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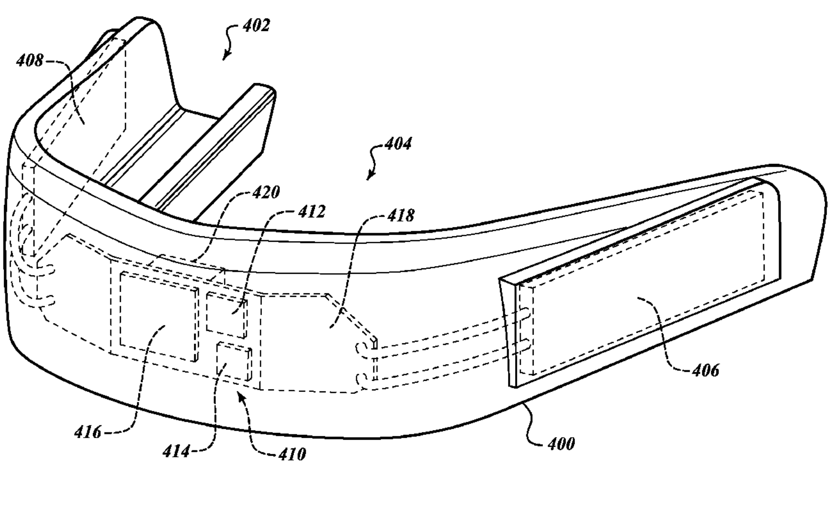

FIG.9

(57) **Abstract**: A mouth guard having a proximity sensor, an impact sensor, a processor in signal communication with the sensor, a memory in data communication with the processor, a transmitter in signal communication with the processor, and a battery. The processor is configured to allow data transmission the mouth guard has been inserted into a mouth. The processor is also configured to instruct the transmitter to transmit a signal if an impact above a predefined first threshold is sensed.

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MOUTH GUARD WITH SENSOR

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PRIORITY CLAIM

[0001] This application claims the benefit of U.S. Application Serial No. 13/009,515 filed January 19, 2011 which claims the benefit of U.S. Provisional Application Serial No. 61/336,429 filed January 22, 2010 and U.S. Provisional Application Serial No. 61/409,906 filed November 3, 2010, the contents of both are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] Participation in athletic activities is increasing at all age levels. All participants may be potentially exposed to physical harm as a result of such participation. Physical harm is more likely to occur in athletic events where collisions between participants frequently occur (e.g., football, field hockey, lacrosse, ice hockey, soccer and the like). In connection with sports such as football, hockey and lacrosse where deliberate collisions between participants occur, the potential for physical harm and/or injury is greatly enhanced. Approximately 300,000 athletes incur concussions in the United States each year. This may be a conservative estimate because many minor head injuries go unreported. Although most concussions occur in high-impact sports, athletes in low-impact sports are not immune to mild traumatic brain injury. Head injuries are caused by positive and negative acceleration forces experienced by the brain and may result from linear or rotational accelerations (or both). Both linear and rotational accelerations are likely to be encountered by the head at impact, damaging neural and vascular elements of the brain.

[0003] At the school level, school authorities have become sensitive to the risk of injury to which student participants are exposed, as well as to the liability of the school system when injury results. Greater emphasis is being placed on proper training and instruction to limit potential injuries. Some players engage in reckless behavior on the athletic field or do not appreciate the dangers to which they and others are subject by certain types of impacts experienced in these athletic endeavors. Unfortunately, the use of mouth guards and helmets does not prevent all injuries. One particularly troublesome problem is when a student athlete experiences a head injury, such as a concussion, of undetermined severity even when wearing protective headgear. Physicians, trainers, and coaches utilize standard neurological examinations and cognitive questioning to determine the relative severity of the impact and its effect on the athlete. Return to play decisions can be strongly influenced by parents and coaches who want a star player back on the field.

[0004] The same problem arises in professional sports where the stakes are much higher for a team, where such a team loses a valuable player due to the possibility of a severe head injury. Recent medical data suggests that lateral and rotational forces applied to the head and neck area (for example, flexion/extension, lateral flexion, and axial rotation) are more responsible for axonal nerve damage than previously thought. Previous medical research had indicated that axially directed forces (such as spinal compression forces) were primarily responsible for such injuries.

[0005] Identifying the magnitude of acceleration that causes brain injury may assist in prevention, diagnosis, and return-to-play decisions. Most field measurements assess the acceleration experienced by the player with accelerometers attached to the helmet. The following show some attempts for measuring the impacts to the skull and brain while the player is participating in a sporting activity. U.S. Pat. No. 5,539,935, entitled "Sports Helmet," issued on Jul. 30, 1996 and U.S. Pat. No. 5,621,922, entitled "Sports Helmet Capable of Sensing Linear and Rotational Forces," issued on Apr. 22, 1997 are examples of some of those attempts. Both patents relate to impact sensors for linear and rotational forces in a football helmet. These devices test the impact to the skull of a player. If an athlete suffers a concussion, for example, it will be possible to determine if the relative magnitude of an impact is dangerously high relative to a threshold to which each sensing device is adjusted, taking into consideration the size and weight of the player.

[0006] Another attempt performs testing impact acceleration to the head with an intraoral device which provides acceleration information of the brain in various sports. Other attempts have been made, however all these attempts can be costly to implement and fail to provide full historical medical information to coaches, trainers and medical professionals in real-time for dozens of players at a time on one or more adjacent fields.

SUMMARY OF THE INVENTION

[0007] The present invention provides a wirelessly linked sports impact sensing and reporting system. The system mainly includes one or more player electronics modules, a sideline module, and a remotely served and remotely accessible recording database module. In one aspect of the invention, the player module is housed independently within the volume of a set of an otherwise standard mouth guard and chin strap assembly, the sideline module is housed within the structure of an otherwise standard clipboard, and the database module is accessible via a network, e.g., public or private Internet.

[0008] In one version of the invention, the player module includes a plurality of sensors capable of detecting impact events in multiple axes, a battery, a data memory storage device, a microprocessor and a LED status indicator array. Each player module includes an RF transducer module and an antenna system, capable of establishing a wireless mesh network for reporting the data associated with an impact to the player. A zinc-air primary cell battery is used with the present player module device, but may be substituted by use of a lithium-polymer rechargeable battery or similar.

[0009] In another version of the invention, the sideline module includes a radio system capable of acting as a node on the wireless network and receiving signals from any of the player modules participating on the wireless mesh network in real-time. The sideline module also includes a battery, a data memory storage device, a microprocessor and a display capable of indicating impact information per player on the wireless mesh network, severity of impact, and recommended action in near real-time. The sideline module also includes a loudspeaker capable of generating audible alert tones to attract a coach's attention to incoming information in real-time. A zinc-air primary cell battery is used with the present player module device, but may be substituted by use of a lithium-polymer rechargeable battery or similar.

[0010] In still another version of the invention, the database module includes a database of players and associated impact data arrangeable by name, team, date, severity of impact, frequency of impact, and many other parameters. The database module is so constructed to be accessible via the public or private data network and is configured to provide various degrees of access to its information contents. Access accounts may be configured according to individual, team, division, league, physician, and administrator levels. Each account will be granted access to the appropriate set of data only, and password protection will ensure dissemination of data only to authorized parties.

[0011] In yet an additional version of the invention, an example system includes a mouth guard having a proximity sensor, an accelerometer, a gyroscope, a processor in signal communication with the accelerometer and gyroscope, a memory in data communication with the processor, a transmitter in signal communication with the processor, and a battery that provides power to the processor, the memory, the accelerometer, and the gyroscope. The processor is configured to allow power from a battery to flow to the accelerometer and gyroscope when the proximity sensor detects that the mouth guard has been inserted into a mouth. The processor is also configured to instruct the transmitter to transmit a signal if an acceleration above a predefined first threshold is sensed and to continue transmitting if an acceleration above a predefined second threshold is sensed before a first time period is complete.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Preferred and alternative embodiments of the present invention are described in detail below with reference to the following drawings:

[0013] Figure 1 is a drawing showing an example of the invention in context of a football player's head in profile, while wearing a football helmet and the sensor-enabled mouth guard and chin strap set, i.e., the player module;

[0014] Figure 2 is a drawing showing the player module in context of its positioning as worn within a human head;

[0015] Figure 3 is a drawing in isometric view showing an example mouth guard element of the player module and indicating the positioning of embedded sensor elements and conductors;

[0016] Figure 4 is a drawing in plan view showing the example mouth guard element of the player module and indicating the positioning of embedded sensor elements and conductors;

[0017] Figure 5 is a drawing showing a side view of an example player module, including the mouth guard element and chinstrap element, and showing the relationship and connection between the two;

[0018] Figure 6 is a drawing in isometric view showing the player module, including mouth guard and chinstrap elements;

[0019] Figure 7 is a drawing showing a portion of an example sideline module embodied as a clipboard, with a display and input buttons in the uppermost region;

[0020] Figure 8 illustrates an exemplary system formed in accordance with an embodiment of the present invention;

[0021] Figure 9 is a perspective view of a mouth guard formed in accordance with an embodiment of the invention;

[0022] Figure 10 is a diagram of a sensing module in the mouth guard shown in Figure 9;

[0023] Figure 11 is a top view of the mouth guard shown in Figure 9;

[0024] Figure 12 is a front view of the mouth guard shown in Figure 9;

[0025] Figure 13 is a side view of the mouth guard shown in Figure 9;

[0026] Figure 14 is a diagram of a system including a mouth guard and a helmet formed in accordance with an embodiment of the invention; and

[0027] Figure 15 is a flowchart of a method of transmitting and storing acceleration data using the mouth guard shown in Figure 9.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0028] A preferred version of the present invention is a system for the detection, measurement, characterization, transmission, and/or reporting of events causing impact forces to be experienced by players, for example football players. Thus, as shown in Figures 1 and 2, a preferred system is configured for use with a mouth guard in a situation in which a player also uses a chinstrap and a helmet. In other examples, various sensors may be incorporated into other housings such as headbands, goggles, or other headgear. The system conveys to an authority figure, preferably a coach or trainer, useful information about the identity of the impacted player, the severity of the impact, and suggested actions for evaluating the condition of the player and for making decisions about the players subsequent status *vis-à-vis* readiness to return to play or referral to a physician's care.

[0029] An example of the player module includes an arrangement of a plurality of low-cost, distributed sensors arranged between the inside surface of the player shell and the bottom surface of a padding elements that provide fit and cushioning to the player's head. These sensors may alternatively be positioned intermediately within the padding element, either at the interface of two laminated elements, or by encapsulation directly within the mass of the padding element. The sensors may also be situated within cavities of the player or in the spaces between padding elements. For example, these sensors may be MEMS type impact sensors, MEMS accelerometers, miniature weighted cantilevers fitted with miniature strain-gauge elements, piezoelectric membranes, or Force-Sensitive-Resistors (FSR).

[0030] In one example, the sensors are incorporated into a sensor unit that is configured as a mouth guard. Thus, as shown in Figures 3 and 4, various sensors may be encapsulated into the material formed as a mouth guard. In the illustrated version, sensors are shown being positioned at a lower surface of the mouth guard, beneath the channel formed to receive a user's teeth. As also illustrated, the exemplary mouth guard of Figures 3 and 4 includes a wire or tether, preferably encapsulated in a protective covering, extending from a forward portion of the mouth guard in order to send data to a base unit or other device. In other versions, as described below, the mouth guard includes an antenna for wirelessly transmitting the data to an intermediate module or directly to a sideline receiving unit.

[0031] The sensors employed in the player module are connected electronically by means of wires or printed flex circuitry to an electronics pod or other similar means, in some versions situated within a primary shell of the player, and within the space available between two or more padding elements. As illustrated in Figures 5 and 6, in some versions the mouth guard sensors are communicatively coupled to a receiving unit contained within a chin strap or other such component external to the mouth. The chin strap includes electronic components to transmit the data received from the mouth guard and then pass it along to a sideline receiving unit. Most preferably the data is passed along in real time, although in some versions the data is stored in a memory and downloaded at a later time.

[0032] The electronics pod (whether in the helmet, the mouth guard, the chin strap, or another location) collects, processes, evaluates, and if appropriate, transmits data pertaining to an impact event via radio to one or more other participant nodes of the wireless network to which the player module belongs. The electronics pod contains electronic circuitry having components such as a microprocessor, flash memory, radio module, antenna, and status display LEDs. In the circuit's memory resides a database lookup table for evaluation of sensor data and comparison to combinations of impact levels that represent suspicious likelihood of Mild Traumatic Brain Injury (MTBI) or concussion. The electronics pod is also configured to monitor, evaluate, and/or display system status information such as link to network, battery charge status, and proper system functioning.

[0033] An example sideline module is an electronic data gathering and display device incorporated into a portable enclosure that is easy for a coach, trainer, or other such game official to carry, consult, and interact with during the activities of the practice or game. In one embodiment, the sideline module is embedded into the topmost section of a clipboard, for example as illustrated in Figure 7. Since the majority of coaches and trainers need to carry clipboards anyway, this is perceived as the most natural and least obtrusive way to provide impact information. However, many other configurations of the sideline module are possible, including building it into a wristband, a stopwatch-style fob with a neck lanyard, a device similar to a mobile phone or pager, etc. The sideline module may be in the form of any electronic receiving device, including laptop computers, mobile phones, or any other such device configurable to receive wireless information. Moreover, the sideline module is described as receiving information directly from the sensor unit, although in some versions of the invention the sensor module may pass its data to an intermediate server or other device which then forwards the information to the sideline module.

[0034] The sideline module includes electronic components arranged into a circuit that allows for participation in the wireless mesh network established by a set of player modules, and specifically for the receipt of data transmissions from the player modules, and subsequently the display of impact event information on a visual display in real-time. The sideline module also produces audible and vibratory alert signals to call attention to the arrival of new data messages in real-time, which are disabled by manual conscious intervention of the coach or trainer, indicating acknowledgement of receipt of impact event data.

[0035] In one embodiment, the sideline module performs the classification of incoming impact data into one of three categories, indicating differing levels of concern and differing levels of urgency of response. The system employs a "GREEN LIGHT" "YELLOW LIGHT" and "RED LIGHT" system, in which a GREEN LIGHT status indicates the absence of significant impact events for a given player, a YELLOW LIGHT indicates the need for immediate sideline evaluation of the player, and RED LIGHT indicates a severe enough impact that the player be removed from play and referred to a physician immediately.

[0036] Upon registering a YELLOW LIGHT impact event, and upon subsequent acknowledgement of receipt of the message by the coach or trainer, the sideline module, in one embodiment, leads the coach or trainer through a simple protocol for evaluation of the player's condition. Through answering a series of simple Yes or No questions, the sideline module guides the coach or trainer to a limited number of possible suggested actions. These potential outcomes could include immediate referral to a physician for further examination, or a period of bench time observation followed by a secondary guided evaluation before allowing the player to return to play.

[0037] In one embodiment, a durable record of data transactions is received in real-time and is kept independently of the sideline module or modules. Such a database provides players, parents, coaches, trainers, administrators and other stakeholders access to a record of what impact event information was conveyed, when, to whom and about which player. The sideline module is equipped with a wide area network radio module for transmission of a record of all data transactions on the system with time stamp and a record of the actions by coaches and content of player evaluations. A standard 1 way or 2 way pager system is used, which has the benefit of being inexpensive and nearly ubiquitous in availability throughout much of the world. Alternatives to pager radio systems are cellular radios of various kinds and other wide area network wireless connections. The knowledge that this information will be available to stakeholders provides accountability to all stakeholders in the health and well being of the player.

[0038] In one embodiment, the database is populated by an automatic interface to the wide area radio network accessed by the sideline network, and is accessible to stakeholders by means of internet based applications, equipped with password protected hierarchical account structures. The system provides parents the ability to log on to their account and review the totality of impact event data and the record of coach responses associated with their player.

[0039] Each player module at the start of each season maps its unique identifier code to a particular player's name and number. It is possible that during the course of events players might accidentally wear the wrong player number and potentially cause confusion by users of the system. It is for this reason that each player module has, in one embodiment, a visual indicator array of LEDs, which will repeatedly flash a visible signal in case of transmission of an impact event of concern. A yellow light flashes to indicate the transmission of a YELLOW LIGHT event, and a red light flashes to indicate the transmission of a RED LIGHT event. When the player is called to the sidelines for evaluation, the coach or trainer can disable the flashing indicator light by simultaneously depressing a button on the player module and a button on the sideline module. This provides positive confirmation that the player who sustained the reported impact is in fact the player being evaluated by the coach or trainer.

[0040] Figure 8 illustrates an exemplary system 100 that performs aggregation of head-acceleration information received from a plurality of sensor units 102 and makes the acceleration information available to relevant parties. The sensor units are the mouth guards or other components as described above that incorporate one or more sensors. The system 100 includes a base unit 104 that is in wireless communication with one or more sensor units 102 and is optionally in wired or wireless communication with one or more devices 106. As described above, the sensor units may be directly coupled to the base unit, or may alternatively pass their data to the base unit indirectly, through a server, network, or other electronic device. The base unit 104 includes a processor 112, a user interface 114, local memory 116, and a communication component 120. The base unit 104 receives acceleration information wirelessly from each of the sensor units 102 and optionally makes that data available to the one or more additional devices 106.

[0041] In some versions, the base unit 104 or any of the devices 106 are in wired or wireless connection with a medical system 124 over a public or private data network 108. The medical system 124 receives acceleration, identification or other information from the base unit 104 or the devices 106 for analysis with regard to stored athlete information and/or storage into a database 126.

[0042] Figure 9 is a perspective view of a mouth guard 400 formed in accordance with an example embodiment of the invention. The mouth guard 400 is an example of one of the types of sensor units 102 that may be used with the system 100 shown in Figure 8. The mouth guard 400 defines a channel 402 for receiving a plurality of teeth of a user. In an example embodiment, the channel 402 is structured such that it covers teeth that include the incisors of a user when the mouthpiece is inserted. The mouth guard 400 also defines an open area 404 that allows the user's tongue to touch their upper palate after the mouth guard 400 has been inserted. This allows the user to maintain verbal communication with others without the additional effort required with other types of mouth guards having a solid portion that covers the upper palate.

[0043] The mouth guard 400 also includes a first battery 406 and a second battery 408. The batteries 406, 408 are electrically connected to a sensing module 410 and may be recharged with a wireless battery charger in some embodiments. In an example embodiment, the sensing module 410 is located at a front portion of the mouth guard 400 that covers the incisors of a user when the mouth guard 400 is inserted. However, the sensing module 410 may be located in a different area of the mouth guard in other embodiments. The sensing module 410 includes a three axis accelerometer 412 that senses acceleration along three orthogonal linear axes, a three axis gyroscope 414, and an electronics module 416 that are attached to a flex-printed circuit 418 (FPC) in an example embodiment. The accelerometer 412 preferably senses accelerations of at least 90 g and the gyroscope is preferably sensitive to at least 6000 degrees per second. In a preferred version, the electronic components described above are all positioned along an outer portion of the mouth guard where they will be located outside the teeth of the user and encapsulated within the material forming the mouth guard.

[0044] In accordance with preferred implementations of the invention, the accelerometer and gyroscope sense attributes of the environment of the mouth guard or other sensor unit 102 to determine a rate of acceleration of the sensor unit and an orientation of the sensor unit over time. Thus, by matching the acceleration and the position, the sensor unit is able to determine not only the fact of an event causing acceleration of a particular magnitude, but also a direction of the acceleration based on the direction of movement of the sensor unit. These data can be coupled, either in the sensor unit, the base unit, or another device, to calculate a vector representative of a combined direction and magnitude of the acceleration experienced by the sensor unit. In some instances the sensed event may be determined to be a straight line vector, while in other instances the motion of the sensor unit may be along an arc or otherwise rotational.

[0045] Although the sensing module 410 includes the three axis accelerometer 412 and the three axis gyroscope 414 in this embodiment, other sensor combinations may be used in other embodiments. For example, a two axis gyroscope in combination with a single axis gyroscope may be used rather than a three axis gyroscope, or additional linear accelerometers may be used rather than a gyroscope. In accordance with preferred implementations of the invention, however, the sensing module includes components that are capable of sensing both acceleration and position of the sensor unit.

[0046] A proximity sensor 420 is also in signal communication with the electronics module 416. The proximity sensor 420 includes a capacitive touch sensor in an example embodiment, but may include other types of sensors in other embodiments such as a temperature sensor or an optical sensor, for example. Most preferably, the proximity sensor is configured to indicate whether the mouth guard or other sensor unit is positioned in the player's mouth or otherwise engaged and in use. The sensing module 410 may also be configured as an application specific integrated circuit (ASIC) in some embodiments.

[0047] Figure 10 is a diagram of the sensing module 410 showing additional detail for the electronics module 416 in accordance with an example embodiment of the invention. The electronics module 416 includes a processor 440 in data communication with a memory 442. The electronics module 416 also includes a transceiver 444 in signal communication with the processor 440.

[0048] In an example embodiment, the accelerometer block 412 includes three single axis accelerometers such as model AD22283 produced by Analog Devices, Inc. The gyroscope block 414 includes a dual axis sensor such as model LPR5150AL produced by STMicroelectronics and a single axis sensor such as model LY5150ALH produced by STMicroelectronics. The processor block 440 includes a microcontroller such as model MSP430F5522 produced by Texas Instruments, the memory block 442 includes a memory module such as model M25P32 produced by Numonyx, and the transceiver block 444 includes a transceiver such as model CC1101 produced by Texas Instruments in an example embodiment. However, different components may be used in other embodiments. For example, piezoelectric and/or piezoresistor based sensors may be used in some embodiments.

[0049] Figures 11-13 show additional views of the mouth guard 400 shown in Figure 9. Figure 11 is a top view of the mouth guard 400. Figure 12 is a front view of the mouth guard 400. Figure 13 is a side view of the mouth guard 400. As best seen in Figure 11, the electronic components are positioned on an outer portion of the channel formed for receiving the teeth of the user.

[0050] Figure 14 is a diagram of an example embodiment of a sensor unit 600 where a portion of the sensor unit 600 is included in a mouth guard 602 and another portion of the sensor unit 600 is included in a helmet 604. In the example shown, the mouth guard 602 is connected to the helmet 604 with a wired tether 606. The mouth guard 602 includes a connection header that provides electrical connectivity to the sensor unit 600 which is enclosed within the mouth guard in some embodiments. The connection header may be of a type such as model number D2514-6002-AR produced by 3M Company, for example, that allows the wired tether 606 to be disconnected from the mouth guard 602. However, in other embodiments, the mouth guard 602 is solely in wireless communication with the helmet 604. The mouth guard 602 includes a mouth guard module 610 that is in signal communication with a helmet module 612. Though the helmet module 612 is illustrated as being positioned outside the helmet, it may alternatively be positioned within the helmet body.

[0051] In some embodiments, the tether 606 includes lines for both power and data communication so that the mouth guard module 610 can be structured to include fewer components than those described with respect to the sensing module 410 in Figure 10. For example, the mouth guard module 610 may include accelerometers and gyroscopes, with a battery, processor, memory, and transceiver all being included in the helmet module 612. In such an embodiment, the battery would provide power to both the processor and transceiver in the helmet module 612 as well as to the accelerometers and gyroscopes in the mouth guard module 610, and linear and rotational signals from the accelerometers and gyroscopes would be routed to the processor in the helmet module 612 over the tether 606. In the version as shown, the helmed module 612 transmits data to the base unit as described above.

[0052] In an example embodiment using wireless communication between the mouth guard module 610 and the helmet module 612, the mouth guard module 610 is configured similarly to the sensing module 410 described with respect to Figure 10 and the helmet module 612 includes a repeater that receives a signal transmitted by a transceiver within the mouth guard module 610 at 433 megahertz (MHz) and transmits a signal at 915 MHz based on the received signal. However other frequencies may be used in other embodiments. In such embodiments, the tether 606 may be absent or may be used for a more limited purpose, such as for conducting power from batteries located in the helmet module 612 to the mouth guard module 610.

[0053] Figure 15 is flowchart of a method 700 of providing acceleration data using the mouth guard 400. First, at a block 702, the processor 440 checks whether the proximity sensor 420 is indicating the mouth guard 400 has been inserted. Then, at a decision block 704, if the proximity sensor 420 is not indicating that the mouth guard has been inserted, the method returns to block 702. If the proximity sensor 420 is indicating that the mouth guard has been inserted, the method proceeds to a block 706. The sensor unit sends an indication to the base unit indicating whether the mouth guard has been inserted, preferably in the form of a toggle type indicator that is sent initially upon insertion or removal of the mouth guard.

[0054] At block 706, power from the batteries 406, 408 is provided to the sensing module 410. Next, at a block 708, the processor 440 receives acceleration data from at least one of the accelerometer 412 and the gyroscope 414 (or another sensor). In a preferred version, the processor further obtains positional orientation information, such as from the gyroscope.

[0055] Next, at a block 710, the processor stores the received acceleration and positional data in the memory 442. In an example embodiment, the buffer time period, or sample rate, is 8 milliseconds (ms). Then, at a decision block 712, the processor 440 determines whether the acceleration data exceeds a previously stored first threshold value. According to one example of the invention, the acceleration data is measured in terms of g-force" and the sampled measurements are compared against a stored threshold value that is indicative of an acceleration level deemed to be of concern. In the preferred version of the invention, the threshold value is stored in the memory of the sensor unit and the sensor unit only transmits an event indicator to the base unit when the sensed acceleration data exceeds the previously stored threshold value. The first threshold value may be adjusted by the user as desired, in order to accommodate different levels of concern.

[0056] In another preferred version, the threshold values are stored in the base unit and adjusted using a software interface in which a coach or other user can input the threshold values as desired. In such a version, the sensor units continually transmit to the base unit even where the sensed acceleration is below the first threshold. The comparison of the sampled data against the threshold values are therefore also preferably made at the base unit in this version. In other versions, however, the sensor unit or other modules can be individually programmed so that internal microprocessors can operate stored programming instructions to make the comparisons locally at the sensor unit, helmet module, or other component worn by the athlete.

[0057] If the acceleration data does not exceed the previously stored first threshold value, the method returns to the block 708. If the acceleration data exceeds the previously stored first threshold value, the processor 440 instructs the transceiver 444 to transmit the buffered data and to continue transmitting acceleration data for a predetermined post first threshold time period. In an example embodiment, the post first threshold time period is 32 ms. In other versions of the invention, the transceiver continues to transmit to the base unit until the sensed acceleration is below the set threshold. In addition to transmitting the acceleration data, the processor 440 stores acceleration data from the buffer time period and the post threshold time period in the memory 442.

[0058] When the device sends acceleration data to the base unit or other remote device, it preferably also transmits positional orientation data along with the acceleration data. The data sent in a fashion in which they can be paired with one another in order to determine an orientation along with the acceleration at each sampled moment in time. This combination allows the base unit (or other device) to determine the direction and magnitude of the event, including whether it was straight or rotational.

[0059] At a decision block 716, the processor 440 determines whether acceleration data from at least one of the accelerometer 412 gyroscope 414 or other device exceeds a second threshold value during the post threshold time period. If the acceleration data does not exceed the second threshold value during the post first threshold time period, the method returns to the block 708. If the acceleration data exceeds the second threshold value during the post first threshold time period, the processor 440 instructs the transceiver 444 to continue to transmit acceleration data beyond the post first threshold time period for a predetermined extension time period at a block 718. The extension time period may be an additional 20 ms beyond the first threshold time period, for example. This comparison continues for additional time periods in some embodiments, where the processor 440 instructs the transceiver 444 to continue to transmit acceleration data beyond the extension time period if an acceleration greater than the second threshold value is detected before the end of the extension time period. Although the steps above are described as occurring sequentially in a particular order, it should be understood that some of the steps may occur in parallel and that a subset of the steps or additional steps may be present in some embodiments.

[0060] While the preferred embodiment of the invention has been illustrated and described, as noted above, many changes can be made without departing from the spirit and scope of the invention. Accordingly, the scope of the invention is not limited by the disclosure of the preferred embodiment. Instead, the invention should be determined entirely by reference to the claims that follow.

[0061] The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A system comprising:

   a mouth guard defining a channel for receiving a plurality of teeth within a mouth of a user;

   a first sensor attached to the mouth guard for detecting whether the mouth guard has been inserted into the mouth; and

   a second sensor attached to the mouth guard, the second sensor being configured to detect movement of the mouth guard.

2. The system of Claim 1, further comprising a processor and a memory integrated into the mouth guard, the processor being in signal communication with the first sensor and the second sensor.

3. The system of Claim 2, further comprising a transmitter integrated into the mouth guard, the processor being configured to cause the transmitter to transmit a first signal in response to a detected movement of the mouth guard by the second sensor.

4. The system of Claim 3, wherein the first sensor, the second sensor, the processor, the memory, and the transmitter are located between a first layer and a second layer of ethyl vinyl acetate forming the mouth guard.

5. The system of Claim 3, further comprising a helmet and a repeater attached to the helmet, wherein the repeater transmits a second signal based on the first signal.

6. The system of Claim 1, further comprising a helmet, wherein the helmet comprises a processor, a memory, and a transmitter are attached to the helmet, the processor being configured to cause the transmitter to transmit a first signal in response to a detected movement of the mouth guard by the second sensor.

7. The system of Claim 1, wherein the first sensor comprises a proximity sensor integrated in the mouth guard, the mouth guard further having a processor and a battery integrated into the mouth guard, the proximity sensor being in signal communication with the processor, wherein the processor is configured to allow power from a battery to flow to the second sensor when the proximity sensor detects that the mouth guard has been inserted into the mouth.

8. The system of Claim 2, wherein the processor is configured to save information in the memory corresponding to movement detected by the second sensor.

9. The system of Claim 8, wherein the second sensor comprises an accelerometer and the detected movement comprises detected acceleration of the mouth guard, and further wherein the information includes the detected acceleration.

10. The system of Claim 9, further comprising a transmitter integrated into the mouth guard, the processor being configured to determine whether the detected acceleration is above a threshold and to cause the transmitter to transmit a signal when the detected acceleration is above the threshold.

11. The system of Claim 1, further comprising a positional orientation sensor attached to the mouth guard.

12. A method comprising:

providing a mouth guard, the mouth guard having a movement sensor attached to the mouth guard;

sensing a movement of the mouth guard with the sensor;

determining, using a processor and a memory, whether the movement exceeds a first threshold; and

transmitting a first signal when the movement exceeds the first threshold.

13. The method of Claim 12, wherein the movement sensor comprises an accelerometer and the step of sensing comprises sensing an acceleration of the mouth guard, and further wherein the step of determining comprises determining a period of time during which the acceleration exceeds the first threshold.

14. The method of Claim 13, wherein the first signal comprises an indication of a magnitude and a duration of the acceleration.

15. The method of Claim 12, further comprising sensing whether the mouth guard is inserted into a mouth.

16. The method of Claim 12, wherein transmitting the first signal includes transmitting a unique identifier associated with the mouth guard.

17. The method of Claim 12, further comprising receiving a time synchronization signal after the first signal has been transmitted.

18. The method of Claim 12, further comprising checking whether a transmission slot is clear before transmitting the first signal.

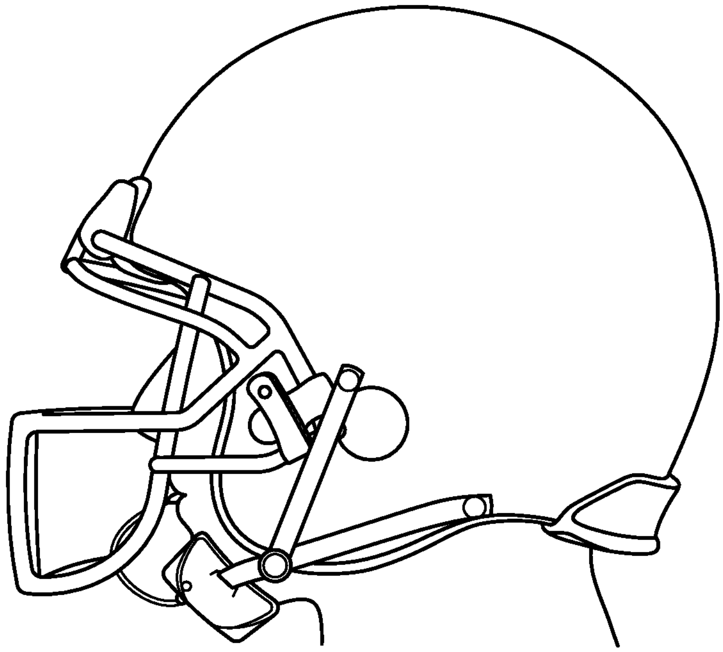

FIG.1

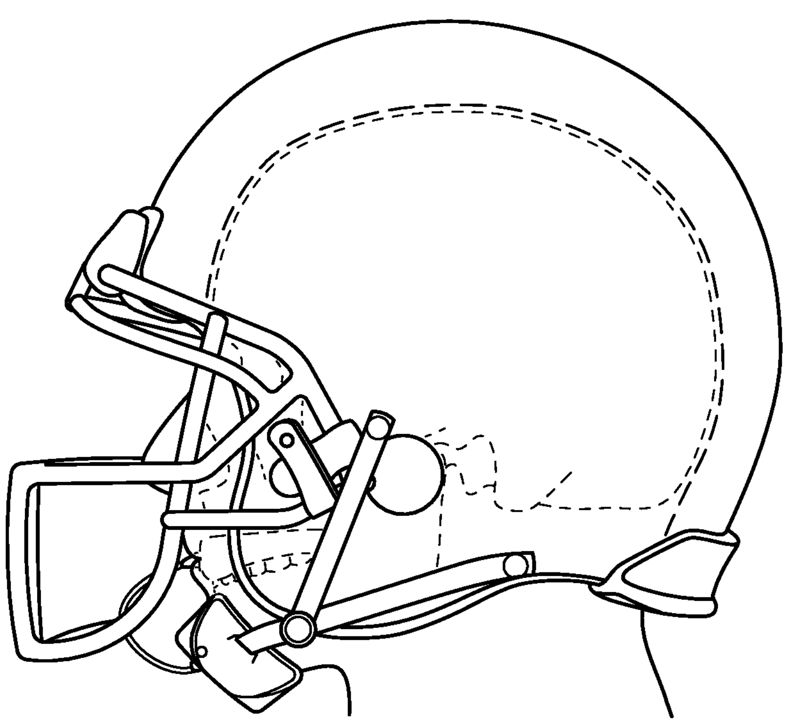

FIG.2

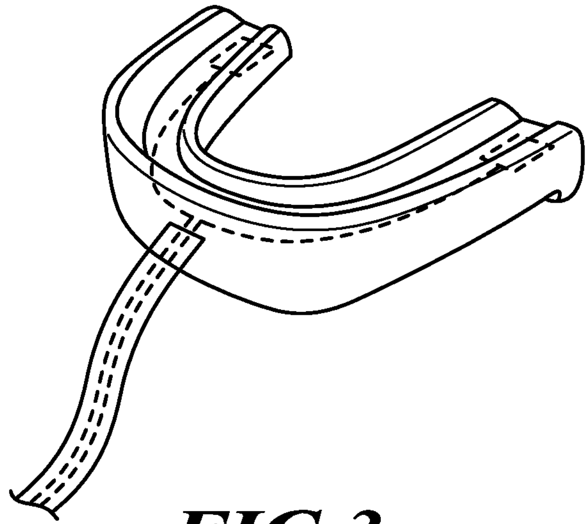

FIG.3

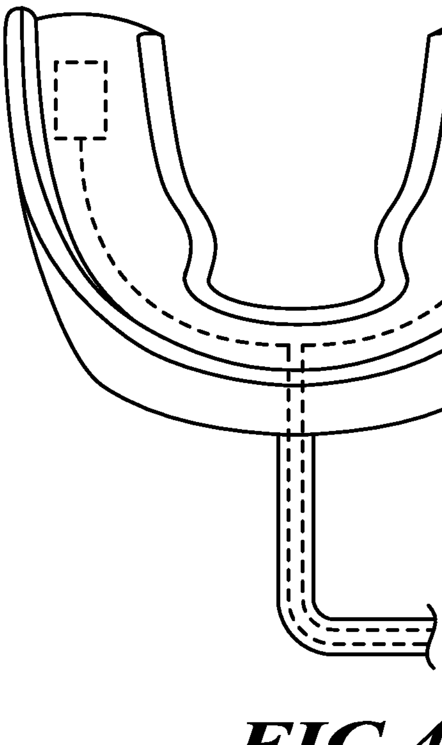

FIG.4

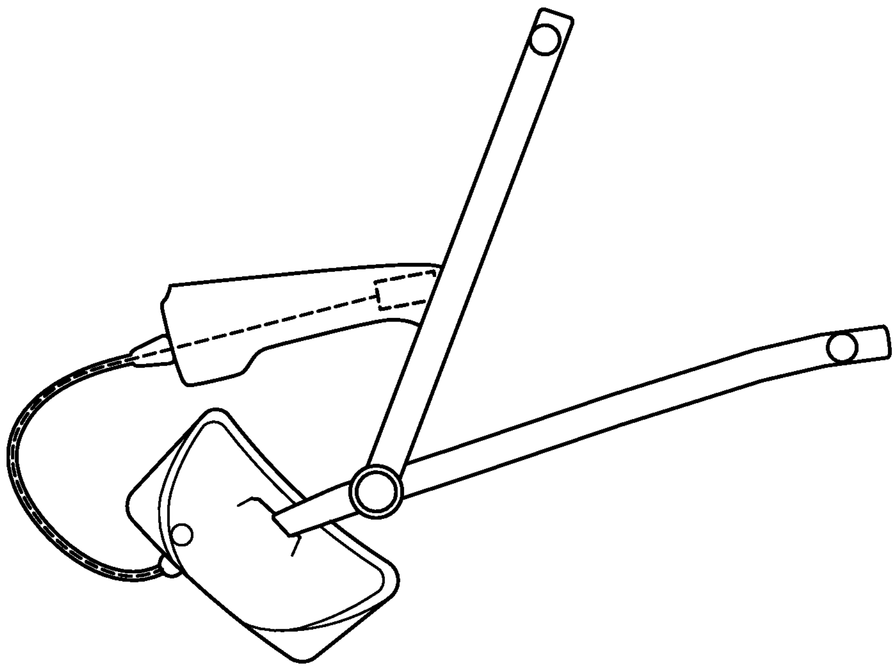

FIG.5

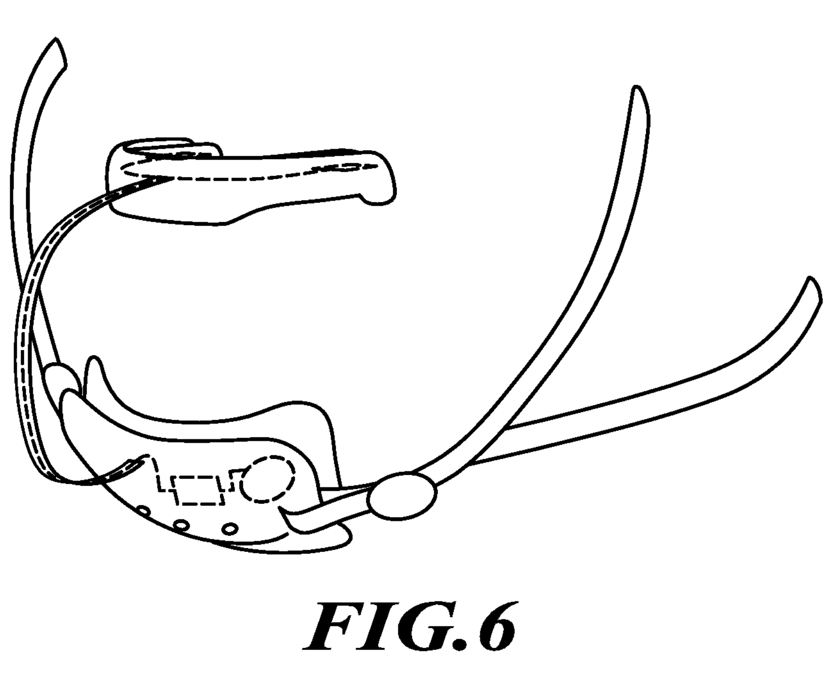

FIG.6

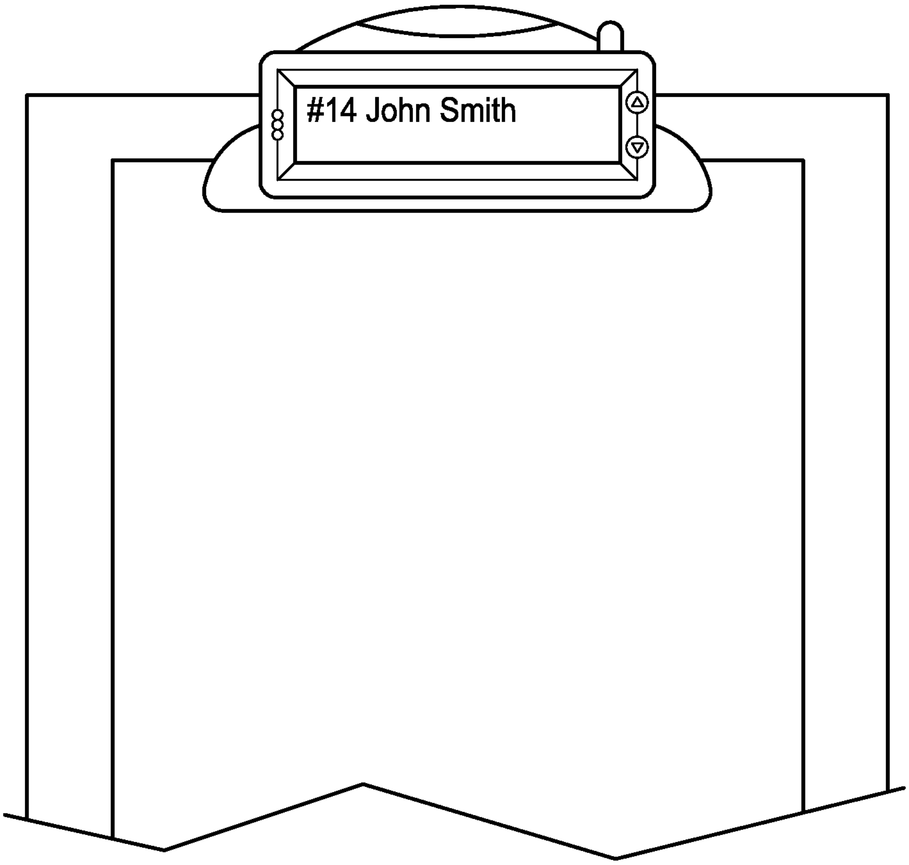

FIG. 7

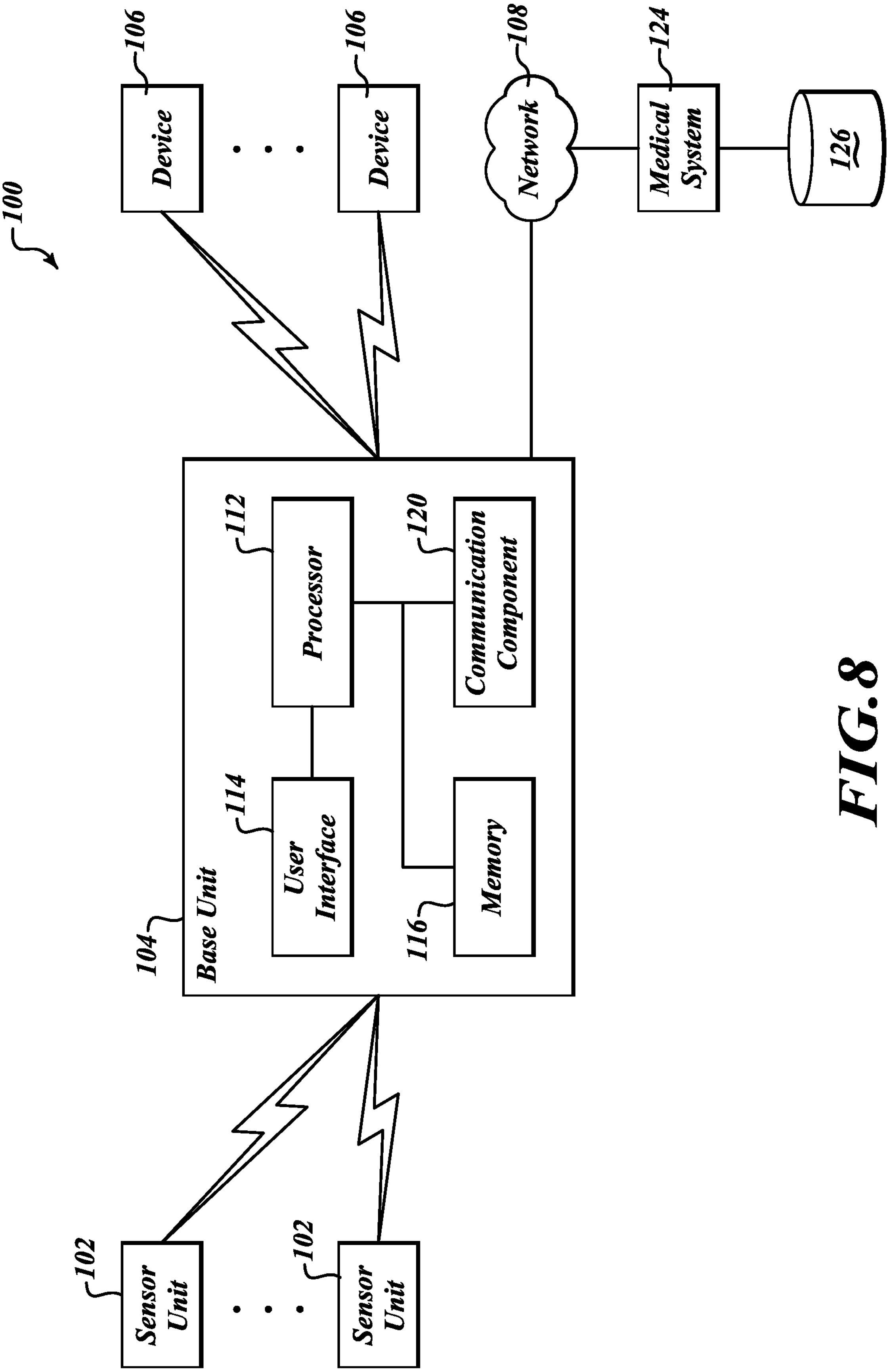
100
106
Device
106
Device
108
Network
124
Medical System
126
104
Base Unit
112
Processor
114
User Interface
120
Communication Component
116
Memory
102
Sensor Unit
102
Sensor Unit

FIG.8

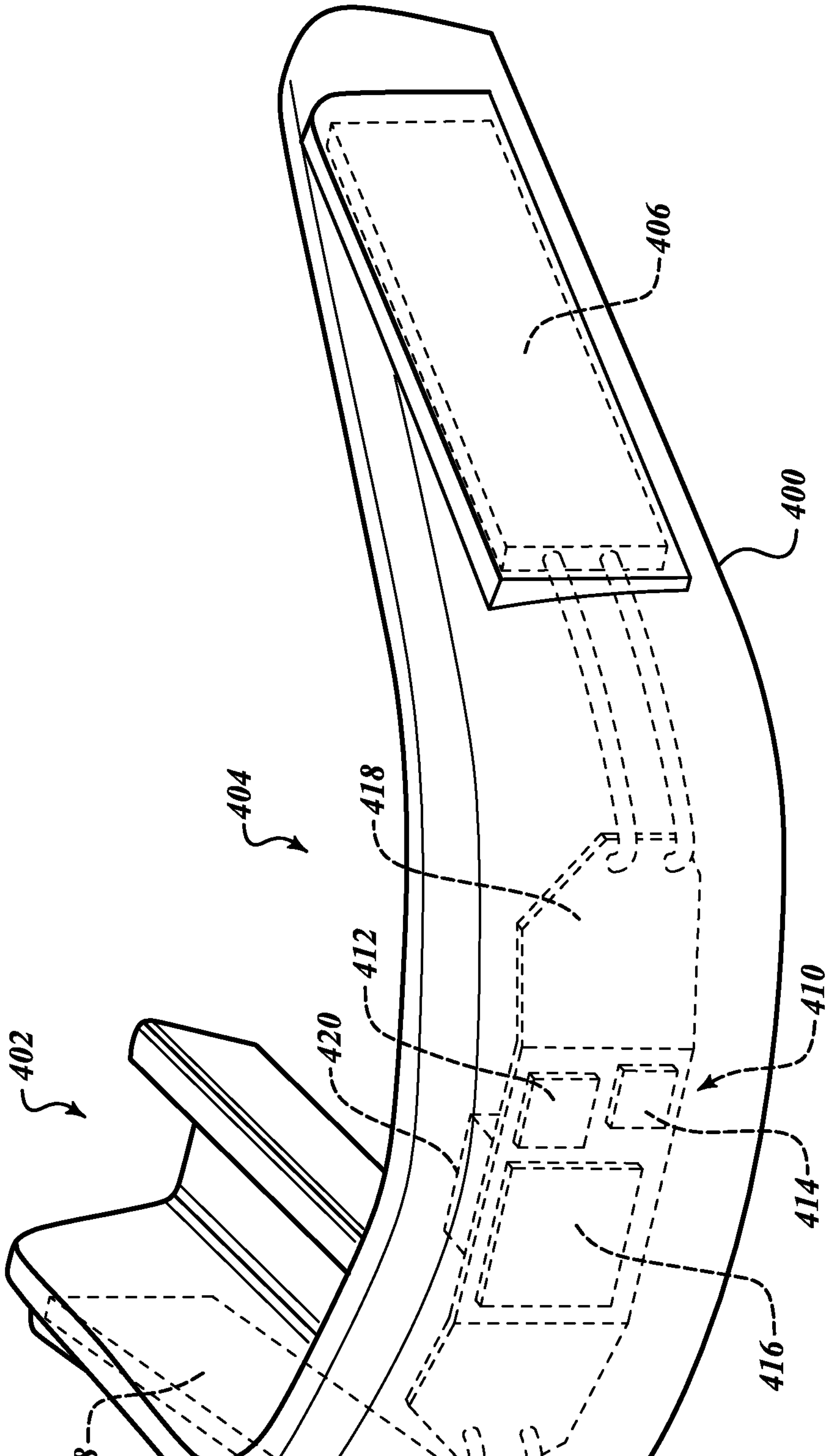

FIG.9

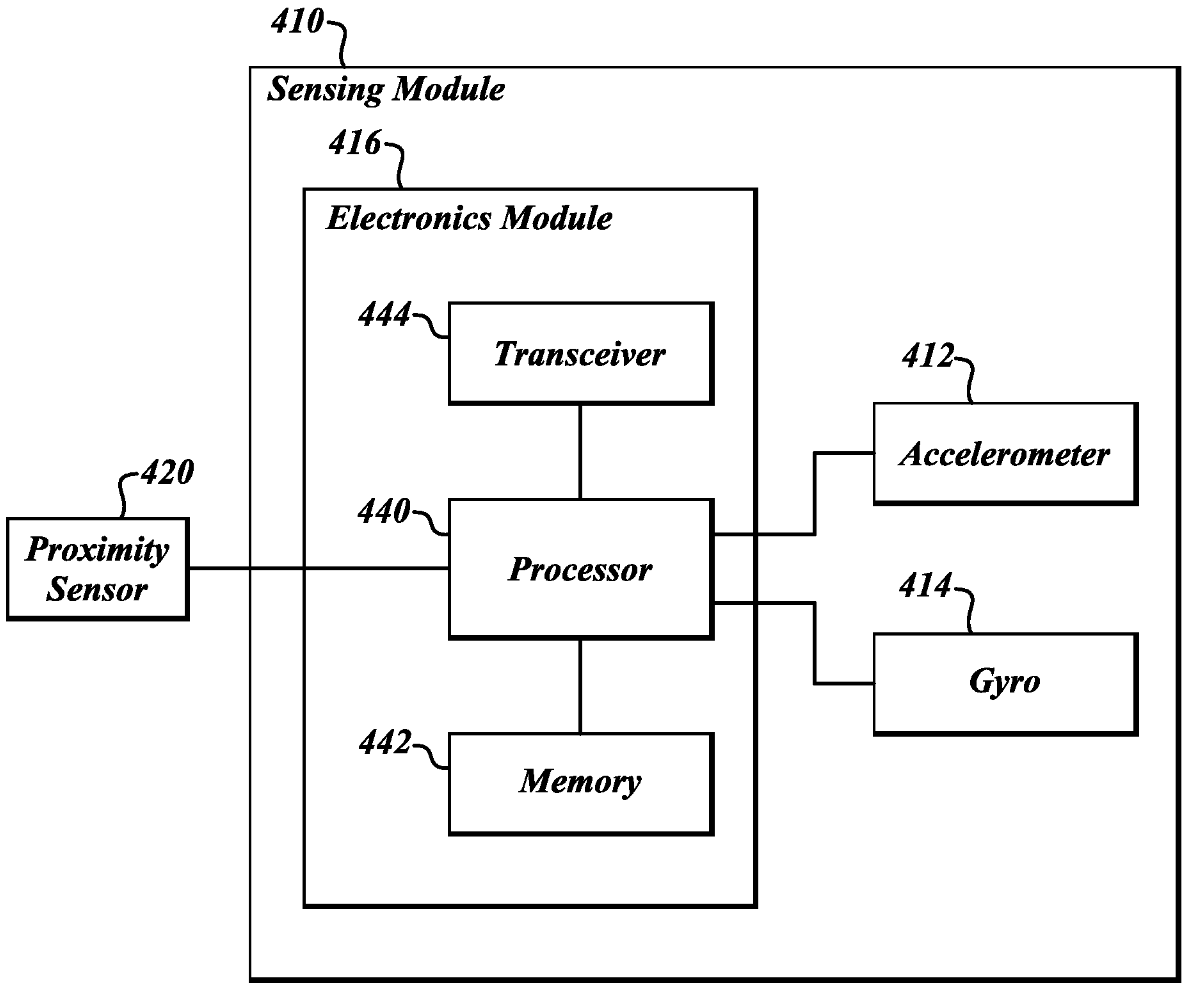
410
Sensing Module
416
Electronics Module
444
Transceiver
440
Processor
442
Memory
412
Accelerometer
414
Gyro
420
Proximity Sensor

FIG.10

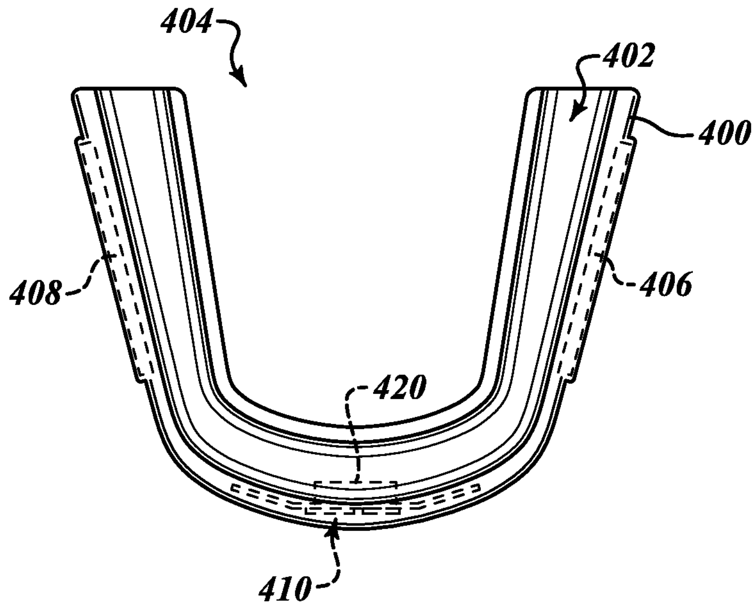

FIG.11

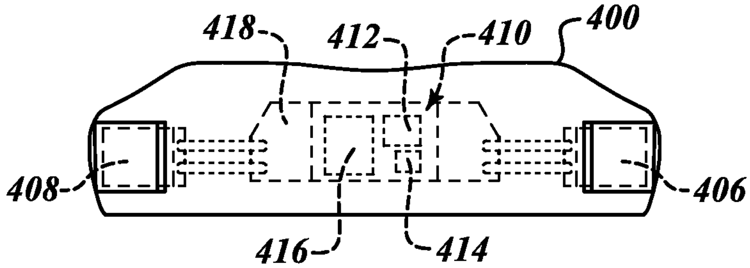

FIG.12

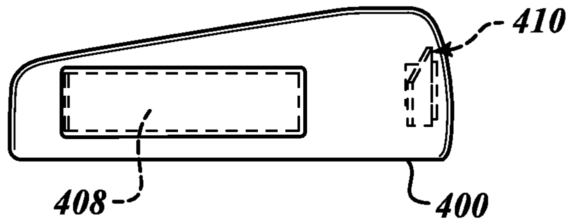

FIG.13

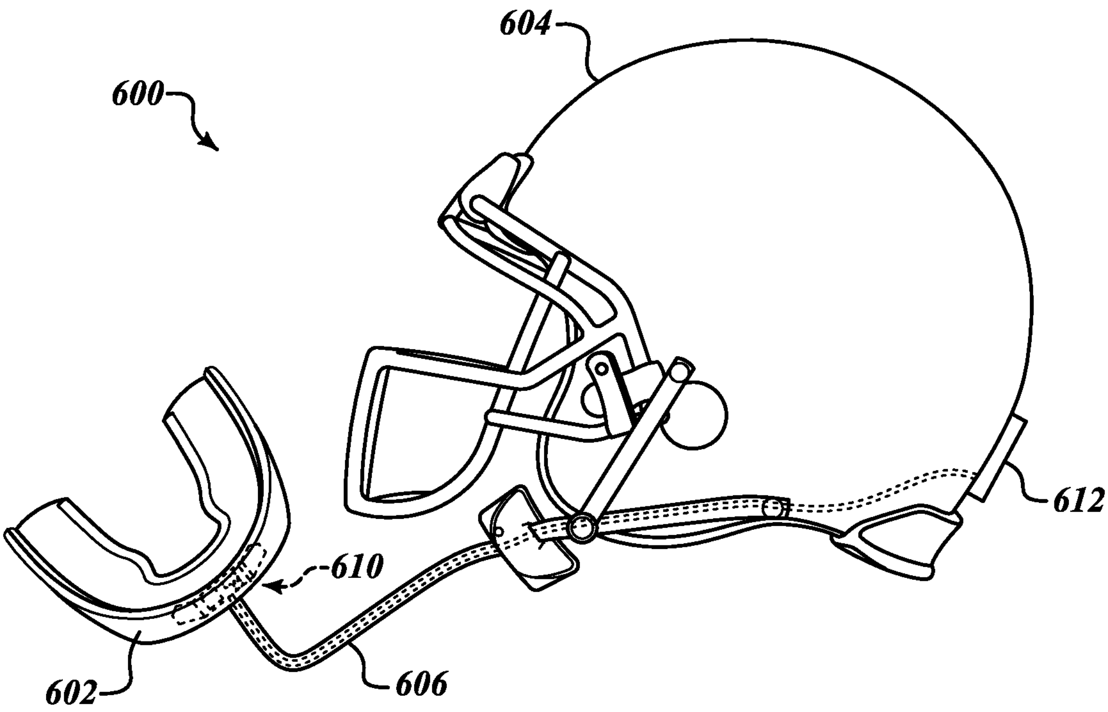

FIG.14

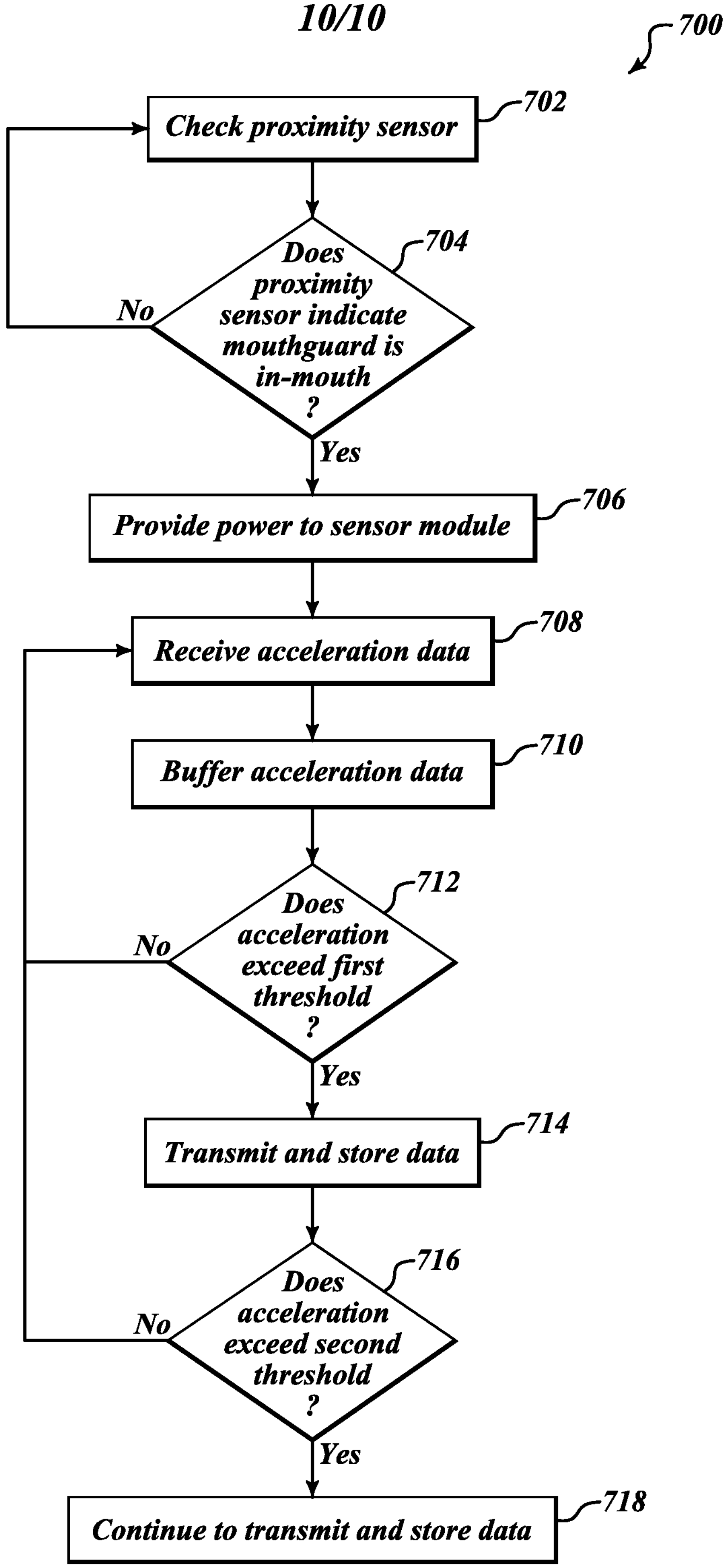
700
Check proximity sensor
702
Does proximity sensor indicate mouthguard is in-mouth ?
704
No
Yes
Provide power to sensor module
706
Receive acceleration data
708
Buffer acceleration data
710
Does acceleration exceed first threshold ?
712
No
Yes
Transmit and store data
714
Does acceleration exceed second threshold ?
716
No
Yes
Continue to transmit and store data
718

FIG.15