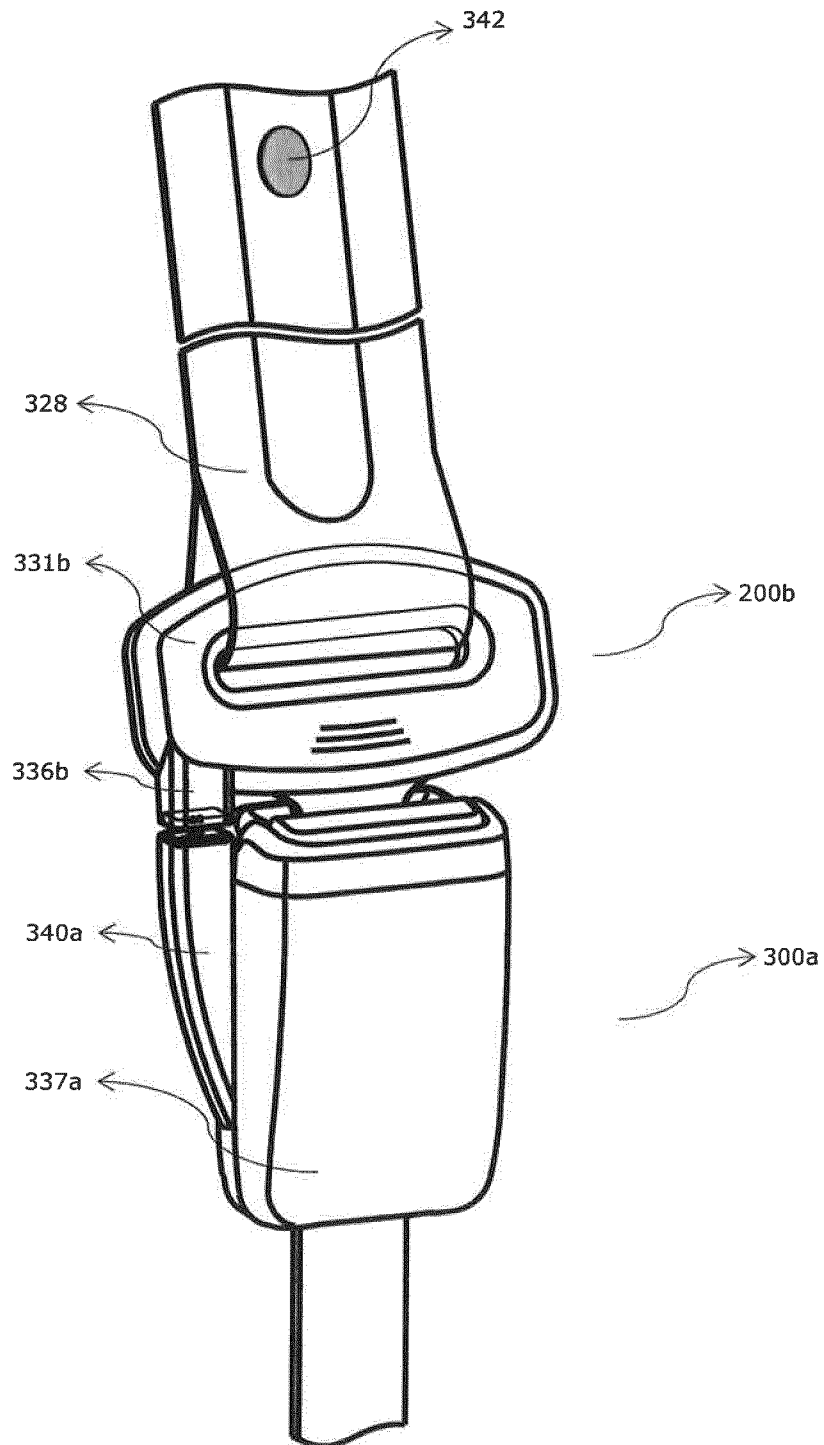


FIG.14

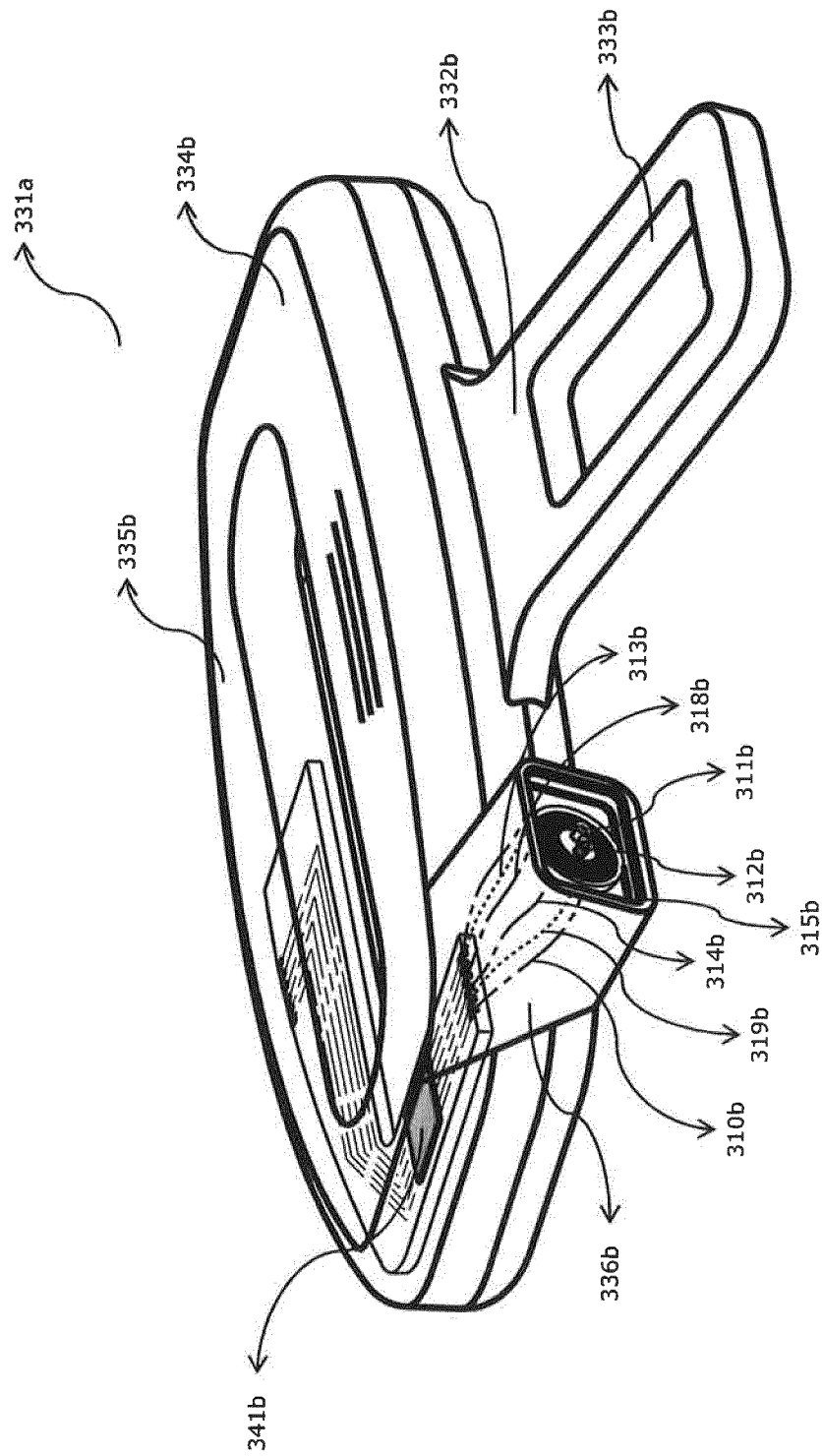


FIG. 15

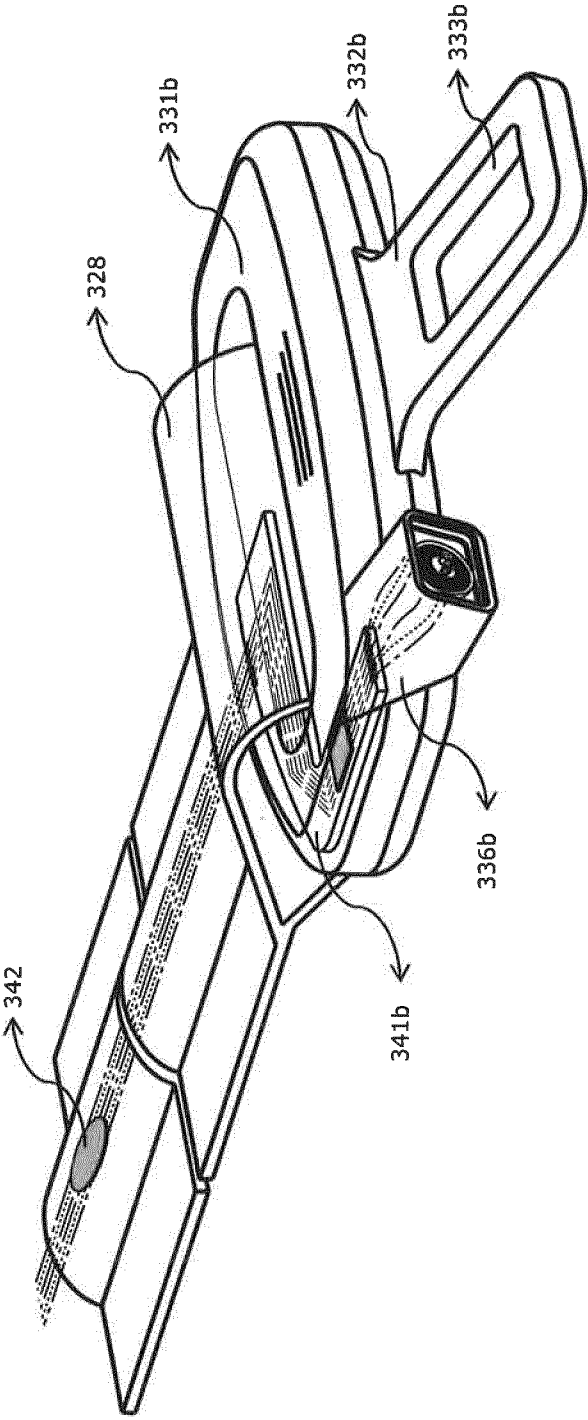


FIG.16

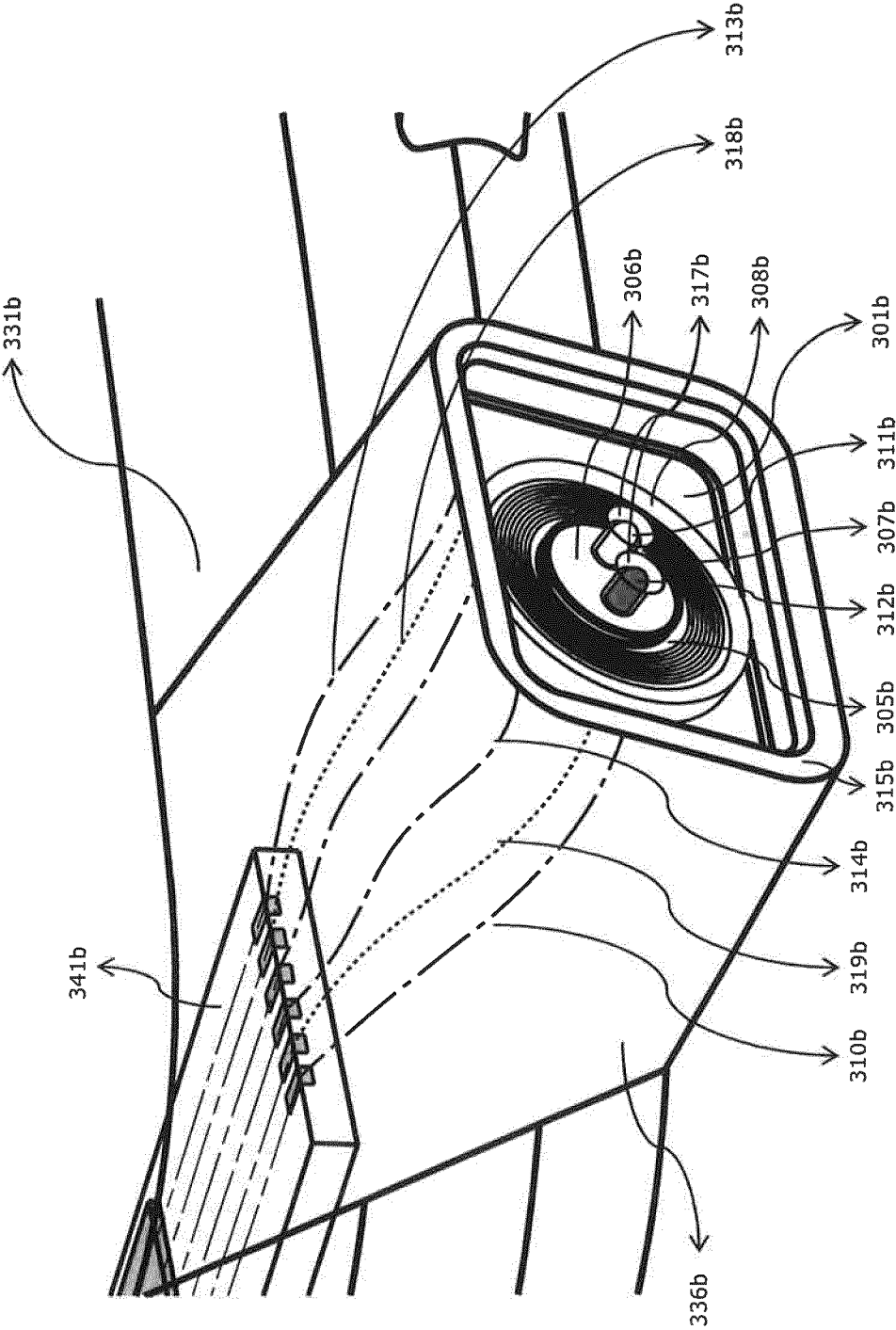


FIG.17

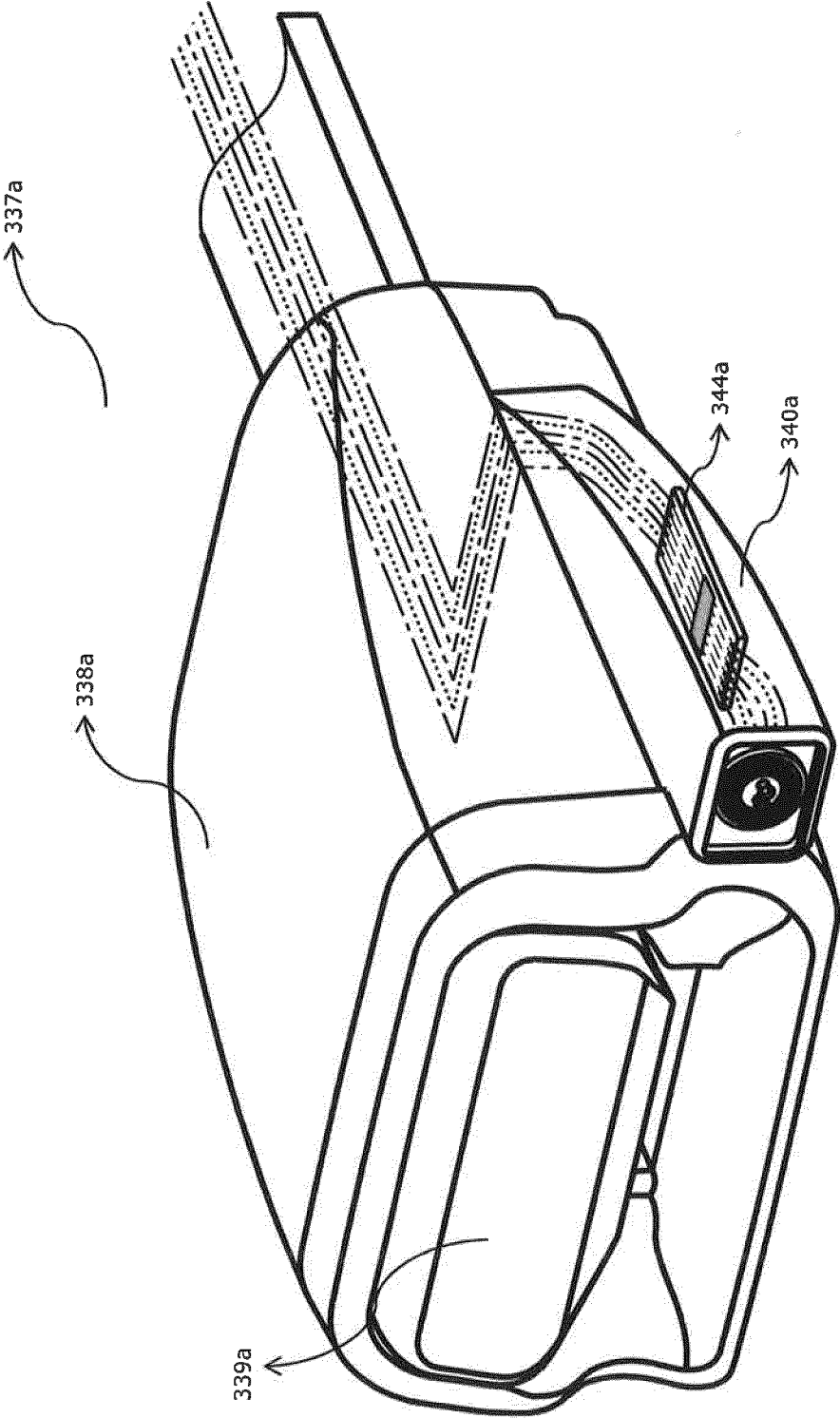


FIG.18

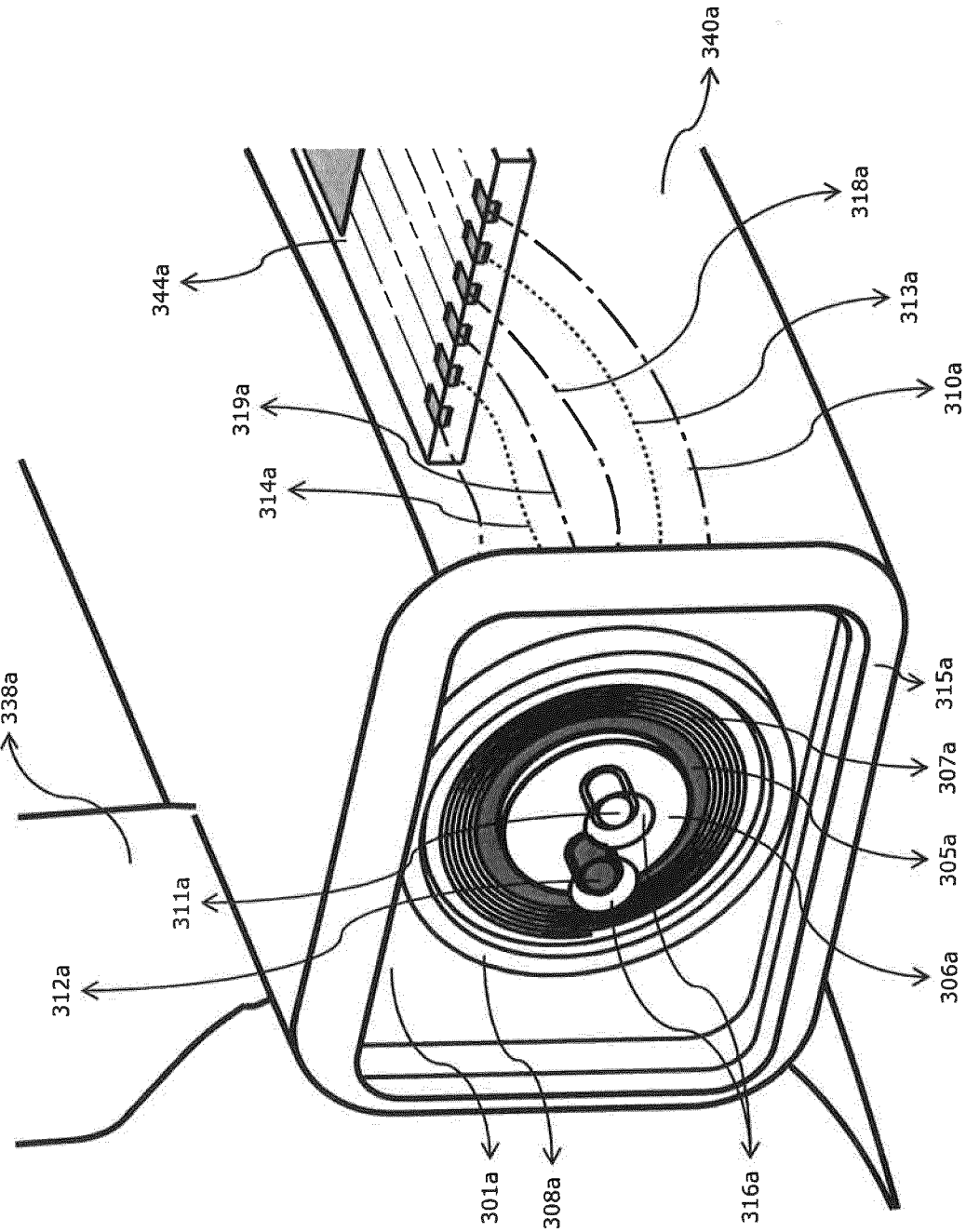


FIG.19

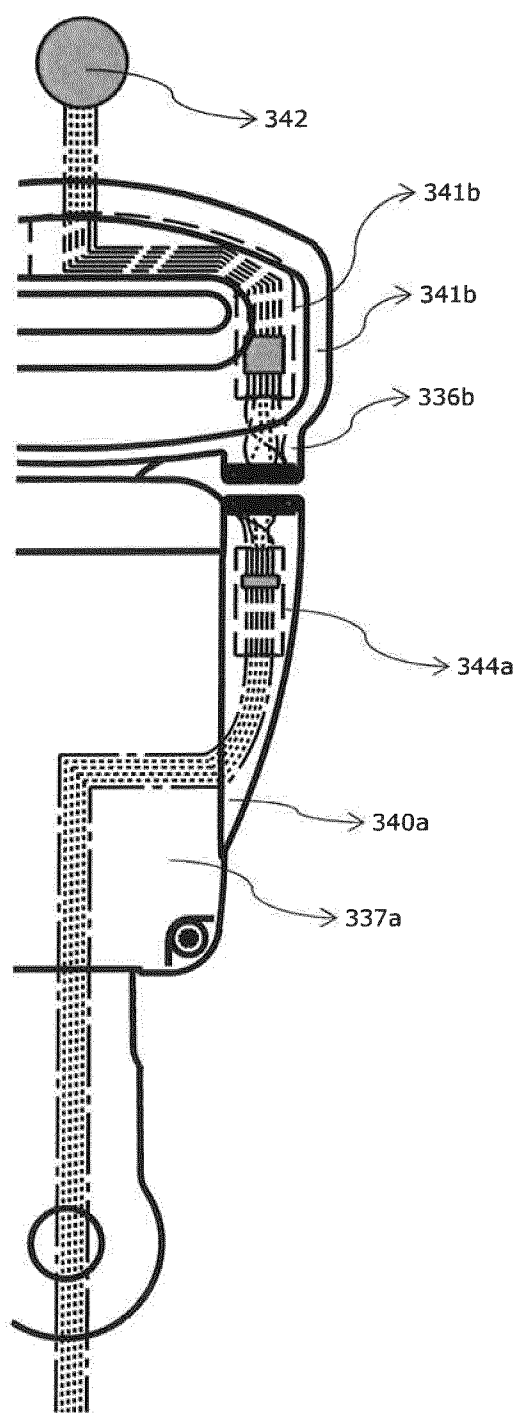


FIG.20

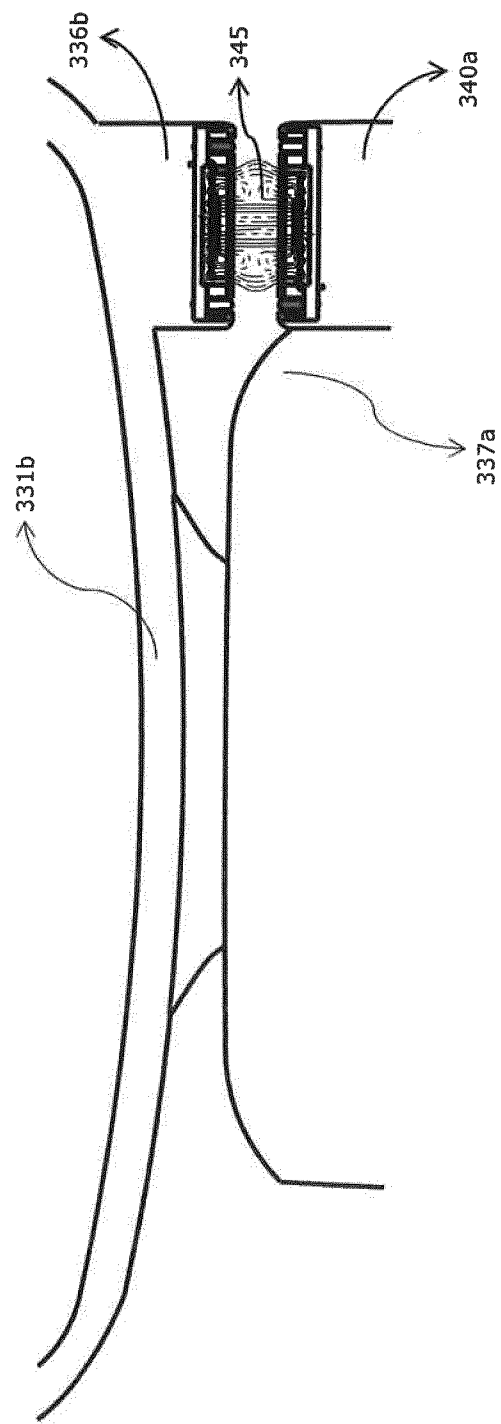


FIG. 21

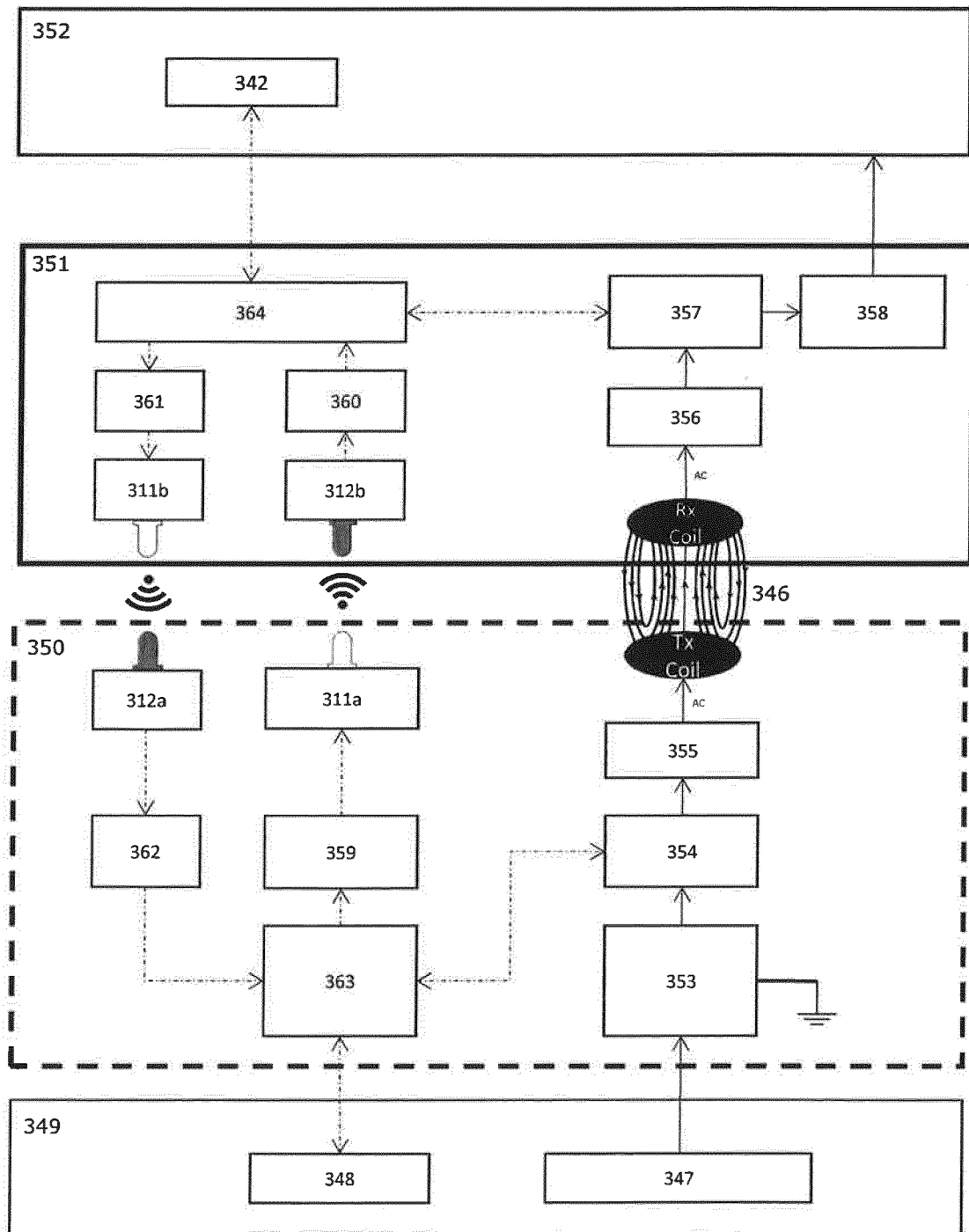


FIG. 22

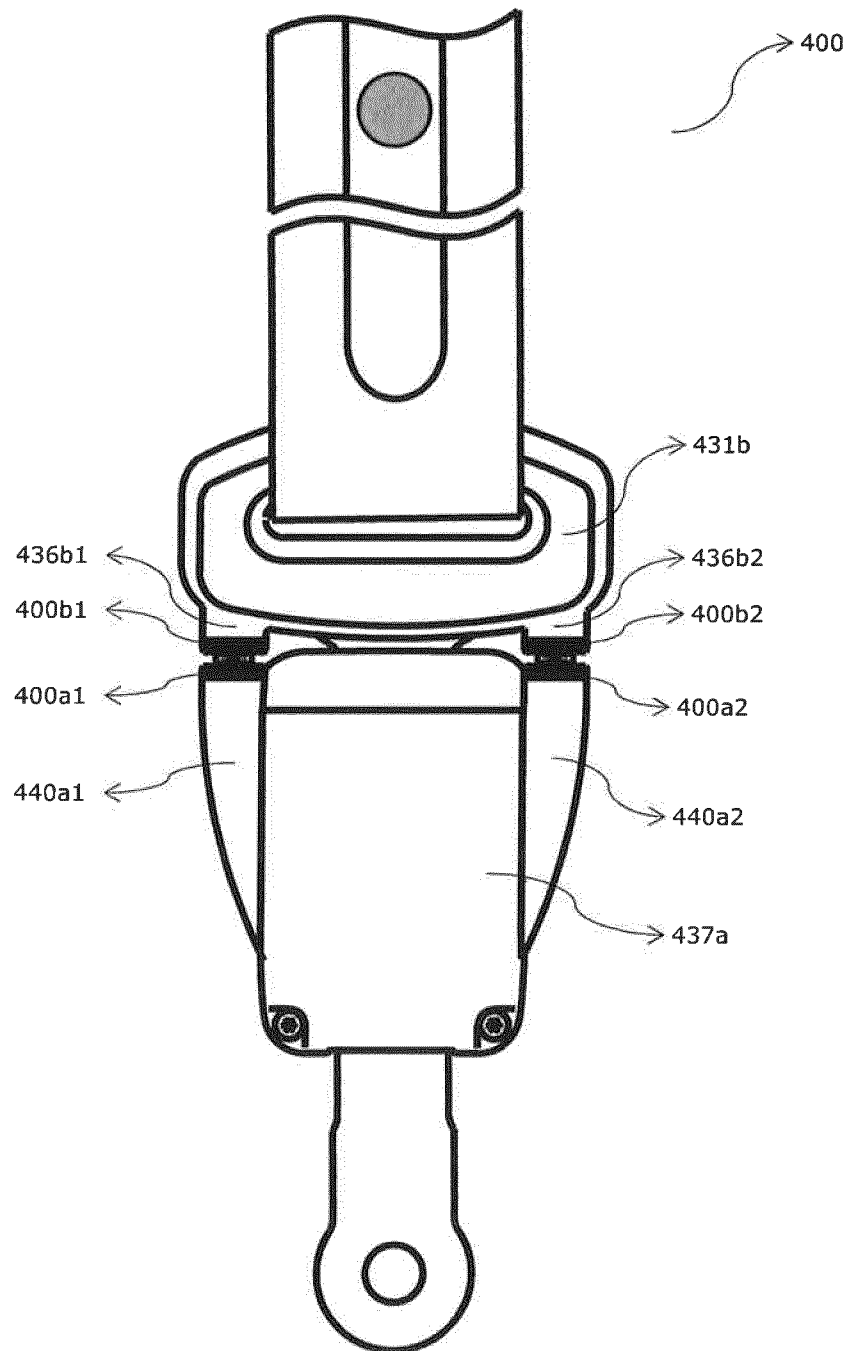


FIG. 23

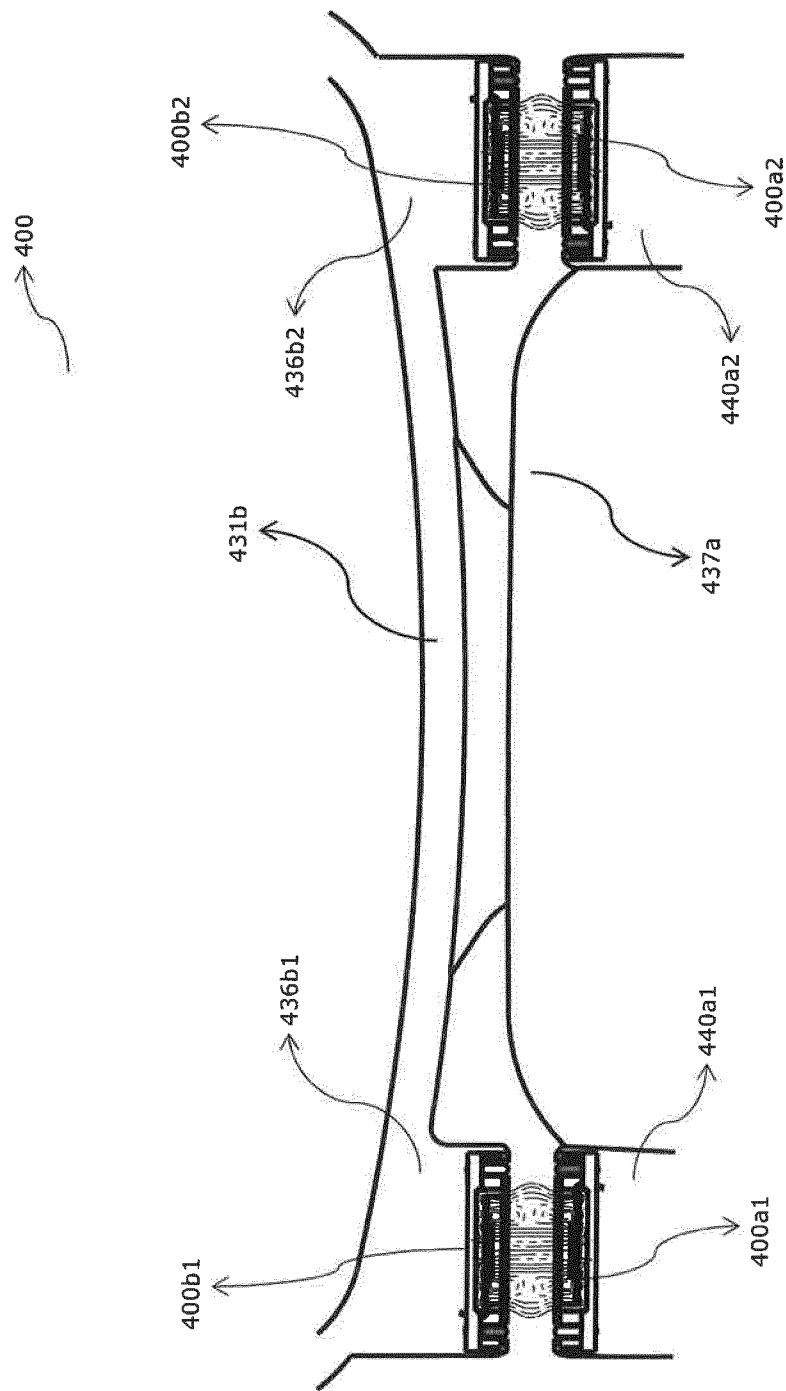


FIG. 24

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/050366

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60R16/03 B60R22/48 H02J50/10 H02J50/80 H04B5/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60R H02J H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2016/196464 A1 (TK HOLDINGS INC [US]) 8 December 2016 (2016-12-08) paragraphs [0063] - [0068]; claim 1; figures 1,2	1-18
A	WO 2018/125709 A1 (PANONSENSE INC [US]; NIKITIN DENIS) 5 July 2018 (2018-07-05) paragraphs [0020], [0021]; claim 1; figures 1-4	10-18
A	US 2015/244182 A1 (OZANA CHARLIE [IL] ET AL) 27 August 2015 (2015-08-27) abstract; figures 1,2,10	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

20 February 2020

Date of mailing of the international search report

28/02/2020

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/050366

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2016196464 A1	08-12-2016	CN 107667041 A	06-02-2018
		DE 112016002497 T5	01-03-2018
		US 2016355157 A1	08-12-2016
		WO 2016196464 A1	08-12-2016

WO 2018125709 A1	05-07-2018	NONE	

US 2015244182 A1	27-08-2015	NONE	
