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(54) **WEARABLE SAFETY APPARATUS INCLUDING A BODY AREA NETWORK TRANSCEIVER**

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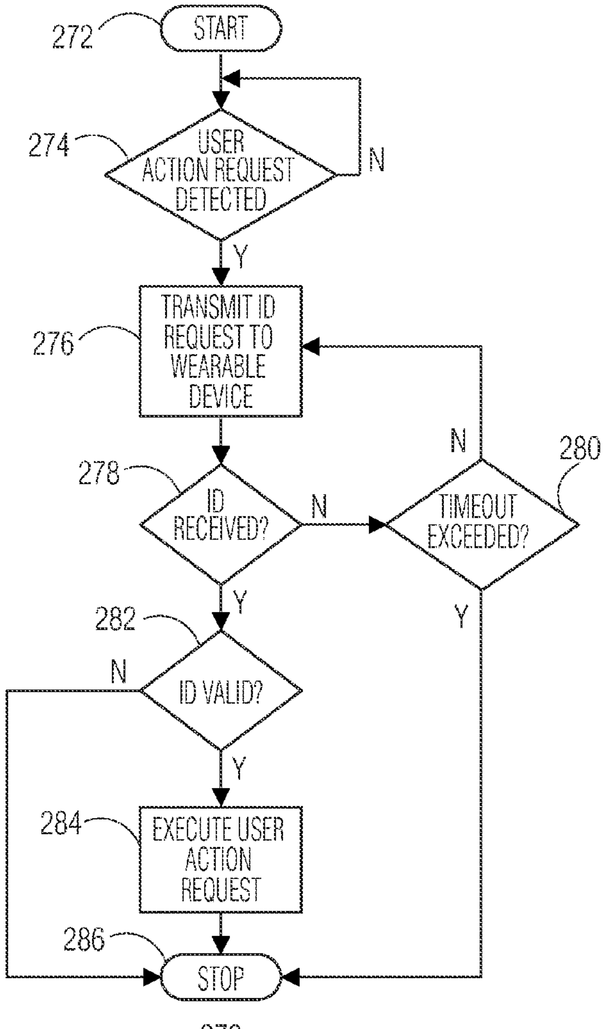
G16H 40/67	(2006.01)

(52) **U.S. Cl.**

CPC ***H04W 4/80*** (2018.02); ***G16H 40/67*** (2018.01); ***G06F 1/163*** (2013.01); ***H04B 1/385*** (2013.01)

(57) **ABSTRACT**

A wearable safety apparatus including a body area network (BAN) transceiver for communicating with a user-controlled apparatus is described. The BAN transceiver includes a processor coupled to a BAN antenna. The processor is configured to receive an identification data request from a user-controlled apparatus in response to an action request of a user of the wearable safety apparatus; and to transmit identification data to the user-controlled apparatus in response to the identification data request. The identification data validates the user action by the user-controlled apparatus. The identification data request is only received when the wearable safety apparatus and the user-controlled apparatus are in contact with the user.


272
START
274
USER ACTION REQUEST DETECTED
N
Y
276
TRANSMIT ID REQUEST TO WEARABLE DEVICE
278
ID RECEIVED?
N
280
TIMEOUT EXCEEDED?
N
Y
282
ID VALID?
N
Y
284
EXECUTE USER ACTION REQUEST
286
STOP

270

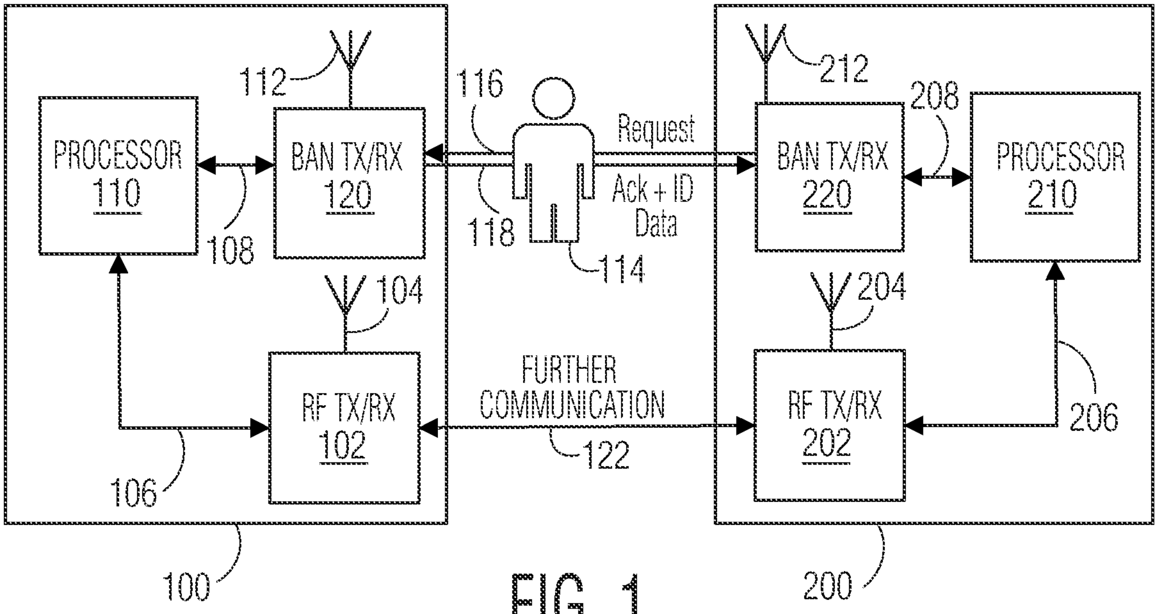

PROCESSOR
110
BAN TX/RX
120
112
108
116
118
Request
Ack + ID
Data
114
BAN TX/RX
220
212
208
PROCESSOR
210
104
RF TX/RX
102
106
FURTHER
COMMUNICATION
122
204
RF TX/RX
202
206
100
200

FIG. 1

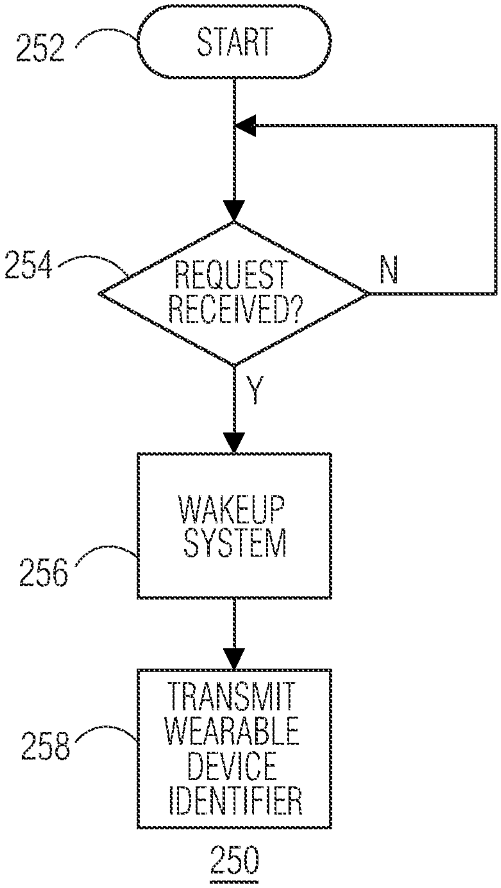

252
START
254
REQUEST
RECEIVED?
N
Y
WAKEUP
SYSTEM
256
258
TRANSMIT
WEARABLE
DEVICE
IDENTIFIER
250

FIG. 2A

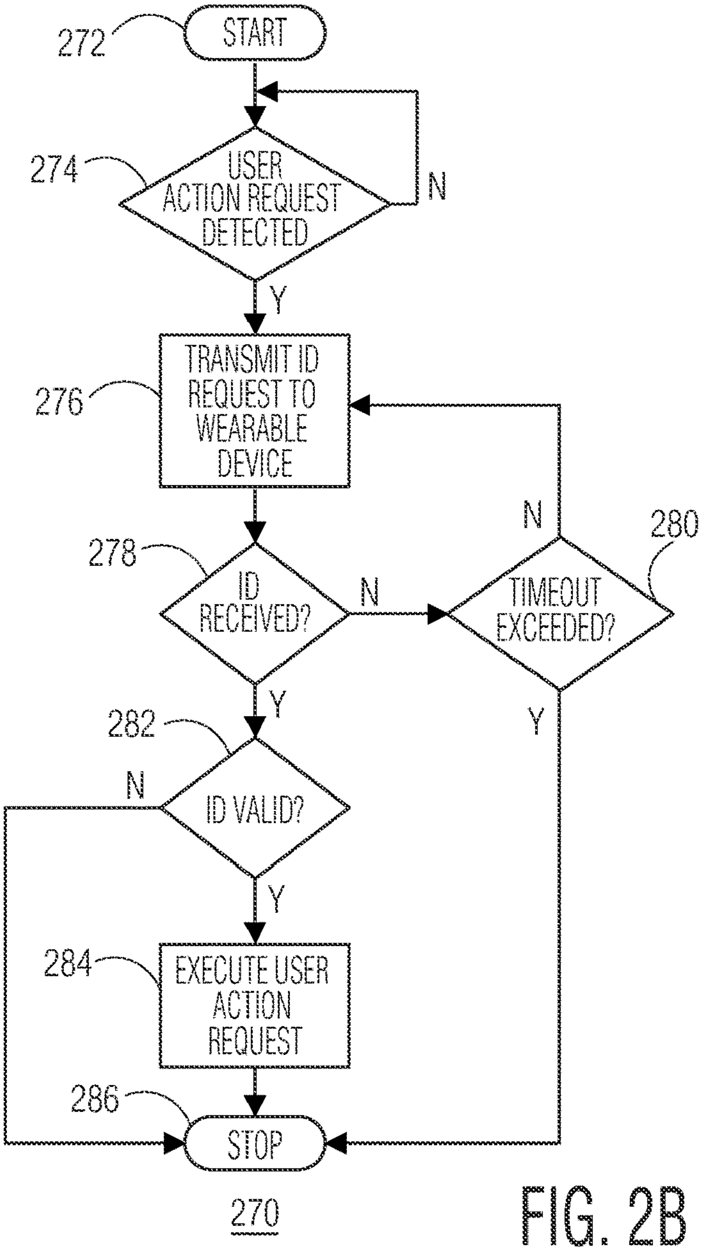

272
START
274
USER ACTION REQUEST DETECTED
N
Y
276
TRANSMIT ID REQUEST TO WEARABLE DEVICE
278
ID RECEIVED?
N
280
TIMEOUT EXCEEDED?
N
Y
Y
282
ID VALID?
N
Y
284
EXECUTE USER ACTION REQUEST
286
STOP
270

FIG. 2B

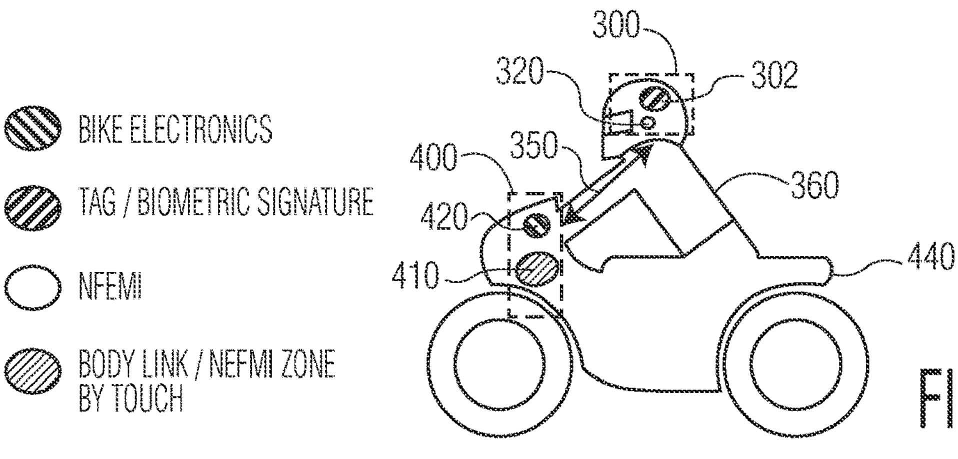

BIKE ELECTRONICS
TAG / BIOMETRIC SIGNATURE
NFEMI
BODY LINK / NEFMI ZONE BY TOUCH
300
320
302
400
350
360
420
410
440

FIG. 3A

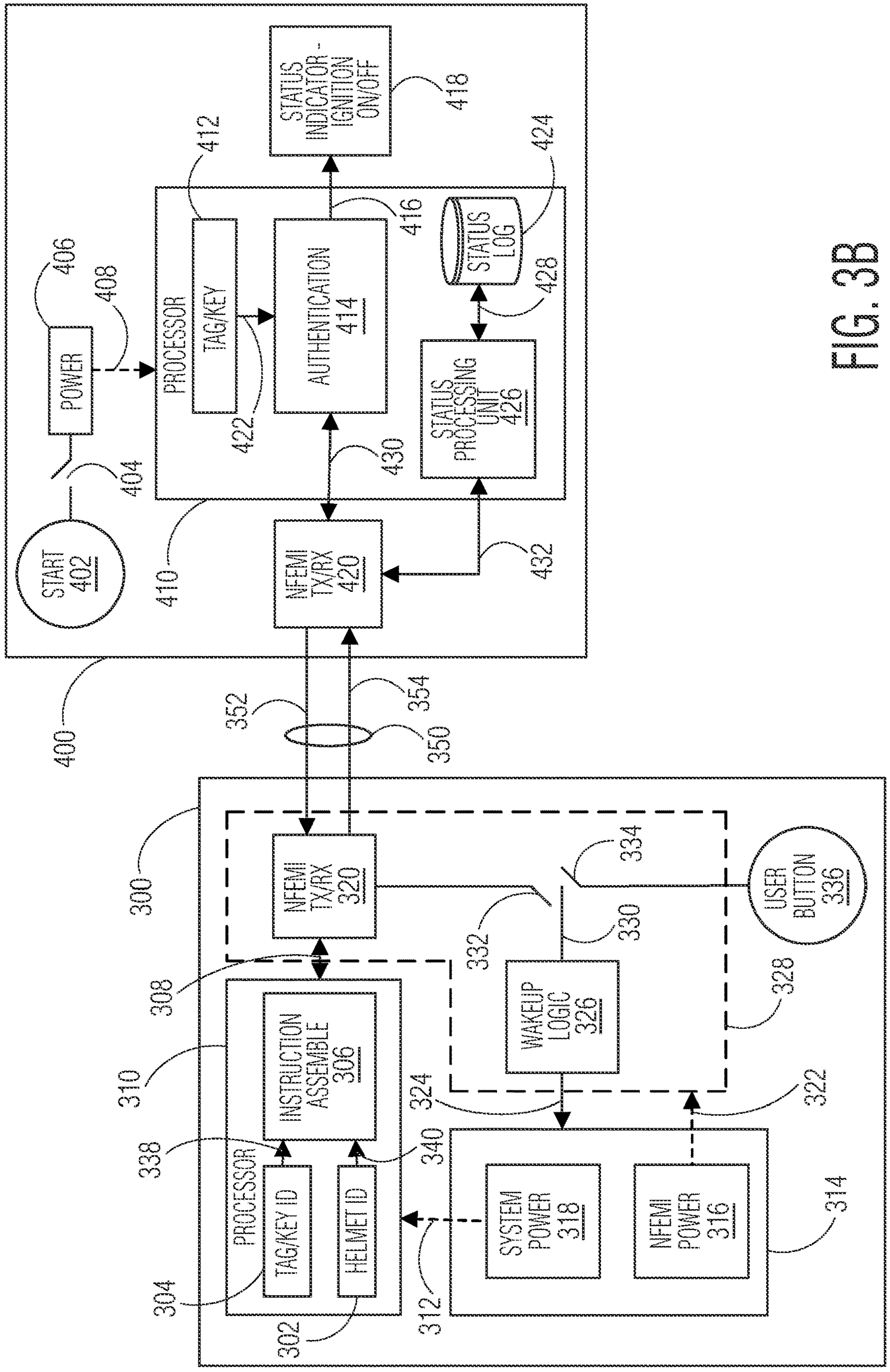

START
402
404
POWER
406
408
PROCESSOR
TAG/KEY
412
422
AUTHENTICATION
414
430
416
STATUS INDICATOR - IGNITION ON/OFF
418
STATUS LOG
424
428
STATUS PROCESSING UNIT
426
410
NFEMI TX/RX
420
432
400
352
354
350
300
NFEMI TX/RX
320
308
PROCESSOR
TAG/KEY ID
304
HELMET ID
302
INSTRUCTION ASSEMBLE
306
338
340
310
WAKEUP LOGIC
326
332
330
334
USER BUTTON
336
328
324
322
SYSTEM POWER
318
NFEMI POWER
316
312
314

FIG. 3B

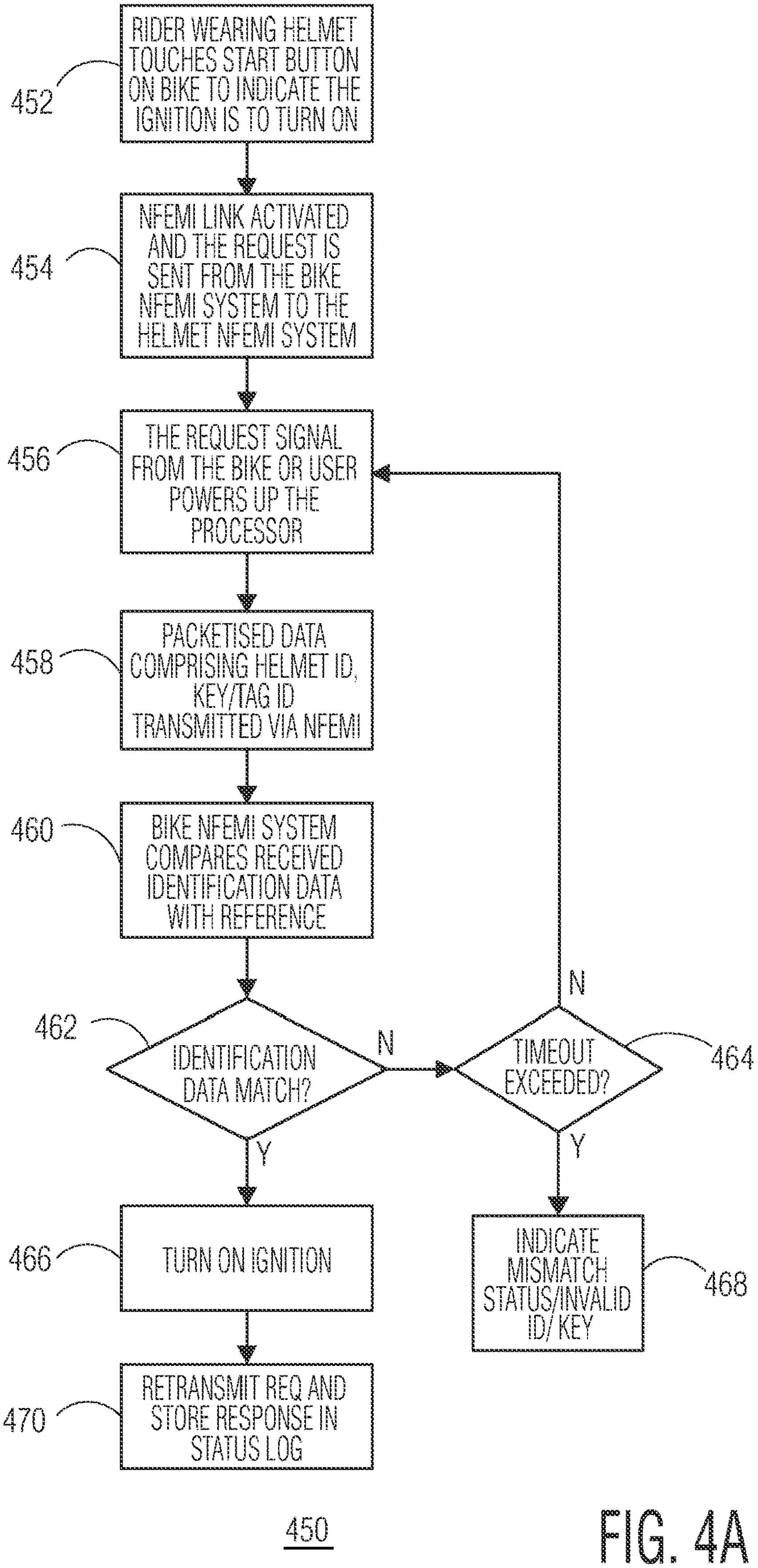

RIDER WEARING HELMET TOUCHES START BUTTON ON BIKE TO INDICATE THE IGNITION IS TO TURN ON
452
NFEMI LINK ACTIVATED AND THE REQUEST IS SENT FROM THE BIKE NFEMI SYSTEM TO THE HELMET NFEMI SYSTEM
454
THE REQUEST SIGNAL FROM THE BIKE OR USER POWERS UP THE PROCESSOR
456
PACKETISED DATA COMPRISING HELMET ID, KEY/TAG ID TRANSMITTED VIA NFEMI
458
BIKE NFEMI SYSTEM COMPARES RECEIVED IDENTIFICATION DATA WITH REFERENCE
460
462
IDENTIFICATION DATA MATCH?
N
TIMEOUT EXCEEDED?
464
N
Y
Y
TURN ON IGNITION
466
INDICATE MISMATCH STATUS/INVALID ID/ KEY
468
RETRANSMIT REQ AND STORE RESPONSE IN STATUS LOG
470
450

FIG. 4A

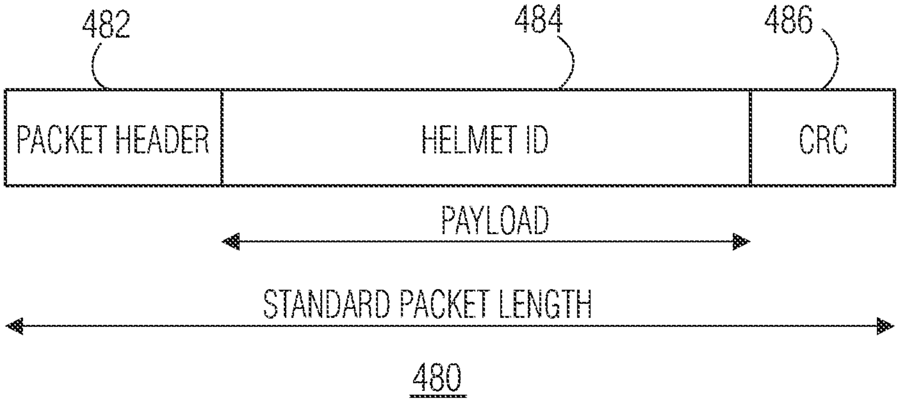

482
484
486
PACKET HEADER
HELMET ID
CRC
PAYLOAD
STANDARD PACKET LENGTH
480

FIG. 4B

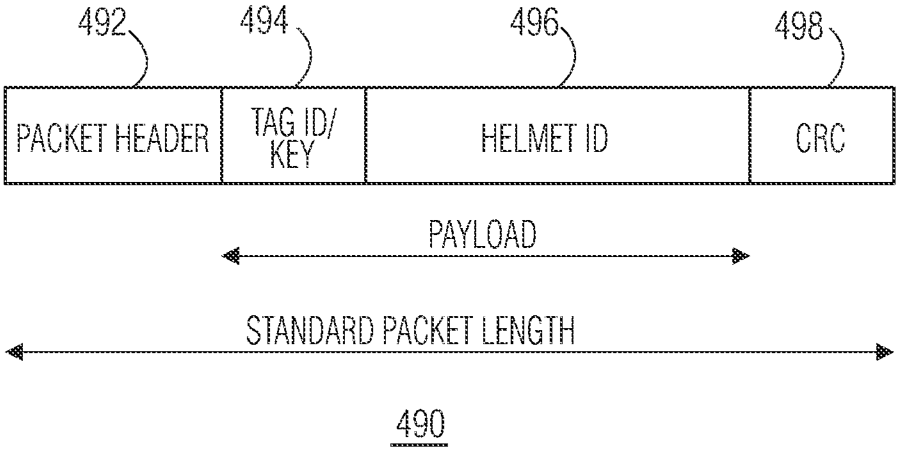

492
494
496
498
PACKET HEADER
TAG ID/ KEY
HELMET ID
CRC
PAYLOAD
STANDARD PACKET LENGTH
490

FIG. 4C

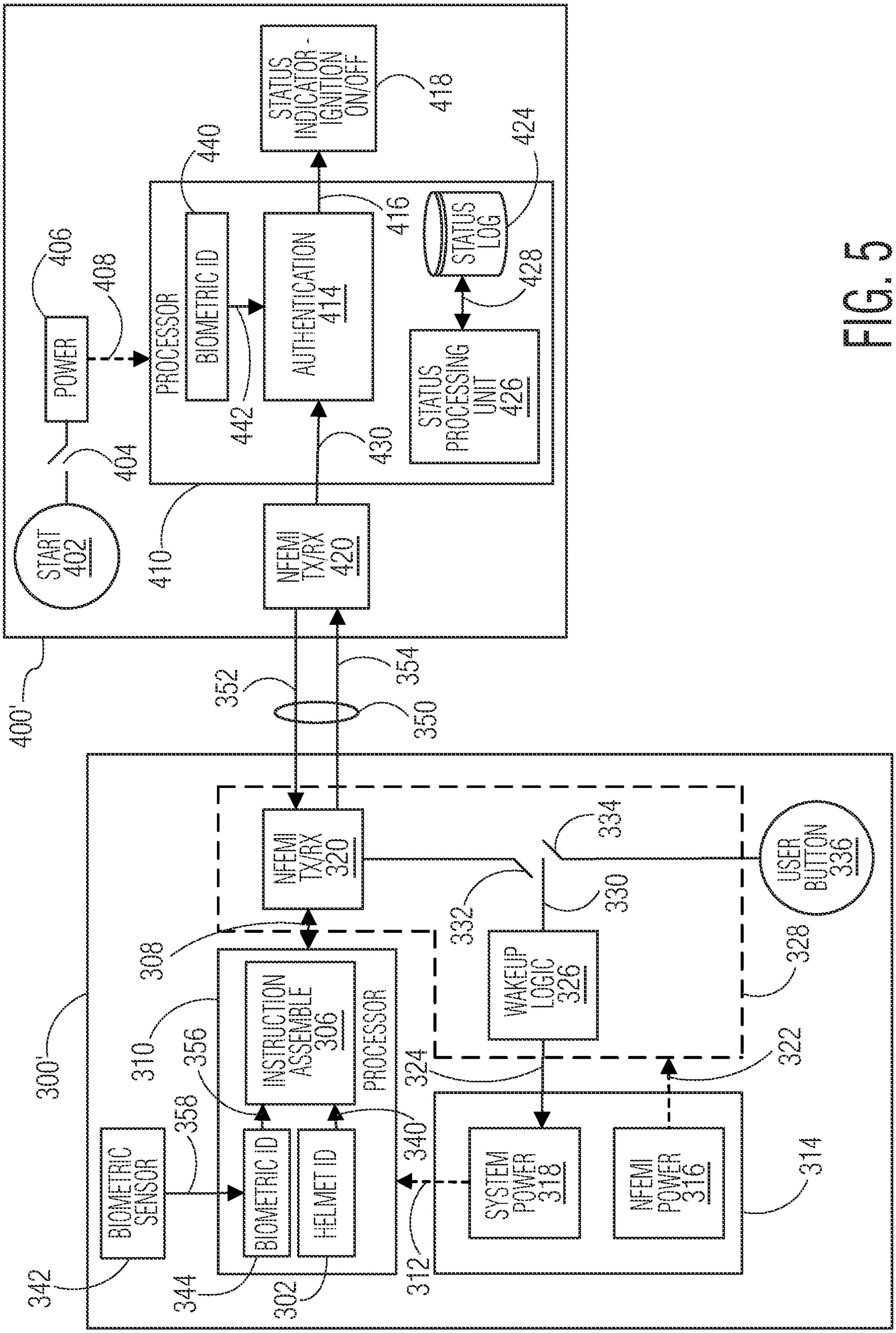

400'
START 402
404
POWER
406
408
PROCESSOR
410
BIOMETRIC ID
440
442
AUTHENTICATION 414
430
416
STATUS INDICATOR - IGNITION ON/OFF
418
STATUS LOG
424
428
STATUS PROCESSING UNIT 426
NFEMI TX/RX 420
352
354
350
300'
BIOMETRIC SENSOR
342
358
BIOMETRIC ID
344
HELMET ID
302
356
INSTRUCTION ASSEMBLE 306
PROCESSOR
310
308
340
312
SYSTEM POWER 318
NFEMI POWER 316
314
324
322
WAKEUP LOGIC 326
332
330
NFEMI TX/RX 320
334
USER BUTTON 336
328

FIG. 5

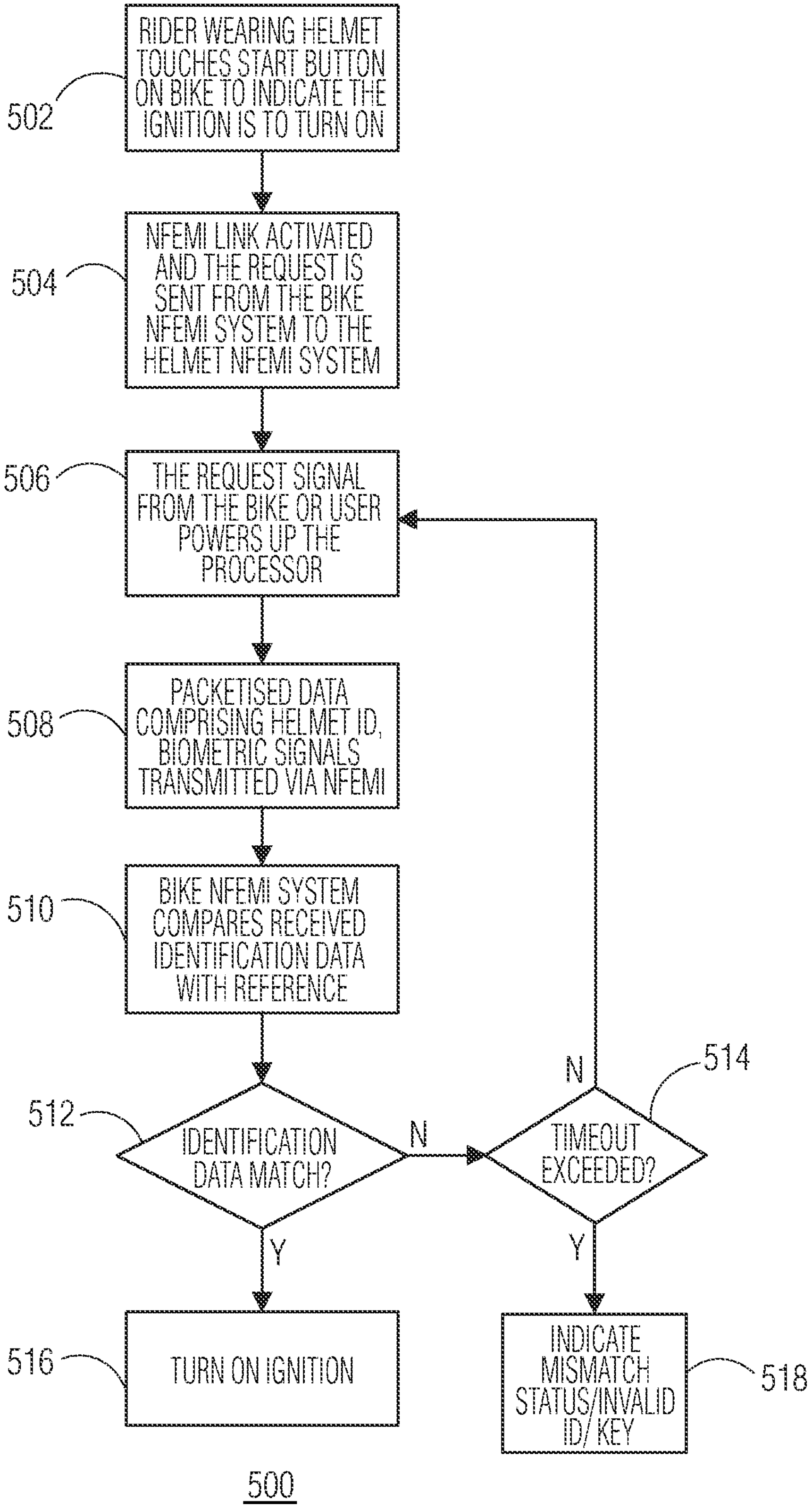

RIDER WEARING HELMET TOUCHES START BUTTON ON BIKE TO INDICATE THE IGNITION IS TO TURN ON
502
NFEMI LINK ACTIVATED AND THE REQUEST IS SENT FROM THE BIKE NFEMI SYSTEM TO THE HELMET NFEMI SYSTEM
504
THE REQUEST SIGNAL FROM THE BIKE OR USER POWERS UP THE PROCESSOR
506
PACKETISED DATA COMPRISING HELMET ID, BIOMETRIC SIGNALS TRANSMITTED VIA NFEMI
508
BIKE NFEMI SYSTEM COMPARES RECEIVED IDENTIFICATION DATA WITH REFERENCE
510
IDENTIFICATION DATA MATCH?
512
N
TIMEOUT EXCEEDED?
514
N
Y
Y
TURN ON IGNITION
516
INDICATE MISMATCH STATUS/INVALID ID/ KEY
518
500

FIG. 6

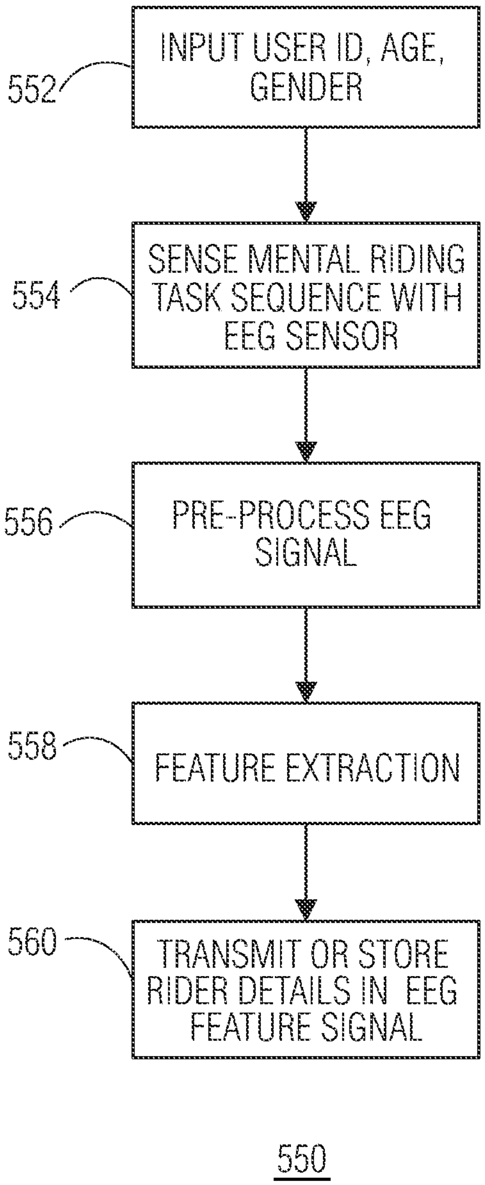

552
INPUT USER ID, AGE, GENDER
554
SENSE MENTAL RIDING TASK SEQUENCE WITH EEG SENSOR
556
PRE-PROCESS EEG SIGNAL
558
FEATURE EXTRACTION
560
TRANSMIT OR STORE RIDER DETAILS IN EEG FEATURE SIGNAL
550

FIG. 7

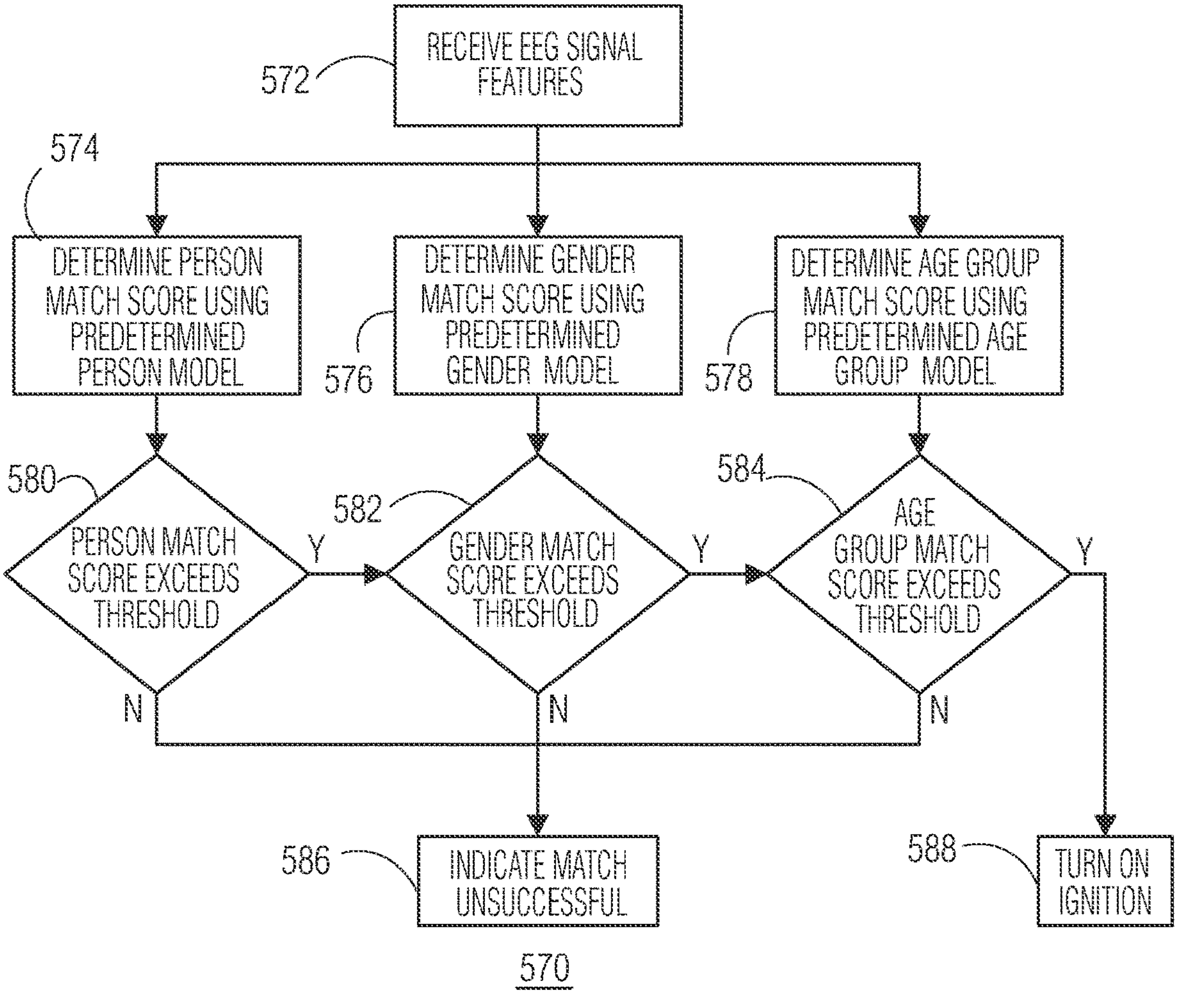

572
RECEIVE EEG SIGNAL FEATURES
574
DETERMINE PERSON MATCH SCORE USING PREDETERMINED PERSON MODEL
576
DETERMINE GENDER MATCH SCORE USING PREDETERMINED GENDER MODEL
578
DETERMINE AGE GROUP MATCH SCORE USING PREDETERMINED AGE GROUP MODEL
580
PERSON MATCH SCORE EXCEEDS THRESHOLD
Y
N
582
GENDER MATCH SCORE EXCEEDS THRESHOLD
Y
N
584
AGE GROUP MATCH SCORE EXCEEDS THRESHOLD
Y
N
586
INDICATE MATCH UNSUCCESSFUL
588
TURN ON IGNITION
570

FIG. 8

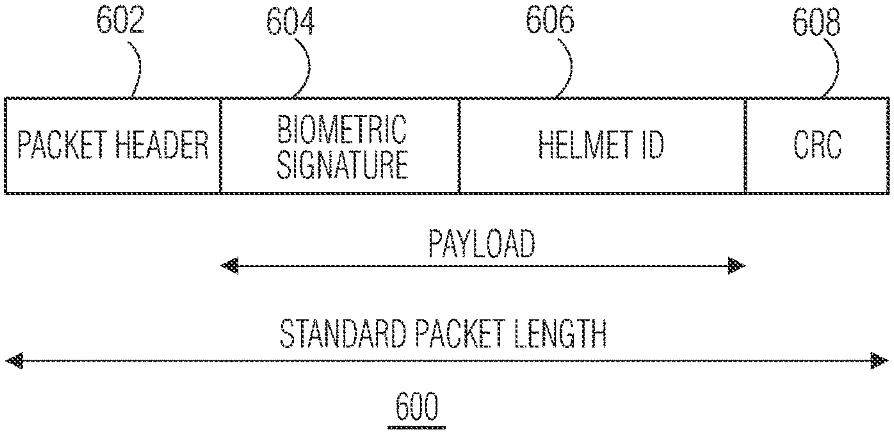

602
604
606
608
PACKET HEADER
BIOMETRIC SIGNATURE
HELMET ID
CRC
PAYLOAD
STANDARD PACKET LENGTH
600

FIG. 9

WEARABLE SAFETY APPARATUS INCLUDING A BODY AREA NETWORK TRANSCEIVER

FIELD

[0001] This disclosure relates to a wearable safety apparatus with a body area network (BAN) transceiver. This disclosure further relates to a system with a wearable safety apparatus including a body area network transceiver and a user-controlled apparatus including a body area network transceiver.

BACKGROUND

[0002] Wearable safety apparatus such as helmets for example motorcycle or cycle helmets, eye protection, ear protection, safety gloves and other safety wear such as protective suits such as hazmat suits are used in a wide variety of applications. For example safety eyewear, ear protectors, and gloves may be required when operating equipment such as machine tools for example computer numerical control (CNC) lathes, industrial robots, and welding equipment. The use of machinery may be restricted to certain authorised users or operators who have appropriate training and only when wearing the appropriate protective equipment. Similarly, in many countries a motorcycle is typically only permitted to be ridden by a person wearing a motorcycle helmet.

SUMMARY

[0003] Various aspects of the disclosure are defined in the accompanying claims. In a first aspect there is provided a wearable safety apparatus comprising a body area network (BAN) transceiver, and a processor coupled to the BAN transceiver, wherein the processor is configured to receive an identification data request via the BAN transceiver from a user-controlled apparatus in response to an action request of a user of the wearable safety apparatus; and to transmit identification data via the BAN transceiver to the user-controlled apparatus in response to the identification data request, the identification data being for validation of the user action by the user-controlled apparatus; and wherein the identification data request is only received when the wearable safety apparatus and the user-controlled apparatus are in contact with the user.

[0004] In one or more embodiments, the processor may be further configured to retransmit the identification data to the user-controlled apparatus.

[0005] In one or more embodiments, the identification data may comprise at least one of wearable safety apparatus identifier data and user identifier data.

[0006] In one or more embodiments, the wearable safety apparatus may further comprise a biometric sensor and wherein the user identifier data comprises biometric data detected by the biometric data while the wearable safety apparatus is in contact with the user.

[0007] In one or more embodiments, the action request of a user may comprise an action for starting the user-controlled apparatus.

[0008] In one or more embodiments, the wearable safety apparatus may comprise one of a motorcycle helmet, a cycle helmet, eyewear, a body protection suit, and gloves.

[0009] In one or more embodiments, the wearable safety apparatus may further comprise a RF transceiver coupled to the processor, and wherein further data is transmitted and received via the RF transceiver. The RF transceiver may comprise one of an Ultra-Wide-Band (UWB) and Bluetooth Low Energy (LE) transceiver.

[0010] In one or more embodiments, the BAN transceiver may comprise a near-field electromagnetic induction (NFEMI) transceiver.

[0011] In a second aspect there is provided a user-controlled apparatus comprising a body area network, BAN, transceiver, and a processor coupled to the BAN transceiver, wherein the processor is configured to transmit an identification data request via the BAN transceiver in response to an action request of a user of a wearable safety apparatus; and to receive identification data via the BAN transceiver from the wearable safety apparatus in response to the identification data request, and wherein the processor is further configured to validate the user action request; and the identification data is only received when the apparatus and the wearable safety apparatus are in contact with the user.

[0012] In one or more embodiments, the processor may be further configured to check for retransmission of the identification data by the wearable safety apparatus and to invalidate the user action request if the identification data has not been received within a predetermined time.

[0013] In one or more embodiments, the identification data may further comprise at least one of least one of wearable safety apparatus identifier data and user identifier data and wherein the processor is further configured to validate the user action request by comparing the received identification data with a pre-determined wearable safety apparatus identifier data set and pre-determined user identifier data set.

[0014] In one or more embodiments, the user identifier data may comprise biometric data and wherein the apparatus is further configured to compare the biometric data with a predetermined biometric data set.

[0015] In one or more embodiments, the biometric data may comprise electroencephalogram (EEG) data and wherein during an enrolment phase the apparatus is configured to receive EEG data from the wearable device and to store the received EEG data and wherein the predetermined biometric data set comprises the received EEG data.

[0016] In one or more embodiments, the user-controlled apparatus may comprise a RF transceiver coupled to the processor, the RF transceiver configured to transmit and or receive further data to or from the wearable apparatus after the identification request has been validated.

[0017] In one or more embodiments, the RF transceiver may be configured as one of a UWB, and Bluetooth LE transceiver.

[0018] In one or more embodiments, the user-controlled apparatus may comprise one of an electric bicycle, a motorcycle, a machine tool, and a power tool.

[0019] In one or more embodiments, the BAN transceiver may comprise a near-field electromagnetic induction, NFEMI, transceiver.

[0020] Embodiments of the wearable safety apparatus and user-control apparatus may be included in a body area network communication system.

[0021] In a third aspect, there is provided body area network communication system comprising a wearable safety apparatus and a user-controlled apparatus, the wearable safety apparatus comprising a first body area network (BAN) transceiver and a first processor coupled to the first

BAN transceiver, and the user controlled-apparatus comprising a second BAN transceiver and a second processor coupled to the second BAN transceiver; wherein

[0022] the second processor is configured to: transmit an identification data request via the second BAN transceiver from the user-controlled apparatus to the wearable safety apparatus in response to an action request of a user;

[0023] the first processor is configured to transmit identification data via the first BAN transceiver from the wearable safety apparatus to the user-controlled apparatus in response to the identification data request; and

[0024] the second processor is further configured to receive the identification data via the second BAN transceiver and to validate the user action request using the identification data; and

[0025] wherein the identification data request is received by the wearable safety apparatus and the identification data is received by the user-controlled apparatus only when the wearable safety apparatus and the user-controlled apparatus are in contact with the user.

[0026] In a fourth aspect there is provided a method for operating a user-controlled apparatus comprising a first body-area-network, (BAN) transceiver, the user-controlled apparatus configured to be operated by a user wearing a wearable safety apparatus comprising a second BAN transceiver, wherein the user, the first BAN transceiver and the second BAN transceiver form a body-area-network, the method comprising:

> **[0027]** transmitting an identification data request from the user-controlled apparatus to the wearable safety apparatus via the body-area-network in response to an action request of the user; transmitting identification data from the wearable safety apparatus to the user-controlled apparatus via the body-area-network in response to the identification data request; validating the user action request by the user-controlled apparatus using the identification data; wherein the identification data request is received by the wearable safety apparatus and the identification data is received by the user-controlled apparatus only when the wearable safety apparatus and the user-controlled apparatus are in contact with the user.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] In the figures and description like reference numerals refer to like features. Embodiments are now described in detail, by way of example only, illustrated by the accompanying drawings in which:

[0029] FIG. **1** shows a system including a wearable apparatus with a BAN transceiver and a user-controlled with a BAN transceiver according to an embodiment.

[0030] FIG. **2**A shows a method of operation for the wearable safety apparatus illustrated in FIG. **1**.

[0031] FIG. **2**B shows a method of operation for the user-controlled apparatus illustrated in FIG. **1**.

[0032] FIG. **3**A shows a motorcycle helmet including an NFEMI transceiver according to an embodiment and a motorcycle including an NFEMI transceiver according to an embodiment.

[0033] FIG. **3**B shows a system including the NFEMI transceiver for a motorcycle helmet and a NFEMI transceiver for a motorcycle according to an embodiment.

[0034] FIG. **4**A shows a method of operation of the system of FIG. **3**B.

[0035] FIG. **4**B shows an example packet for transmission by the NFEMI transceiver system for the helmet of FIG. **3**B.

[0036] FIG. **4**C shows an example packet for transmission by an NFEMI transceiver system for the helmet of FIG. **3**B.

[0037] FIG. **5** shows an NFEMI transceiver system for a motorcycle helmet and a NFEMI transceiver system for a motorcycle according to an embodiment.

[0038] FIG. **6** shows a method of operation of the system of FIG. **5**.

[0039] FIG. **7** shows a method of generating a biometric ID for transmission by the NFEMI transceiver system for a motorcycle helmet or for enrolment by the NFEMI transceiver system for a motorcycle.

[0040] FIG. **8** shows a method of authenticating a biometric ID received by the NFEMI transceiver system for a motorcycle.

[0041] FIG. **9** shows an example packet for transmission by a NFEMI transceiver system operating according to the method of FIG. **7** and received by a NFEMI transceiver system operating according to the method of FIG. **8**.

DETAILED DESCRIPTION

[0042] FIG. **1** shows a system including a wearable safety apparatus **100** with a BAN transceiver **120** and a user controlled apparatus **200** with a BAN transceiver **220** according to an embodiment. The user controlled apparatus **200** may also be referred to as an operator controlled apparatus. The wearable safety apparatus **100** may for example be protective eyewear such as spectacles or goggles, a protective helmet, ear defenders, a protective body suit or gloves. The wearable safety apparatus **100** has a processor **110** and optionally a radio-frequency (RF) transceiver **102**. Examples of the RF transceiver may include but are not limited to a an Ultra-Wideband (UWB), a Bluetooth or WIFI transceiver. The term UWB transceiver as used herein includes transceivers implemented according to IEEE standard 802.15.4. The BAN transceiver **120** includes a BAN antenna **112**. The RF transceiver **102** includes a RF transceiver antenna **104**. The processor **110** may have a bidirectional connection **108** to the BAN transceiver **120** and a bidirectional connection **106** to the RF transceiver **102**. The wearable safety apparatus **100** may be implemented in hardware or a combination of hardware and software.

[0043] The user controlled apparatus **200** may be as a non-limiting example a machine tool, industrial robot, welding equipment, or a motor vehicle such as a motorcycle or a car. The user controlled apparatus **200** has a processor **210** and optionally a RF transceiver **202**. Examples of the RF transceiver may include but are not limited to an Ultra-Wideband (UWB), a Bluetooth or WIFI transceiver. The BAN transceiver **220** includes a BAN antenna **212**. The RF transceiver **202** includes a RF transceiver antenna **204**. The processor **210** may have a bidirectional connection **208** to the BAN transceiver **220** and a bidirectional connection **206** to the RF transceiver **202**. The processor **210** may be implemented in hardware or a combination of hardware and software.

[0044] A BAN communication channel between the BAN transceivers **120** and **220** may be formed when a user **114** is coupled with both the BAN antenna **112** and the BAN antenna **212** by being simultaneously in contact with the wearable safety apparatus **100** and the user-controlled apparatus **200**. Data may be transmitted from the user controlled apparatus **200** to the wearable safety apparatus **100** via communication channel or path **116** and data may be sent from the wearable safety apparatus **100** to the user controlled apparatus **200** via communication channel or path **118**. The term user contact as referred to in the present disclosure may be a contact directly with the user **114** or may be an indirect contact via one or more items of clothing or other wearable that is being worn by the user **114**. Examples of body area network (BAN) transceivers **120**, **220** include a near field electromagnetic induction (NFEMI) transceiver, transceivers forming a body area network which uses the human body to form a communication path as described in IEEE Std 802.15.2-202, or other transceivers using human body-coupled communication.

[0045] An example operation of the system illustrated in FIG. **1** is shown in FIGS. **2**A and **2**B.

[0046] FIG. **2**A shows an example method of operation **250** which may be implemented by the wearable safety apparatus **100**. In step **252** the method **250** starts. In step **254**, the method may check if a request has been received via the BAN transceiver **120** from the user controlled apparatus **200**. If a request has been received, then in optional step **256** elements of the system that were previously powered down may be powered up These elements may include for example the processor **110** and the RF transceiver **102**. Once powered up, the processor **110** may receive the request directly or indirectly from the BAN transceiver. In step **258**, the processor **110** may transmit an acknowledge together with identification data via the BAN transceiver **120** to the user controlled apparatus **200**. This identification data may include the helmet identifier stored in the helmet identification module and/or a key stored in the tag key module **304**.

[0047] FIG. **2**B shows an example method of operation **270** for the user controlled apparatus **200**. In step **272** the method **270** starts. In step **274**, the method may check if a user action request has been received. This user action request may be for example be a request to start a motor in the user controlled apparatus **200**. If a user request has been received, then in step **276** a request may be transmitted by the processor **210** via BAN transceiver **220**. In step **278**, the processor **210** may check to see whether identification data has been received via the BAN transceiver **220**. If identification data has not been received then in step **280**, the processor **210** may check to determine whether a timeout has been exceeded. If the timeout value has been exceeded then the method stops at step **286**. If a timeout value has not been exceeded then the method returns to step **276** and the processor **210** may retransmit the ID request. Returning to step **278**, if identification data has been received, then in step **282** the method checks if the ID data is valid. If the ID data is not valid, then the method ends at step **286**. If the ID data is valid, then in step **284**, the user action request is executed and the method ends at step **286**.

[0048] Optionally, following the initial pairing operation of the wearable safety apparatus **100** and the user controlled apparatus **200**, further communication **122** between the wearable safety apparatus **100** and the user controlled apparatus **200** may use the respective RF transceivers **102**, **202**. Subsequent communication may then be via the RF communication path following the initial authentication via the Body-Area-Network. In some examples this communication could be for example audio data communicated between the wearable apparatus and the user controlled apparatus. In some examples the RF transceivers **102**,**202** may not be used, and may be omitted.

[0049] The inventors of the present disclosure have appreciated that using a BAN communication channel between the wearable safety apparatus **100** and the user-controlled apparatus **200** can ensure that the user or operator is wearing the correct equipment before the user-controlled apparatus is actuated by checking the identification data. Since the user has to be in physical contact with both the wearable safety apparatus **100** and the motorcycle, the BAN communication channel provides a secure and simple way of ensuring that a user is authorised to operate the user-controlled apparatus **200**.

[0050] FIG. **3**A shows an apparatus including a motorcycle helmet NFEMI system **300** according to an embodiment and a motorcycle NFEMI system **400** according to an embodiment. FIG. **3**B shows further details of the apparatus of FIG. **3**A.

[0051] The motorcycle helmet NFEMI system **300** includes a processor **310**, power control module **314**, an NFEMI transceiver **320**, wakeup logic **326**, and user button **336**.

[0052] The processor **310** may include a helmet identifier module **302** and tag or key identifier module **304** and instruction assembler **306**. The tag identifier module **304** which may be a memory which stores the tag identifier may have an output **338** connected to an input of the instruction assembler **306**. In some examples, the tag identifier module **304** may be omitted. The helmet identifier module **302** may include a memory which stores the helmet ID data. The helmet identifier module **302** may have an output **340** connected to the instruction assembler **306**. The instruction assembler **306** may have a bidirectional connection **308** to the NFEMI transceiver **320**. The user button **336** may be connected via switch **334** to wake-up logic input **330**. The power module **314** may have a system power module **318** which supplies power to the processor **310** shown by the power connection **312**. The system power module **318** may have an input connected to a wake-up logic output **324**. The power module **314** may have an NFEMI power module **316** having a power connection **322** to an "always-on" power domain **328** which may include the NFEMI transceiver **320** and the wake-up logic **326**. In some examples the NFEMI transceiver may be replaced with other BAN transceivers. In some examples an additional RF transceiver may be coupled to the processor **310** similar to the wearable safety apparatus **100**.

[0053] The motorcycle control system **400** may include a start button **402** coupled via switch **404** to a power module **406**. The power module **406** may provide power to a processor **410** via power connection **408**. The motorcycle control system **400** may include an NFEMI transceiver **420** and a status indicator **418**. The processor **410** may have a reference data module **412** having an output **422** connected to an authentication module **414**. The reference data module may be a memory which includes authorized reference data such as valid helmet identification data and/or tag identification data and/or keys. The NFEMI transceiver **420** may have a bidirectional connection **430** to authentication module **414**. The authentication module **414** may have an output **416** to a status indicator **418**. The NFEMI transceiver **420** may have a bidirectional connection **432** to a status processing unit **426**. The status processing unit **426** may have a bidirectional connection **428** to a status log module **424**. In some examples the NFEMI transceiver may be replaced with other BAN transceivers. In some examples an additional RF transceiver may be coupled to the processor **410** similar to the user-controlled apparatus **200**.

[0054] FIG. **4**A shows a method of operation **450** of the NFEMI communication system including the motorcycle helmet NFEMI system and motorcycle NFEMI system of FIGS. **3**A and **3**B. In step **452** a rider **360** wearing the helmet **300** may touch the start button **402** on the motorcycle **440** to indicate to the ignition to turn on. In step **454** the NFEMI link **350** may be activated by processor **410** and a request sent via channel **352** from the bike NFEMI system **400** to the helmet NFEMI system **300**. This request may be transmitted by processor **410** via NFEMI transceiver **420**. The NFEMI link **350** is only activated as a result of the rider **360** being in contact with both the helmet **300** and the motorbike **440**. The body of the rider **360** therefore forms part of the communication channel **350** between the helmet NFEMI system **300** and the motorcycle NFEMI system **400**. In step **456** the request signal received from the bike NFEMI system **400** may trigger the wake-up logic **326** to power up the processor **310** using the system power module **318**. Alternatively in step **456** the user may power up the processor **310** by pressing user button **336** which also may trigger the wake-up logic **326** to power up the processor **310** using the system power module **318**. The switches **332** and **334** which connect the user button **336** and the NFEMI transceiver **320** to the wake-up logic may be alternatively implemented using logic gates to implement for example a logic or function. Once powered up, the processor **310** may receive the request directly from the NFEMI transceiver **320**. In other examples, the processor **310** may respond to the power up signal from the system power module **318** as a request to transmit identification data. In step **458** packet data comprising at least the helmet identification from the helmet ID module **302** and optionally a tag or key identifier from tag key identification module **304** may be assembled by the instruction assembler **306** and then the processor **310** may transmit the assembled instruction via the NFEMI transceiver **320** and via the channel **354** from the helmet NFEMI system **300** to the bike NFEMI system **400**.

[0055] In step **460** the bike NFEMI system processor **410** may compare the identification data received via the NFEMI transceiver **420** with the reference data stored in the reference module **412** using the authentication module **414**. In step **462** the authentication module **414** checks whether there is an identification data match. If there is an identification data match the method proceeds to step **466** and the ignition of the motorcycle **440** is turned on. Following on from step **466**, optionally in step **470** the request may be retransmitted by the status processing unit **426**. This retransmission may be a single or multiple retransmission. The response received from the helmet NFEMI system **300** may be logged in the status log module **424**. Returning to step **462** if the identification data does not match, then the processor **410** may check in step **464** whether a timeout value has been exceeded. If the timeout value has not been exceeded then the method returns to **456** and the request signal is retransmitted. If the timeout value has been exceeded then in step **468** a mismatch may be indicated by the status indicator **418**.

[0056] FIG. **4**B shows an example packet **480** used to transmit a helmet identifier which consists of a packet header **482** payload which includes the helmet identifier **484** and a CRC check **486**. FIG. **4**C shows an example packet **490** used to transmit both a helmet identifier and a tag or key. Packet for 90 includes a packet header **492** payload consisting of a field for the tag identifier or key **494** and the helmet identifier **496** and finally a CRC check **498**. Packets **480** and **490** may be assembled by the instruction assembler **306**.

[0057] The inventors of the present disclosure have appreciated that using an NFEMI communication channel between the helmet of a rider and a motorcycle can ensure that the rider is wearing a helmet before the motorcycle is started by checking the helmet identification. Since the rider has to be in physical contact with both the helmet and the motorcycle, the NFEMI communication channel provides a secure and simple way of ensuring that a rider is authorised to ride the motorbike. Alternatively or in addition by having an additional tag identification or key, an additional authentication step may be made to determine that a particular rider is authorised to use the motorcycle. In addition by storing a status log by periodically transmitting requests from the motorcycle NFEMI system and receiving data back from the helmet, data may be stored showing whether the rider continues to wear the helmet for the entire duration of a trip. This information may be used for example by insurance providers to ensure whether the rider was wearing the helmet during a time of an accident. In some examples the motorbike with a physical key or fingerprint of the owner may act as a master key to configure or set the details of the unique helmet identifier in the motorbike during an initial enrolment phase of the helmet keys in the motorbike. The user may programme the list of keys in the bike with a master key. The keys may be multiple and shareable keys. Helmets including the NFEMI system may act as a shareable key with control limitations set by the user to control for example properties such as the maximum speed limit or distance that a user is allowed to ride.

[0058] FIG. **5** shows an NFEMI transceiver system **300'** for a motorcycle helmet and a NFEMI transceiver system **400'** for a motorcycle according to an embodiment. The NFEMI transceiver system **300'** has similar features to the NFEMI transceiver system **300** with the addition of a biometric sensor **342**. The tag key ID module **304** is replaced with a biometric ID module **344** having an input connected to the biometric sensor output **358** and an output **356** connected to the instruction assembler module **306**. Similarly motorcycle NFEMI transceiver system **400'** has biometric ID module **440** having an output **442** to authentication module **414** instead of the tag module **412**. The other features of motorcycle NFEMI transceiver system **400'** are the same as motorcycle NFEMI transceiver system **400**.

[0059] FIG. **6** shows a method of operation **500** of the motorcycle helmet and motorcycle control system of FIG. **5**. In step **502** a rider wearing the helmet including the helmet NFEMI transceiver system **300'** may touch the start button **402** on the motorcycle **442** to indicate to the ignition to turn on. In step **504** the NFEMI link **350** may be activated and a request **352** is sent from the bike NFEMI system **400'** to the helmet NFEMI system **300'**. The NFEMI link **350** is only activated as a result of the rider **360** being in contact with both the helmet **300** and the motorbike **440**. The body of the rider **360** therefore forms part of the communication channel **350** between the helmet NFEMI system **300'** and the motorcycle NFEMI system **400'**. In step **506** the request signal received from the bike NFEMI system **400** may trigger the wake-up logic **326** to power up the processor **310** using the system power module **318**. Alternatively in step **456** the user may power up the processor **310** by pressing user button **336** which also may trigger the wake-up logic **326** to power up the processor **310** using the system power module **318**. The switches **332** and **334** which connect the user button **336** and the NFEMI transceiver **320** to the wake-up logic may be alternatively implemented using logic gates to implement for example a logic OR function. In step **508** packet data comprising biometric signals sensed by biometric sensor **342** which may be an EEG sensor are stored in biometric ID module **344**. The stored biometric data and the helmet identification from the helmet ID module **302** may be assembled by the instruction assembler **306** and then transmitted by the processor **310** via the NFEMI transceiver **320** from the helmet NFEMI system **300'** to the bike NFEMI system **400'**.

[0060] In step **510** the bike NFEMI system **400'** compares the received identification data with a reference using the authentication module **414**. In step **512** the authentication module **412** checks whether there is an identification data match. If there is an identification data match the method proceeds to step **516** and the ignition of the motorcycle **440** is turned on. Returning to step **512** if the identification data does not match, then a check is made in step **514** as to whether a timeout has been exceeded. If the timeout has not been exceeded then the method returns to **506** and the request signal is retransmitted. If the timeout has been exceeded then in step **518** a mismatch is indicated on status indicator **418**.

[0061] FIG. **7** shows further detail of the method for biometric sensing using an EEG sensor **550**. The method **550** may either be used by the motorcycle helmet NFEMI system **300'** once the data request has been received or as part of an enrolment procedure to sense and store authorised biometric signatures in the motorcycle NFEMI system **400'**. In step **552** a user ID age and gender may be received as an input. In step **554** an EEG sensor is enabled to sense a mental riding task sequence from a user or potential user of the motorcycle. In step **556** the EEG signal may be pre-processed. In step **558** features from the EEG may be extracted and in step **560** when used in enrolment the rider details may be stored in an EEG featured signal in the biometric ID module **440**. Alternatively, when used for sensing by the helmet NFEMI transceiver system **300'**, the feature signal may be transmitted via the NFEMI transceiver **320**.

[0062] FIG. **8** shows a method of authentication using biometric EEG signals **570** that may be implemented for example by the authentication module **414**. In step **572**, the EEG signal features may be received. In step **574** a person match score may be determined using a predetermined person model. In step **580** a comparison is made to determine whether the person match score exceeds a threshold value. In parallel with step **574**, in step **576** a gender match score may be determined using a predetermined agenda model. In step **582** a comparison is made to determine whether the gender match score exceeds a threshold value. Also in parallel with step **574**, in step **578** an age group match score may be determined using a predetermined age-group model. In step **584** a comparison is made to determine whether the age group match score exceeds a threshold value. If any of the comparison steps **580**,**582**, and **584** are unsuccessful, then in step **586** an indication is made that the biometric signature match is unsuccessful. If all the match scores in steps **580**, **582** and **584** exceed the threshold values then in step **588** the ignition is turned on.

[0063] FIG. **9** shows an example data packet **600**. Packet **600** includes a packet header **602** payload consisting of a biometric identifier **604** and the helmet identifier **606** and finally a CRC check **608**. Packet **600** may be assembled by the instruction assembler **306**.

[0064] Example methods of pre-processing and EEG classification are described for example in the following:

[0065] "Biometrics from Brain Electrical Activity: A Machine Learning Approach", Praniiappan and Mandic, IEEE Transactions on pattern analysis and machine intelligence vol 29, No 4, April 2007.

[0066] "Authentication with brainwaves: a review on the application of EEG as an authentication method", Azizi et al, IEEE 2018 Fourth International Conference on Advances in Computing, Communication & Automation (ICACCA), 26-28 Oct. 2018 Malaysia.

[0067] "Multi-factor EEG-based User Authentication", Pham et el, 2014 International Joint Conference on Neural Networks, July 2014, Beijing, China.

[0068] The system described in FIGS. **5**,**6**,**7** and **8** allows motorcycles to operate only when the rider is wearing a helmet. The purpose of this is two-fold: 1) to make use of electronics to help preventing bike usage with riders wearing a helmet for safety purposes, and 2) to obtain a biometric signature from the rider to be used to allow bike operation only for authorized user. The system makes use NFeMI radio technology to use the human body as channel, thereby allowing communication between helmet and motorcycle only when the rider is touching the bike, which may prevent any man-in-the-middle security attacks. The intelligent helmet is equipped with a unique ID tag and a EEG-based biometric sensing system for collecting a biometric signature of the rider when wearing the helmet. The motorcycle electronics initiate the NFeMI communication to detect the presence of the tag (i.e. the rider is wearing the helmet) and reads out the biometric signature of the helmet wearer. One or both elements are used to unlock the motorcycle for operation. Optionally this information can be logged for a trip.

[0069] Examples described herein include a helmet equipped with NFEMI radio technology, to communicate between helmet and bike via the human body (i.e. tag as a key to unlock the bike for operation by touch). NFEMI may be used for pairing with bike by touch. Further data centric communication can be enabled either via NFEMI, Bluetooth LE (BLE) or UWB or any other wireless communication technology. Helmet equipped with unique tag that is used to detect whether the rider is wearing the helmet. The tag may be read by the bike electronics by means of NFEMI. Helmets can act as a sharable key with a master command from user with set and/or predefined speed limits. In some examples a helmet or other wearable safety apparatus in contact with the head of a user may be equipped with EEG-based biometric sensing technology, and may collect a biometric signature of the rider for authorizing the usage of the bike. Bike electronics equipped with authentication process to authenticate the rider via tag (helmet use, i.e. safety) or biometric signature (EEG-based, i.e. security) etc. Interpretation of the signature and authentication process is done at the bike electronics to turn the ignition on or off. The helmet can be having wireless charging option, rechargeable battery. A bike owner can determine the maximum speed the shared person can ride. Bike electronics include an NFEMI system that log the status of rider wearing the helmet for the Insurance providers. Other examples may be used to pair a helmet or other wearable safety apparatus with another motor vehicle including a NFEMI transceiver.

[0070] In other examples, other wearable safety apparatus such as eyewear, ear-defenders and gloves including a NFEMI transceiver system and identification data may be used to communicate with other user-controlled equipment or vehicles including an NFEMI. Since the user forms at least the communication channel between the wearable safety apparatus and the user-controlled apparatus, this may allow secure authentication and/or verification that the correct safety apparatus is being worn prior to activating the user-controlled equipment.

[0071] A wearable safety apparatus including a body area network (BAN) transceiver for communicating with a user-controlled apparatus is described. The BAN transceiver includes a processor coupled to a BAN antenna. The processor is configured to receive an identification data request from a user-controlled apparatus in response to an action request of a user of the wearable safety apparatus; and to transmit identification data to the user-controlled in response to the identification data request. The identification data validates the user action by the user-controlled apparatus. The identification data request is only received when the wearable safety apparatus and the user-controlled apparatus are in contact with the user.

[0072] In some example embodiments the set of instructions/method steps described above are implemented as functional and software instructions embodied as a set of executable instructions which are effected on a computer or machine which is programmed with and controlled by said executable instructions. Such instructions are loaded for execution on a processor (such as one or more CPUs). The term processor includes microprocessors, microcontrollers, processor modules or subsystems (including one or more microprocessors or microcontrollers), or other control or computing devices. A processor can refer to a single component or to plural components.

[0073] In other examples, the set of instructions/methods illustrated herein and data and instructions associated therewith are stored in respective storage devices, which are implemented as one or more non-transient machine or computer-readable or computer-usable storage media or mediums. Such computer-readable or computer usable storage medium or media is (are) considered to be part of an article (or article of manufacture). An article or article of manufacture can refer to any manufactured single component or multiple components. The non-transient machine or computer usable media or mediums as defined herein excludes signals, but such media or mediums may be capable of receiving and processing information from signals and/or other transient mediums.

[0074] Example embodiments of the material discussed in this specification can be implemented in whole or in part through network, computer, or data based devices and/or services. These may include cloud, internet, intranet, mobile, desktop, processor, look-up table, microcontroller, consumer equipment, infrastructure, or other enabling devices and services. As may be used herein and in the claims, the following non-exclusive definitions are provided.

[0075] In one example, one or more instructions or steps discussed herein are automated. The terms automated or automatically (and like variations thereof) mean controlled operation of an apparatus, system, and/or process using computers and/or mechanical/electrical devices without the necessity of human intervention, observation, effort and/or decision.

[0076] Although the appended claims are directed to particular combinations of features, it should be understood that the scope of the disclosure of the present invention also includes any novel feature or any novel combination of features disclosed herein either explicitly or implicitly or any generalisation thereof, whether or not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the present invention.

[0077] Features which are described in the context of separate embodiments may also be provided in combination in a single embodiment. Conversely, various features which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub combination.

[0078] The applicant hereby gives notice that new claims may be formulated to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

[0079] For the sake of completeness it is also stated that the term "comprising" does not exclude other elements or steps, the term "a" or "an" does not exclude a plurality, a single processor or other unit may fulfil the functions of several means recited in the claims and reference signs in the claims shall not be construed as limiting the scope of the claims.

1. A wearable safety apparatus comprising a body area network, BAN, transceiver, and a processor coupled to the BAN transceiver, wherein the processor is configured to receive an identification data request via the BAN transceiver from a user-controlled apparatus in response to an action request of a user of the wearable safety apparatus; and to transmit identification data via the BAN transceiver to the user-controlled apparatus in response to the identification data request, the identification data being for validation of the user action by the user-controlled apparatus, and wherein the identification data request is only received when the wearable safety apparatus and the user-controlled apparatus are in contact with the user.

2. The wearable safety apparatus of claim **1** wherein the processor is further configured to retransmit the identification data to the user-controlled apparatus.

3. The wearable safety apparatus of claim **1** wherein the identification data comprises at least one of wearable safety apparatus identifier data and user identifier data.

4. The wearable safety apparatus of claim **3** further comprising a biometric sensor and wherein the user identifier data comprises biometric data detected by the biometric data while the wearable safety apparatus is in contact with the user.

5. The wearable safety apparatus of claim **1** wherein the action request of a user comprises an action for starting the user controlled apparatus.

6. The wearable safety apparatus of claim **1** comprising one of a motorcycle helmet, a cycle helmet, eyewear, a body protection suit, and gloves.

7. The wearable safety apparatus of claim **1** comprising a RF transceiver coupled to the processor, and wherein further data is transmitted and received via the RF transceiver.

8. The wearable safety apparatus of claim **7** wherein the RF transceiver comprises one of a Wi-Fi transceiver, a UWB transceiver and a Bluetooth LE transceiver.

9. The wearable safety apparatus of claim **1** wherein the BAN transceiver comprises a near-field electromagnetic induction, NFEMI transceiver.

10. A user-controlled apparatus comprising a body area network, BAN, transceiver, and a processor coupled to the BAN transceiver, wherein the processor is configured to transmit an identification data request via the BAN transceiver in response to an action request of a user of a wearable safety apparatus; and to receive identification data from the wearable safety apparatus in response to the identification data request, and wherein the processor is further configured to validate the user action request; and the identification data is only received when the apparatus and the wearable safety apparatus are in contact with the user.

11. The user-controlled apparatus of claim **10** wherein the processor is further configured to check for retransmission of the identification data by the wearable safety apparatus and to invalidate the user action request if the identification data has not been received with in a predetermined time.

12. The user-controlled apparatus of claim **10** wherein the identification data comprises at least one of least one of wearable safety apparatus identifier data and user identifier data and wherein the processor is further configured to validate the user action request by comparing the received identification data with a pre-determined wearable safety apparatus identifier data set and pre-determined user identifier data set.

13. The user-controlled apparatus of claim **10** wherein the user identifier data comprises biometric data and wherein the apparatus is further configured to compare the biometric data with a predetermined biometric data set.

14. The user-controlled apparatus of claim **13** wherein the biometric data comprises EEG data and wherein during an enrolment phase the apparatus is configured to receive EEG data from the wearable device and to store the received EEG data and wherein the predetermined biometric data set comprises the received EEG data.

15. The user-controlled apparatus of claim **10** comprising RF transceiver coupled to the processor, the RF transceiver configured to transmit and or receive further data to or from the wearable apparatus after the identification request has been validated.

16. The user-controlled apparatus of claim **15** wherein the RF transceiver is configured as one of a Wi-Fi transceiver, a UWB transceiver and a Bluetooth LE transceiver.

17. The user-controlled apparatus of claim **10** comprising one of an electric bicycle, a motorcycle, a machine tool, and a power tool.

18. The user-controlled apparatus of claim **10** wherein the BAN transceiver comprises a near-field electromagnetic induction (NFEMI) transceiver.

19. A body area network communication system comprising a wearable safety apparatus and a user-controlled apparatus, the wearable safety apparatus comprising a first body area network (BAN) transceiver and a first processor coupled to the first BAN transceiver, and the user controlled-apparatus comprising a second BAN transceiver and a second processor coupled to the second BAN transceiver; wherein

the second processor is configured to: transmit an identification data request via the second BAN transceiver from the user-controlled apparatus to the wearable safety apparatus in response to an action request of a user;

the first processor is configured to transmit identification data via the first BAN transceiver from the wearable safety apparatus to the user-controlled apparatus in response to the identification data request; and

the second processor is further configured to receive the identification data via the second BAN transceiver and to validate the user action request using the identification data; and

wherein the identification data request is received by the wearable safety apparatus and the identification data is received by the user-controlled apparatus only when the wearable safety apparatus and the user-controlled apparatus are in contact with the user.

20. A method for operating a user-controlled apparatus comprising a first body-area-network, (BAN) transceiver, the user-controlled apparatus configured to be operated by a user wearing a wearable safety apparatus comprising a second BAN transceiver, wherein the user, the first BAN transceiver and the second BAN transceiver are configurable to form a body-area-network, the method comprising:

transmitting an identification data request from the user-controlled apparatus to the wearable safety apparatus via the body-area-network in response to an action request of the user; transmitting identification data from the wearable safety apparatus to the user-controlled apparatus via the body-area-network in response to the identification data request; validating the user action request by the user-controlled apparatus using the identification data; wherein the identification data request is received by the wearable safety apparatus and the identification data is received by the user-controlled apparatus only when the wearable safety apparatus and the user-controlled apparatus are in contact with the user.

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