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Aircraft system and method

Abstract

A method of communicating configuration data of a tire pressure monitoring device configured to be affixed to a wheel in use. The method includes, at the tire pressure monitoring device, receiving a request to confirm configuration data, and responsive to receipt of the request to confirm configuration data, transmitting a configuration data signal which encodes the configuration data. The configuration data signal is configured to be received and understood by a human. The configuration data signal is indicative of any of an aircraft wheel location at which the tire pressure monitoring device is intended to be located, and a security code representative of security parameters of the tire pressure monitoring device.

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Background/Summary

RELATED APPLICATION
(1) This application incorporates by reference and claims priority to United Kingdom patent application GB 2115730.0, filed Nov. 2, 2021.
TECHNICAL FIELD
(2) The present invention relates to tire pressure monitoring devices, and methods of

communicating configuration data from tire pressure monitoring devices.

BACKGROUND

(3) Checking tire pressure is an important part of the maintenance of a vehicle. Tire pressures should be maintained at predetermined pressures to ensure that a tire performs as intended by the manufacturer. Incorrect tire pressure can lead to a tire failing, perhaps bursting and causing damage to the vehicle and/or a loss of control. To check a tire pressure, it is important to know what reference pressure is defined for the tire.

SUMMARY

(4) A first aspect of the present invention provides a method of communicating configuration data of a tire pressure monitoring device configured to be affixed to a wheel in use. The method comprises, at the tire pressure monitoring device: receiving a request to confirm configuration data; responsive to receipt of the request to confirm configuration data, transmitting a configuration data signal which encodes the configuration data; wherein the configuration data signal is configured to be received and understood by a human, and the configuration data signal is indicative of any of an aircraft wheel location at which the tire pressure monitoring device is intended to be located, and a security code representative of security parameters of the tire pressure monitoring device.
(5) This allows the data from the tire pressure monitoring device to be confirmed without requiring intermediate devices to interpret or display the data. In particular, it may be necessary to ensure that configuration data has been correctly entered into a tire pressure monitoring device in a way which can be trusted. By reducing intermediate devices, then the requirement for intermediate devices to also be trusted is removed. For example, in aircraft, in order to obtain a desired Development Assurance Level (DAL, for example DAL B) for a vehicle tire system a strict certification is required. It is desirable to reduce intermediate devices to provide a robust system while reducing certification requirements. Reducing intermediate devices may reduce the cost of a system, may reduce the cost of manufacture of a system, and may reduce the cost of operation in use.
(6) By transmitting the configuration data signal from the tire pressure monitoring device, it can be ensured that the configuration data signal has come from a known, trusted, source. Furthermore, by ensuring that the configuration data signal is configured to be received and understood by a human, the need for a trusted device may be reduced and/or eliminated. Thus the required DAL may be achieved without the need for an additional trusted device, and the human receiving the data may verify the data. Untrusted information sources cannot be used to directly verify data when DAL is required in view of their untrusted nature. In the present case, untrusted information sources can be used, with a user interacting with the untrusted device and forming the trusted source. For example, by inputting confirmation of configuration data transmitted directly from the tire pressure monitoring device to an untrusted device, the user can form a trusted source. The configuration data signal may be configured to be directly transmitted to a human from the tire pressure monitoring device, for example without first being transferred to a further intermediate device.
(7) Verifying that the aircraft wheel location at which the tire pressure monitoring device is intended to be located is correctly installed in the tire pressure monitoring device may ensure that tire pressure monitoring devices are correctly configured. Verifying security codes may, for example, ensure that correct configuration of the tire pressure monitoring device, such as configuration for encrypted communication between tire pressure monitoring devices, has been performed.
(8) The configuration data signal may comprise a visual signal, and the visual signal may be transmitted using a visual indicator of the trusted tire pressure monitoring device. A visual signal is a relatively straightforward signal type, which can be easily received and understood by a human.
(9) The visual indicator may comprise a light source, and the method then comprises selectively illuminating the light source to transmit the configuration data signal. The presence and absence of light can be easily received and understood by a human, and hence the configuration data signal may be relatively simple.

(10) The light source may comprise a Light Emitting Diode (LED). The light source may be a multi-purpose light source, for example a light source configured to provide functionality in addition to transmitting the configuration data signal. This can reduce the cost and complexity of the tire pressure monitoring device. For example, the light source may also be configured to be selectively illuminated to display a health status of a tire or a tire system, such as whether a monitored tire pressure is acceptable or if maintenance is required.
(11) The configuration data signal may comprise a number, and the selective illumination of the light source may comprise encoding the number into an illumination sequence representing individual digits of the number. For example, a first number of illuminations of the light source may represent a first digit of the number, a second number of illuminations of the light source may represent a second digit of the number, and so on. This provides a relatively simple signal which is easily received and understood by a human. The number of illuminations may directly correspond to the digit of the number, for example with one illumination representing the digit “1”, and five illuminations representing the digit “5”. Each illumination may be a distinct flash of the light source having an illumination period of at least 100 ms, at least 200 ms, at least 300 ms, at least 400 ms or at least 500 ms, so that it can be observed directly by a human.
(12) In other examples, the visual indicator comprises a display of the tire pressure monitoring device. For example, the display may be a matrix-display or segment-display on which configuration data can be displayed in readable characters to enable a user to read configuration data from the display.
(13) The configuration data signal may comprise an audible signal, and the audible signal may be transmitted using a transducer of the trusted tire pressure monitoring device. The method may comprise selectively actuating the transducer to transmit the signal. For example, the transducer can be caused to beep or a text-to-speech engine can convert configuration data into spoken information. Some examples may communicate the configuration data signal using both an audible signal and a visual signal.
(14) The configuration data signal may comprise a number, and the selective actuation of the transducer may comprise encoding the number into an actuation representing individual digits of the number. For example, a first number of actuations or sounds of the transducer may represent a first digit of the number, a second number of actuations or sounds of the transducer may represent a second digit of the number, and so on. As discussed above this can be easily received and understood by a human.
(15) The configuration data signal may comprise a start signal indicating a start of transmission, an end signal indicating an end of transmission, and an intermediate signal indicative of configuration data stored in the trusted tire pressure monitoring devices. This helps a human receiving the data configuration signal to interpret it, enabling the start and end, and when the configuration data is meant to be received, to be understood.
(16) The start signal may comprise a first type of signal, the intermediate signal may comprise a second type of signal, and the end signal may comprise a third type of signal. This can further distinguish between the start, end and intermediate signals, and provide further clarity for a human as to which signal indicates configuration data. Various combinations of the first, second and third types of signals are possible. For example, the first and third types of signals may comprise an audible signal and the second type of signal may comprise a visual signal, or vice versa. Alternatively, or additionally, the first type of signal may comprise a first type of visual signal, such as a first colour of light, the second type of signal may comprise a second type of visual signal, such as a second colour light different to the first colour light, and the third type of signal may comprise a third type of visual signal, such as a third colour light different to the first and second colours of light. This can provide a straightforward way to distinguish between the start/end signals and the intermediate signal.
(17) The configuration data signal may comprise a plurality of sub-signals, each sub-signal

comprising a start signal indicating a start of transmission of the sub-signal, an end signal indicating an end of transmission of the sub-signal, and an intermediate signal indicative of at least a portion of configuration data stored in the tire pressure monitoring device. This enables the data configuration signal to be split into smaller pieces, making it more easily understood by a human. Each intermediate signal may be indicative of a portion of configuration data stored in the tire pressure monitoring device. For example, each intermediate signal may be indicative of a digit of a reference pressure stored in memory of the tire pressure monitoring device.

(18) An end signal of a first sub-signal may comprise a start signal of a second sequential sub-signal. For example, a same sub-signal signal may indicate the end of one sub-signal and the start of another sub-signal. This can reduce the time required to transmit the configuration data signal.

(19) In some examples, each sub-signal is confirmed as being received and understood by a human before a next sequential sub-signal is transmitted. This improves the reliability of the verification of the configuration data because a human receiving the data does not have to rely on their memory to the same extent. Each sub-signal may be transmitted in response to verification of a previous sub-signal by a user.

(20) The method may comprise transmitting an alert indicating that transmission of the configuration data signal is about to begin. This may enable a human to know when a signal is to be transmitted for easier understanding and subsequent verification of the data configuration signal. For example, this may enable the configuration data signal to be received, understood, and verified in a stepwise manner, which may be clear to a human. The alert can be a different signal from the start signal discussed above and can be additional or alternative to the start signal. For example, the alert can be a first type of signal, such as an audible signal, and the start signal can be a second type of signal, such as a visual signal.

(21) The method may comprise verifying, by a human, that the configuration data of the tire pressure monitoring device matches an expected configuration data. This removes the need for another trusted device to perform verification, because the human may be regarded as a trusted source. Verification by a human that the configuration data of the trusted tire pressure monitoring device matches expected configuration data may take place using an untrusted device, for example by an untrusted intermediate device, such as a smartphone, tablet or other computing device, which provides the user with a prompt of what configuration data is expected. Although the intermediate device is untrusted, if it is faulty or has malicious software installed then the end result will be that the configuration is not verified, so safety is provided. This may reduce cost associated with the verification procedure compared to a process that requires an intermediate, independent, trusted device. It can also more provide more flexibility; because the intermediate device is untrusted its functionality can be provided by an application or app running on different hardware platforms without all those platforms having to be certified.

(22) Verifying, by a human, that the configuration data of the tire pressure monitoring device matches the expected configuration data, may comprise comparing the configuration data to expected configuration contained in an aircraft maintenance manual accessible to the human.

(23) The expected configuration data may comprise a security code representative of security parameters of a further tire pressure monitoring device. The security code representative of security parameters of a further tire pressure monitoring device may be transmitted to the human in a further data configuration signal from the further tire pressure monitoring device.

(24) The request to confirm configuration data may be received at the tire pressure monitoring device via a short-range communication protocol. This provides security benefits as physical proximity is required and can also provide an operational benefit if the range is short enough that is generally received by a single device to prevent a request from being picked-up by a wrong tire pressure monitoring device. The request may be submitted via a communication protocol with a range of less than 5 m, less than 2 m, less than 1 m, less than 50 cm, less than 30 cm or less than 15 cm. Suitable communication protocols include Near Field Communication (NFC). In some

examples, no identifier is included in the request to confirm configuration data, with a short range of transmission and physical proximity indicating the device to respond. Alternatively, the request may include a unique identifier of a device. The unique identifier may be input by a user by reading a marking on the tire pressure monitoring device or determined by data provided on or by the tire pressure monitoring device, such as by scanning or a QR code of the tire pressure monitoring device, NFC, or Radio Frequency Identification (RFID) tag interrogation.
(25) The method may comprise transmitting the configuration data signal to a further tire pressure monitoring device, and subsequently transmitting the configuration data signal from the further tire pressure monitoring device to be received and understood by a human. This may allow for configuration of one or more tire pressure monitoring devices to be transmitted from a single tire pressure monitoring device, which can simplify a procedure where the configuration data of several tire pressure monitoring devices needs to be verified. For example, a need to move between devices can be reduced and/or a tire pressure monitoring device which is positioned so that it is difficult for a human to receive the configuration data signal can be relayed by another of the devices. All the tire pressure monitoring devices may be trusted, so another tire pressure monitoring device can be a trusted intermediary. This does not significantly increase the cost or complexity of the system as a whole because no additional trusted devices are required.
(26) For example, the method may comprise, at a first tire pressure monitoring device, receiving a request for configuration data of a second tire pressure monitoring device; transmitting the request from the first tire pressure monitoring device to the second tire pressure monitoring device; transmitting, from the second tire pressure monitoring device to the first tire pressure monitoring device, a configuration data signal indicative of configuration data stored in the second tire pressure monitoring device; and transmitting, from the second tire pressure monitoring device to a human, the configuration data signal indicative of configuration data stored in the second tire pressure monitoring device.
(27) A second aspect of the present invention provides a data carrier comprising machine readable instructions, which when executed by a processor of a tire pressure monitoring device, cause the tire pressure monitoring device to perform the method according to the first aspect of the present invention. The machine-readable instructions may also cause the tire pressure monitoring device to execute any of the optional features also described. The data carrier may be a non-transitory computer readable medium.
(28) A third aspect of the present invention provides a tire pressure monitoring device configured to perform the method of the first aspect of the present invention.
(29) A fourth aspect of the present invention provides a tire pressure monitoring device comprising a memory for storing configuration data, a light source, and a processor configured to selectively illuminate the light source to transmit a signal indicative of configuration data stored in the memory, the configuration data comprising any of an aircraft wheel location at which the tire pressure monitoring device is intended to be located, and a security code representative of security parameters of the tire pressure monitoring device. For example, any of the methods discussed above to communicate a configuration data signal with a light source can be used.
(30) The tire pressure monitoring device may be configured to communicate with a further tire pressure monitoring device, for example to send a further configuration data request to the further tire pressure monitoring device and/or to receive a further configuration data signal indicative of further configuration data stored in memory of the further tire pressure monitoring device. The tire pressure monitoring device and the further tire pressure monitoring device may comprise respective unique identifiers, for example unique identifiers which are presented in response to appropriate interrogation.
(31) A fifth aspect of the present invention provides an aircraft comprising a tire pressure monitoring device according to the third or fourth aspect of the present invention.
(32) A sixth aspect of the present invention provides a method of communicating configuration data

from a network of tire pressure monitoring devices, the method comprising at a first tire pressure monitoring device, receiving a request for configuration data of a second tire pressure monitoring device, transmitting the request from the first tire pressure monitoring device to the second tire pressure monitoring device, transmitting from the second tire pressure monitoring device to the first tire pressure monitoring device a configuration data signal indicative of configuration data stored in the second tire pressure monitoring device, and transmitting from the first tire pressure monitoring device the configuration data signal indicative of configuration data stored in the second tire pressure monitoring device.
(33) Features of aspects of the present invention may be equally applied to other aspects of the present invention, where appropriate.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:
(2) FIG. **1** is a schematic view of a tire pressure monitoring device according to an example.
(3) FIG. **2** is a schematic illustration of a first signal indicative of configuration data of a tire pressure monitoring device;
(4) FIG. **3** is a schematic view illustrating a first example method of communicating configuration data of a tire pressure monitoring device;
(5) FIG. **4** is a schematic illustration of a second signal indicative of configuration data of a tire pressure monitoring device;
(6) FIGS. **5**A to **5**G are schematic views illustrating a display of an untrusted device used to verify the signal of FIG. **4**;
(7) FIG. **6** is a schematic view illustrating a second example method of communicating configuration data of a tire pressure monitoring device;
(8) FIG. **7** is a schematic view of a first network of tire pressure monitoring devices according to an example;
(9) FIG. **8** is a schematic view illustrating a method of operating the network of FIG. **7**;
(10) FIG. **9**A is a schematic illustration of a third signal indicative of configuration data of a tire pressure monitoring device;
(11) FIGS. **9**B and **9**C are schematic views illustrating a display of an untrusted device used to verify a location indication in the signal of FIG. **9**A;
(12) FIG. **10** is a schematic view illustrating an aircraft comprising the tire pressure monitoring device of FIG. **1** or the network of FIG. **7**;
(13) FIG. **11** is a schematic illustration of a fourth signal indicative of configuration data of a tire pressure monitoring device;
(14) FIGS. **12**A and **12**B are schematic views illustrating a display of an untrusted device used to verify the signal of FIG. **11**;
(15) FIG. **13** is a schematic illustration of a third signal indicative of configuration data of a tire pressure monitoring device;
(16) FIGS. **14**A to **14**F are schematic views illustrating a display of an untrusted device used to verify the signal of FIG. **13**; and
(17) FIG. **15** is a schematic illustration of a second network of tire pressure monitoring devices according to an example.
DETAILED DESCRIPTION
(18) A tire pressure monitoring device **10** according to an example is shown schematically in FIG. **1**. The tire pressure monitoring device **10** comprises a processor **12**, a memory **14**, a transceiver **16**,

a visual indicator or display which is an LED **18** in this example, a sensor **19** and a power source **21**.
(19) The processor **12** may be any suitable processor including single and multi-core processors, an Application Specific Integrated Circuit (ASIC) or like. The processor **12** is communicatively coupled to the transceiver **16**, the LED **18**, the memory **20** and the sensor **21**.
(20) Memory **14** is a flash memory that stores configuration data **20** and also computer readable instructions for execution by the processor **12** in operation, although it will be appreciated that other types of memory may be used. The configuration data **20** can therefore be updated as required with configuration data. A reference tire pressure is stored in the configuration data **20**. Additional data can also be stored in the configuration data **20**, for example an aircraft identifier (such as an aircraft Tail identifier) and a wheel position. The configuration data **20** in some examples may further include a security code which is indicative of security parameters generated by the tire pressure monitoring device **10** during configuration. In some examples the security code is a numerical value, which may be generated using a hash function based on the remaining parameters of the configuration data, such as reference tire pressure, aircraft identifier and wheel location, along with any security keys of the tire pressure monitoring device **10**. It will be appreciated that the hash value may be truncated to provide a security code of an appropriate length.
(21) Transceiver **16** is an appropriate transceiver capable of receiving a request to confirm the configuration data **20**. In this embodiment, the transceiver **16** comprises a short-range radio signal transceiver operating according to the NFC protocol. It will be appreciated, however, that other communication protocols may be used, including, for example, a Bluetooth low energy (BLE) communication protocol. When the transceiver **16** receives a request to confirm the configuration data **20**, the processor **12** encodes the configuration data **20** stored in the memory **14** of the tire pressure monitoring device **10**, and transmits a signal **22** indicative of the configuration data **20** via the LED **18** to a user **24** observing the tire pressure monitoring device **10**. Here the LED **18** is a three-colour LED which is capable of displaying red, blue, and green coloured light. Other examples may use a different number of colours of light than three and/or use other colours than red, blue, and green. In examples herein, the user **24** is a human.
(22) An example of the signal **22** is shown schematically in FIG. **2**, where the signal encodes a reference tire pressure stored in configuration data **20** of the tire pressure monitoring device **10**. Checking a reference tire pressure has been correctly stored in a tire pressure monitoring device is an important part of setup to confirm correct operation after configuration. It is possible that the configuration data is corrupted and stores an incorrect value, or an incorrect value may have been loaded in error or by a bad actor. The consequences of an incorrect reference tire pressure level in use may be severe, for example making a tire blow-out more likely if the tire is operated at too low a pressure.
(23) As shown in FIG. **2**, the reference tire pressure of the tire pressure monitoring device **10** is 178 PSI (1.23 MPa). The signal **22** as a whole has a start signal **26** in the form of a green flash of light from the LED **18**, and an end signal **28** in the form of another green flash of light from the LED. The signal **22** is split into a number of sequential sub-signals **30**, with each sub-signal **30** being representative of a digit of the reference tire pressure. Each sub-signal **30** has a start signal in the form of a green flash of light from the LED **18**, an end signal in the form of another green flash of light from the LED **18**, and an intermediate signal in the form of a flash/a number of red flashes of light from the LED **18**.
(24) As shown in FIG. **2**, the start of the first sub-signal **30** is coincident with the start signal **26** of the overall signal **22**, and the end of the last sub-signal **30** is coincident with the end signal **28** of the overall signal **22**, such that the start **26** and end **28** signals resemble prolonged flashes of the LED **18**. Furthermore, a flash of the LED to indicate the end of the first sub-signal **30** also functions as a start signal of the second sub-signal.

(25) In the signal **22**, the intermediate signals of each sub-signal **30** encode and are indicative of the reference tire pressure. For example, in the first sub-signal **30**, there is one flash of red light from the LED **18**, indicating that the first digit of the reference tire pressure is the number “1”. In the second sub-signal **30**, there are seven flashes of red light from the LED **18**, indicating that the second digit of the reference tire pressure is the number “7”. In the third sub-signal **30**, there are eight flashes of red light from the LED **18**, indicating that the third digit of the reference tire pressure is the number “8”. Thus, the LED **18** can be used to output the signal **22** to the user **24**, with the signal **22** being in a manner that is easily receivable and understandable by the user **24**. The duration of each flash can be chosen depending on the length of the overall sequence and the length of flash needed to be clear to the user **24**, and in the example of FIG. **2** each flash is 0.5 s long. In other examples, the colour of the flashes can be different, for example with a different colour of light being used for each digit of the reference tire pressure so that a first colour indicates “units”, a second colour indicates “tens” and a third colour indicates “hundreds”.
(26) Once the signal **22** is received by the user **24**, the user **24** may take appropriate action to confirm that the reference tire pressure stored in the memory **14** is correct, or may take appropriate remedial action if the reference tire pressure is incorrect. In some examples, the user **24** uses an untrusted device **32**, for example a mobile phone or tablet computer running an application, to verify the configuration data **20**. As the user **24** can be taken to be a trusted source, and the tire pressure monitoring device **10** is itself a trusted source, the untrusted device **32** can be used to input the user's verification of the configuration data **20**. For example, the untrusted device **32** can display a prompt with an expected reference pressure. The verification can be trusted because it occurs between the user **24** (who is trusted) and tire pressure monitoring device **10** (which is trusted because of its certification to a particular DAL).
(27) Whilst the tire pressure monitoring device **10** is depicted in FIG. **1** as comprising an LED **18**, and the signal **22** comprises flashes of the LED **18**, it will be appreciated that in another embodiment the tire pressure monitoring device **10** may comprise a transducer in the form of a beeper or speaker, and that that the signal **22** may instead comprise audible noises instead of flashes of light. In other examples the signal may additionally or alternatively take the form of any of a signal displayed on an LCD screen in the form of flashing lights, pictures, or text. Similarly, other examples may display flashing lights, pictures or text on an LED matrix display.
(28) A method **100** of operating the tire pressure monitoring device **10** is shown schematically in FIG. **3**. The method **100** comprises receiving **102** a request to confirm the configuration data **20** of the tire pressure monitoring device **10** at the transceiver **16**. Responsive to the request, a configuration data signal **22** encoding the configuration data **20** is transmitted **104** by the LED **18**.
(29) In another example, a signal **22′** takes a different form, as illustrated schematically in FIG. **4**. In this instance, sub-signals **30′** are discrete signals separate from one another. This allow the signal **22′** to be split such that each sub-signal **30′** is easily recognisable and verifiable by a user. In this example, an untrusted device **32** may communicate with a tire pressure monitoring device **10**, and the tire pressure monitoring device **10** may cause a sequence of discrete sub-signals **30′** to be provided in response to instructions received over the receiver from the untrusted device.
(30) For example, in response to a request from the user **24**, submitted via the untrusted device **32**, to check or determine the configuration data stored in a tire pressure monitoring device **10**, a first message indicating what form a first sub-signal **30′** will take is displayed on the untrusted device **32**. This first message is shown schematically in FIG. **5**A. It provides data of what the reference pressure is expected to be, in this case 178 PSI (equivalent to 1.23 MPa, or 12.3 BAR), and of what signal is expected to be provided by the tire pressure monitoring device **10**. In this case the signal is one red flash, indicating the digit **1**, and one green flash, indicating the end of a sub-signal for that digit. The user **24** interacts with a user interface element **52** on the untrusted device **32** to cause the first sub-signal **30′** to be transmitted by the LED **18**. In this case, the user interface element is a button displayed on a touch screen of the untrusted device **32** which displays the text “go”. In

response to activation of the user interface element **52**, such as by a tap, the untrusted device **32** transmits a signal to the tire pressure monitoring device **10** to cause it to transmit or communicate the first sub-signal **30**′. Meanwhile, the untrusted device **32** displays a first verification message, allowing the user **24** to indicate that the first sub-signal **30**′ has been received and understood by a user interface element **54**, as shown schematically in FIG. **5**B. A message is also provided to remind the user what they should have observed, in this case one red flash.
(31) When the user interface element **54** is activated, such as by a tap on a touch screen of the untrusted device **32**, a second message indicating what form a second sub-signal **30**′ will take is displayed on the untrusted device, as shown schematically in FIG. **5**C. Again, this states the reference pressure and what the next signal is expected to be, in this case seven red flashes for the digit **7** followed by a green flash to indicate the end of the sub-signal. A user interface element **56** is provided which, when selected by the user, causes the tire pressure monitoring device **10** to transmit or communicate the second sub-signal **30**′, in the same way as described above for FIG. **5**A. Once the second sub-signal **30**′ has been transmitted, a second verification message is displayed on the untrusted device **32**, shown schematically in FIG. **5**D. A user can confirm the second sub-signal **30**′ has been observed by interacting with a user interface element **58**, in the same as described above for FIG. **5**B.
(32) Next, a third message indicating what form a third sub-signal **30**′ will take is displayed on the untrusted device **32**, as shown schematically in FIG. **5**E. Again, this includes the reference pressure and an indication that the third sub-signal **30**′ will comprise eight red flashes, corresponding to the digit **8**. As discussed above with reference to FIG. **5**A, the user interacts with a user interface element **60** that causes the third sub-signal **30**′ to be transmitted or communicated by the LED **18**. Once the third sub-signal **30**′ has been transmitted, a third verification message **62** is displayed on the untrusted device, allowing the user to indicate that the third sub-signal **30**′ has been received and understood, as shown schematically in FIG. **5**F.
(33) Finally, a confirmation message is displayed on the untrusted device **32** once all sub-signals **30**′ have been received, as shown schematically in FIG. **5**G. Although described here with reference to three sub-signals, it will be recognised that the number of sub-signals may vary depending on the configuration data requested. Other configuration data than pressure may be indicated and alphabetical data as well as numerical data can be communicated. Other encoding schemes can also be used, for example Morse code, but a direct correlation between a numerical value and the number of flashes has the benefit of requiring no specific user knowledge and potentially more reliable to recognise.
(34) As discussed above with reference to FIGS. **5**A to **5**G, only a single user interface element is displayed to allow the user to provide positive confirmation. A timer may be associated with each screen after which a negative result may be assumed and the process terminates without confirmation. Alternatively a specific negative option, to cancel the process or to indicate that the observed sequence did not match that which was expected, can be included in the user interface to allow a user to indicate that the data has not been confirmed.
(35) This process allows an untrusted device to guide a user through the process because if the untrusted device attempts to mislead the user as to the configured pressure, the user, who is trusted, will notice that the signal from the tire pressure monitoring device does not match what is expected. Similarly, the use of a simple encoding where the number of flashes matches the digit, a user can identify potential false guidance on the untrusted device. If any of the observed sub-signals **30**′ are noted by the user as not being received or understood, a user interface element on the untrusted device **32** may be used to indicate this, and the user **24** may be required to repeat a configuration of the tire pressure monitoring device **10** and/or conduct further analysis and/or replace the tire pressure monitoring device **10**.
(36) The process enables the user to identify any of incorrectly entered configurations, a faulty tire pressure monitoring device **10**, a faulty untrusted device **32**, and a malicious application running on

the untrusted device **32**.
(37) A further example method **200** of operating a system comprising the tire pressure monitoring device **10** and the untrusted device **32** is shown schematically in FIG. **6**, with the signal **22′** taking the form depicted in FIG. **4**.
(38) The method **200** comprises submitting, at block **202**, a request for configuration data from the tire pressure monitoring device using the untrusted device **32**, by interacting with the user interface of the untrusted device **32**. In response to the request, a start transmission option is chosen, at block **204**, by interacting with the user interface of the untrusted device. The first sub-signal **30′** is transmitted at block **206**, and a user is required to verify at block **208** that the first sub-signal **30′** has been correctly received by interacting with the user interface of the untrusted device **32**. A start transmission option is chosen **210** for the second sub-signal **30′**, again interaction with a user interface of the untrusted device **32**. The second sub-signal **30′** is transmitted at block **212**, and a user is required to verify at block **214** that the second sub-signal **30′** has been correctly received by interacting with the user interface of the untrusted device **32**. A start transmission option is then chosen at block **216** for the third sub-signal **30′**, again using a user interface of the untrusted device **32**. The third sub-signal **30′** is transmitted at block **218**, and a user is required to verify at block **220** that the third sub-signal **30′** has been correctly received, using the user interface of the untrusted device **32**. The transmission sequence is then ended **222**.
(39) In such a manner, the method **200** may transmit the sub-signals **30′** in a stepwise manner, with verification of each sub-signal **30′** being required before a next sub-signal in the sequence is transmitted. This can improve clarity of the signal for the user, and provide for easier verification of the configuration data in use while also reducing user error because there is less reliance on a user's memory.
(40) An example of a network **300** of a first **302** and a second **304** tire pressure monitoring devices is shown schematically in FIG. **7**. The first **302** and second **304** tire pressure monitoring devices have generally the same structure as the tire pressure monitoring device **10** of FIG. **1**, but with differences that will now be described.
(41) Each of the first **302** and second **304** tire pressure monitoring devices has a processor **306**, and a memory **308**. The processor **306** may be any conventional processor, and the memory **308** stores respective configuration data **310**,**312**. The first tire pressure monitoring device **302** has a receiver **314** for communicating with an untrusted device **316**, a transceiver **318** for communicating with the second tire pressure monitoring device **304**, and a visual indicator in the form of an LED **320**. The LED **320** in this example is an LED which is capable of displaying both red, blue, and green coloured light as discussed above with reference to FIG. **1**, other examples may use other types of visual indicator and other colours of light. The second tire pressure monitoring device **304** has a transceiver **322** for communicating with the transceiver **318** of the first tire pressure monitoring device **302**. Two devices are shown here for clarity, but it will be appreciated that there will typically be more than two devices, with each tire having an associated tire pressure monitoring device.
(42) A method **400** of operating the network **300** is shown schematically in FIG. **8**. The method **400** comprises receiving, at block **402**, at the receiver **314** of the first tire pressure monitoring device **302**, a request to confirm the configuration data **312** stored in the memory **308** of the second tire pressure monitoring device **304**. The first tire pressure monitoring device **302** uses its transceiver **318** to transmit, at block **404**, the request to the transceiver **322** of the second tire pressure monitoring device **304**. In response to receipt of the request, the processor **306** of the second tire pressure monitoring device **304** encodes the configuration data **312** stored in the memory **308** of the second tire pressure monitoring device **304**, and the processor **306** uses the transceiver **322** of the second tire pressure monitoring device **304** to transmit, at block **406**, a signal representative of the configuration data **312** to the transceiver **318** of the first tire pressure monitoring device **302**. The LED **320** of the first tire pressure monitoring device **302** then transmits **408** a signal **324**

representative of the configuration data **312** stored in the memory **308** of the second tire pressure monitoring device **304** in manner such that the signal **324** can be received and understood by a user **24**.

(43) Thus the configuration data **312** stored in the memory **308** of the second tire pressure monitoring device **304** can be requested at and subsequently displayed by the first tire pressure monitoring device **302**. This can provide for easier and simpler operation in use, as a user can request configuration data from multiple tire pressure monitoring devices at a single tire pressure monitoring device. This can also reduce the time taken to obtain configuration data, as a user does not need to move from device to device in order to request and obtain configuration data. This can also enable an arrangement where the second tire pressure monitoring device **304** is hidden from view, for example beneath a hubcap or other components, and/or where the second tire pressure monitoring device **304** is located internally within a wheel/tire.

(44) In some examples, the signal communicated to the user may include additional elements to indicate which tire pressure monitoring device the configuration data applies to, for example by encoding a wheel position before or after the reference pressure. For example, where the second tire pressure monitoring device **304** is at a wheel allocated number “3”, the LED **320** of the first tire pressure monitoring device **302** may flash three times to indicate that it is the configuration data of the tire pressure monitoring device of wheel “3” that is transmitted as the signal **324**.

(45) FIG. **9**A depicts an example of a signal **324** including a location indication **350** of a tire pressure monitoring device. The location indication is an example of additional information as described above. An associated indication message and confirmation message to be displayed on the untrusted device **316** are depicted in FIGS. **9**B and **9**C, respectively. The indication message of FIG. **9**B is displayed as a message which indicates the number of red flashes corresponding to the tire pressure monitoring device location being checked, followed by a green flash to indicate end of transmission expected be observed by the user on the LED **320**. In the example of FIG. **9**B, the wheel location is “3” and the message indicates that three red flashes for the location indication **350** are expected. In response to user interaction with a user interface element **352** on the untrusted device **316**, the location indication **350** is communicated or transmitted by causing the LED to provide three red flashes followed by a green flash.

(46) Subsequent to communicating the location indication **350**, the confirmation message of FIG. **9**C is displayed by the untrusted device **316** which asks the user **24** to confirm that they have correctly received the location indication **350**. Confirmation is provided via interaction with a user interface element **354** on the untrusted device **316**. Once confirmation has taken place, an initial message similar to that of FIG. **5**A may be displayed on the untrusted device **316**, and the remainder of the signal **324** may take a form similar to that of the signal **22**′ of FIG. **4**, with the user continuing to work through the method of FIG. **6** to confirm the configuration data.

(47) In some examples, a unique identifier may be used to identify one or both of the first **302** and second **304** tire pressure monitoring devices and used to indicate which device(s) should communicate stored configuration information. The unique identifier can be determined by an untrusted device or entered manually into the untrusted device. For example, the unique identifier can be determined by the untrusted device by: Near Field Communication (NFC) or Radio Frequency Identification (RFID) interrogation of the tire pressure monitoring device; by reading a printed indication of the serial number, such as a barcode (one- or two-dimensional) using a camera, reading characters of a serial number using Optical Character Recognition (OCR) using a camera or the like. Manual entry may involve entering the unique identifier as printed on a device or instead providing an aircraft tail identifier and an associated wheel position for which it is desired to confirm the configuration data.

(48) In examples previously described, only two colours of light, red and green, have been utilised in the signals **22**,**22**′,**324**,**350**. It will be appreciated that signals where three or more colours of light are utilised are also envisaged, for example where red, blue, and green are utilised.

(49) Illustrative signals **600**,**602**,**604**,**606**,**608**,**610** that utilise red, blue, and green to indicate device location are shown in FIG. **11**. Here, for each device location, a green flash indicates start of the signal **600**,**602**,**604**,**606**,**608**,**610**, a red flash indicates end of the signal **600**,**602**,**604**,**606**,**608**,**610**, and blue flashes intermediate the green and red flashes indicate device location. In the example of FIG. **11**, six tire pressure monitoring devices **10** are installed on an aircraft, with one at each of the left nose wheel, the right nose wheel, a first landing gear wheel, a second landing gear wheel, a third landing gear wheel, and a fourth landing gear wheel, and a different number of blue flashes is used to distinctly identify each of those locations.
(50) In the example of FIG. **5**A, the user interface of the untrusted device **32** displays to the user **24** the expected flash sequence. In alternative examples, an aircraft maintenance manual (AMM) task card may provide to the user **24** a list of tire pressure monitoring device locations, e.g., nose left, nose right, and so on, along with an associated expected flash sequence for the LED **18** which would correctly indicate the associated tire pressure monitoring device location. Such an AMM task card may provide numerical values for expected flashes and/or may provide pictorial representations of the expected flashes such as seen in FIG. **11**. It will be appreciated that the AMM task card may be provided separately to the user **24** as a physical task card, or, for example, as a display on a separate electronic device to the untrusted device **32**.
(51) When checking the location stored in configuration data **20** of a tire pressure monitoring device **10**, the user **24** submits a request for the tire pressure monitoring device **10** to display the stored location, using a user interface of the untrusted device **32**. The stored location is then displayed by the LED **18**. The untrusted device **32** does not tell the tire pressure monitoring device **10** which sequence to flash, but rather provides an instruction for the tire pressure monitoring device **10** to flash its sequence indicative of the stored location. An exemplary user interface **612** for starting the check is shown in FIG. **12**A, with the user **24** interacting with user interface element **614** to start the check. An exemplary user interface **616** for a user **24** to verify the signal **600**,**602**,**604**,**606**,**608**,**610** is shown in FIG. **12**B, with the user **24** interacting with user interface elements **618**,**620** to provide an input indicative of whether the signal **600**,**602**,**604**,**606**,**608**,**610** is verified or not. If the signal **600**,**602**,**604**,**606**,**608**,**610**, here indicative of stored location of the tire pressure monitoring device **10**, is not verified, then the configuration data **20** needs to be reloaded.
(52) As the user **24** can be taken to be a trusted source, and the tire pressure monitoring device **10** is itself a trusted source, the untrusted device **32** can be used to input the user's verification of the configuration data **20**. The verification can be trusted because it occurs between the user **24** (who is trusted) and tire pressure monitoring device **10** (which is trusted because of its certification to a particular DAL).
(53) Similar to the signals **600**,**602**,**604**,**606**,**608**,**610** of FIG. **11** that indicate device location, signals **700**,**702**,**704** that use three colours of light, i.e., red, blue, and green, to indicate reference pressure are shown in FIG. **13**. As illustrated in FIG. **13**, the reference pressure to be communicated is 178 PSI, and each signal **700**,**702**,**704** is used to communicate one digit of the reference pressure. The first signal **700** comprises one green flash, followed by one blue flash, followed by one red flash, to communicate that the “hundreds” digit is “1”. The second signal **702** comprises one green flash, followed by seven blue flashes, followed by one red flash, to communicate that the “tens” digit is “7”. The third signal **704** comprises one green flash, followed by eight blue flashes, followed by one red flash, to communicate that the “units” digit is “8”.
(54) An AMM task card can also be used when checking the reference pressure stored in the tire pressure monitoring device **10**. For example, the AMM task card may provide an expected flash sequence for each signal **700**,**702**,**704** so that a user can verify the flash sequence seen relative to the AMM task card. In some examples, the user **24** may be required to complete a portion of the AMM task card to complete the expected flash sequence for the reference pressure based on the location of the tire pressure monitoring device **10** that is being checked.
(55) When checking the stored reference pressure of the tire pressure monitoring device **10** using

the AMM task card, the user **24** submits a request for the tire pressure monitoring device **10** to display the stored reference pressure, via the LED **18**, using a user interface of the untrusted device **32**. The untrusted device **32** does not tell the tire pressure monitoring device **10** which sequence to flash, but rather provides an instruction for the tire pressure monitoring device **10** to flash its sequence indicative of the stored reference pressure. An exemplary user interface **706** for starting the check for the "hundreds" digit is shown in FIG. **14**A, with the user **24** interacting with user interface element **708** to start the check for the "hundreds" digit. An exemplary user interface **710** for a user **24** to verify the signal **700** for the "hundreds" digit is shown in FIG. **14**B, with the user **24** interacting with user interface elements **711**,**712** to indicate whether the signal **700** is verified, i.e., that seen on the AMM task card, or not.

(56) Similarly, an exemplary user interface **714** for starting the check for the "tens" digit is shown in FIG. **14**C, with the user **24** interacting with user interface element **716** to start the check for the "tens" digit. An exemplary user interface **718** for a user **24** to verify the signal **702** for the "tens" digit is shown in FIG. **14**D, with the user **24** interacting with user interface elements **720**,**722** to indicate whether the signal **702** is verified or not. An exemplary user interface **724** for starting the check for the "units" digit is shown in FIG. **14**E, with the user **24** interacting with user interface element **726** to start the check for the "units" digit. An exemplary user interface **728** for a user to verify the signal **704** for the "units" digit is shown in FIG. **14**F, with the user **24** interacting with user interface elements **730**,**732** to indicate whether the signal **704** is verified or not.

(57) A further parameter which may be communicated to the user **24** by appropriate flashing of an LED of a tire pressure monitoring device is the security code. As previously discussed, in some examples the security code is a numerical value, which may be generated using a hash function based on the remaining parameters of the configuration data **20**, such as reference tire pressure, aircraft identifier and wheel location, along with any security keys of the tire pressure monitoring device **10**. Such a numerical value may be communicated to the user **24**.

(58) Communication of a security code may be of particular utility in a network of tire pressure monitoring devices, with such a network **800** illustrated schematically in FIG. **15**. Here the network **800** comprises first **802** and second **804** tire pressure monitoring devices, each having substantially the same structure as the tire pressure monitoring device **10** of FIG. **1**. Like reference numerals are used for the sake of clarity. The network **800** has been set-up such that the first **802** and second **804** tire pressure monitoring devices can communicate with one another securely. To do so, each of the first **802** and second **804** tire pressure monitoring devices exchange cryptographic parameters, such as cryptographic keys, such that secure communication between the first **802** and second **804** tire pressure monitoring devices is established.

(59) The processors **12** of the first **802** and second **804** tire pressure monitoring devices each generate a respective security code based on data that is common to the first **802** and second **804** tire pressure monitoring devices. In some examples, such common data may comprise cryptographic keys shared by the first **802** and second tire pressure monitoring devices. Security codes may be generated by taking a hash, or truncated hash, of the common data, to provide a numerical value that can be communicated to the user **24**. As the security codes are generated based on common data, the security codes generated by the first **802** and second **804** tire pressure monitoring devices should be the same.

(60) The security codes can then be communicated to the user **24** by flashing of the respective LEDs **18** in a similar manner to that previously described. By verifying that the security codes communicated by the first **802** and second **804** tire pressure monitoring devices are the same, the user **24** can verify that correct establishment of secure communication between the first **802** and second **804** tire pressure monitoring devices has occurred because the devices all share the same data on which the security code is based. It will be appreciated that the security codes themselves can be thought of as forming part of the overall configuration data **20** of the first **802** and second **804** tire pressure monitoring devices.

(61) The tire pressure monitoring devices described herein may be useful for confirming safety critical configuration data with a high degree of reliability assurance. It is particularly suited for use in aircraft. An aircraft **500** comprising a respective tire pressure monitoring device **10** of FIG. **1** for each tire **502** is shown schematically in FIG. **10**. The tire pressure monitoring devices can form a network as discussed above with reference to FIGS. **7** and **15** or operate independently.
(62) It is to be noted that the term "or" as used herein is to be interpreted to mean "and/or", unless expressly stated otherwise.
(63) The above embodiments are to be understood as illustrative examples of the invention. It is to be understood that any feature described in relation to any one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.

Claims

1. A method of communicating configuration data of a tire pressure monitoring device affixed to a wheel of a vehicle, the method comprising, at the tire pressure monitoring device: receiving a request to confirm the configuration data; and responsive to the receipt of the request to confirm the configuration data, transmitting a configuration data signal which encodes the configuration data; wherein the configuration data signal includes data identifying at least one of an intended wheel location on the vehicle to which the tire pressure monitoring device is intended to be located or a security code representative of at least one security parameter of the tire pressure monitoring device; wherein the configuration data signal is configured to be received and understood by a human, wherein the configuration data signal is indicative of the at least one of the wheel location or the security code, wherein the configuration data signal comprises at least one of an audible signal or a visual signal, and wherein the audible signal is transmitted using a transducer of the tire pressure monitoring device and/or the visual signal is transmitted using a visual indicator of the tire pressure monitoring device.
2. The method as claimed in claim 1, wherein the visual indicator comprises a light source, and the method further comprises selectively illuminating the light source to transmit the configuration data signal.
3. The method as claimed in claim 2, wherein the configuration data signal comprises a number, and the selective illumination of the light source comprises encoding the number into an illumination sequence representing individual digits of the number.
4. The method as claimed in claim 1, wherein the configuration data signal comprises a start signal indicating a start signal indicating a start of transmission, an end signal indicating an end of the transmission, and an intermediate signal indicative of configuration data stored in the tire pressure monitoring device.
5. The method as claimed in claim 4, wherein the start signal comprises a first type of signal, the intermediate signal comprises a second type of signal, and the end signal comprises a third type of signal.
6. The method as claimed in claim 5, wherein the first type of signal comprises a first color light, the second type of signal comprises a second color light different to the first color light, and the third type of signal comprises a third color light different to the first and second colors of light.
7. The method as claimed in claim 1, wherein the configuration data signal comprises a plurality of sub-signals, each of the sub-signals comprising a start signal indicating a start of transmission of the sub-signal, an end signal indicating an end of transmission of the sub-signal, and an intermediate signal indicative of at least a portion of configuration data stored in the tire pressure

monitoring device.
8. The method as claimed in claim 7, wherein each sub-signal is confirmed as being received and understood by a human before a next sequential sub-signal is transmitted.
9. The method as claimed in claim 1, wherein the method further comprises transmitting an alert indicating that the transmission of the configuration data signal is about to begin.
10. The method as claimed in claim 1, wherein the tire pressure monitoring device comprises a trusted tire pressure monitoring device, and the method further comprises: verifying, by a human, that the configuration data of the tire pressure monitoring device matches expected configuration data, and verification by a human that the configuration data of the trusted tire pressure monitoring device matches expected configuration data takes place using an untrusted device.
11. The method as claimed in claim 10, wherein the expected configuration data comprises a security code representative of security parameters of a further tire pressure monitoring device.
12. The method as claimed in claim 10, wherein a request to confirm configuration data is submitted via a short-range communication protocol.
13. The method as claimed in claim 10, wherein the method further comprises: transmitting the configuration data signal to a further trusted tire pressure monitoring device, and subsequently transmitting the configuration data signal from the further trusted tire pressure monitoring device to be received and understood by a human.
14. A tire pressure monitoring device configured to perform the method claimed in claim 1.
15. A tire pressure monitoring device comprising: a memory configured to store configuration data, a light source, and a processor configured to selectively illuminate the light source to transmit a visual signal indicative of the configuration data stored in the memory, wherein the configuration data identifies at least one of an aircraft wheel location on an aircraft at which the tire pressure monitoring device is intended to be located, or a security code representative of security parameters of the tire pressure monitoring device, and wherein the tire pressure monitoring device is configured to be affixed to a wheel of a vehicle.
16. An aircraft comprising a tire pressure monitoring device as claimed in claim 15.
17. The method of claim 1, wherein the configuration data and the configuration data signal include the intended wheel location, and wherein the intended wheel location does not correspond to an actual wheel location on the vehicle.
18. The method of claim 17, further comprising determining that the tire pressure monitoring device is at a wheel location on the vehicle different than the intended wheel location based on the audible signal and/or the visual signal.
19. The method of claim 1, wherein the configuration data and the configuration data signal include the security code representative of the at least one security parameter, wherein the at least one security parameter includes a security key as a first security parameter and, as a second security parameter, at least one of a reference tire pressure, an identifier of the vehicle and the intended wheel location, and wherein the security code is generated using a hash function based on the first security parameter and the second security parameter.
20. The method of claim 1, further comprising using the audible signal or the visual signal to obtain the security code from the tire pressure monitoring device, determining whether the security code obtained from the audible or the visual signal to matches another security code obtained from another tire pressure monitoring device on the vehicle, and verifying that the tire pressure monitoring device is capable of secure communication with the another tire pressure monitoring device if there is a match between the security code from the audible or visual signal and the another security code.