US 20190005753A1

(19) United States

(12) Patent Application Publication

Leconte

(10) Pub. No.: US 2019/0005753 A1

(43) Pub. Date: Jan. 3, 2019

(54) **METHOD FOR ESTIMATING A DISTANCE AND ELECTRONIC UNIT FOR A VEHICLE**

(71) Applicant: **VALEO COMFORT AND DRIVING ASSISTANCE**, Créteil (FR)

(72) Inventor: **Eric Leconte**, Créteil (FR)

(73) Assignee: **VALEO COMFORT AND DRIVING ASSISTANCE**, Créteil (FR)

(21) Appl. No.: **15/769,188**

(22) PCT Filed: **Oct. 17, 2016**

(86) PCT No.: **PCT/EP2016/074908**

§ 371 (c)(1),
(2) Date: **Sep. 20, 2018**

(30) **Foreign Application Priority Data**

Oct. 19, 2015 (FR) 1559960

Publication Classification

(51) **Int. Cl.**

G07C 9/00	(2006.01)
G01S 13/84	(2006.01)
B60R 25/24	(2006.01)

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

CPC ***G07C 9/00309*** (2013.01); ***G01S 13/84*** (2013.01); *G07C 2009/00325* (2013.01); ***B60R 25/245*** (2013.01); *G07C 2009/00555* (2013.01); ***B60R 25/241*** (2013.01)

(57) **ABSTRACT**

The invention relates to a method for estimating a distance (d) between a vehicle (**10**) fitted with a first wireless communication module (**12**) and an identifier (**20**) fitted with a second wireless communication module (**22**), including the following steps: generating a randomly ordered list; receiving, by at least one of the first and second wireless communication modules (**12**, **22**), electromagnetic signals having a frequency that changes consecutively from among a plurality of frequencies in accordance with said list; for each frequency in the plurality of frequencies, measuring a reception phase of the electromagnetic signal having the relevant frequency; estimating said distance (d) on the basis of the measured phases. An electronic unit (**11**) for a vehicle (**10**) is also described.

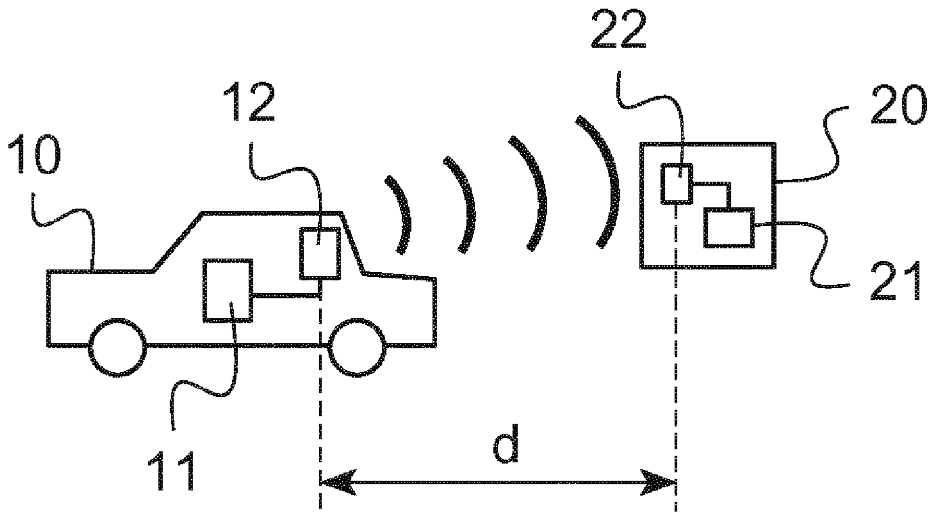


Fig.1

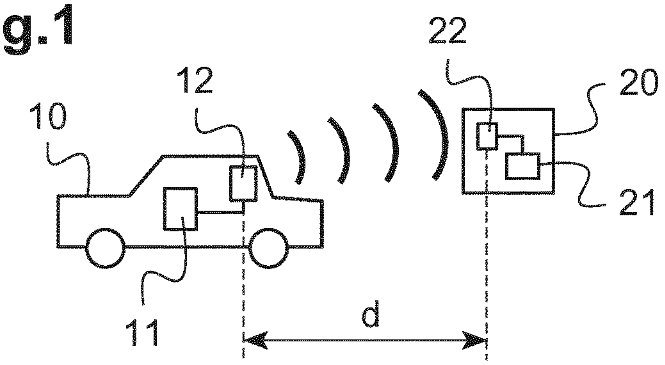


Fig.2

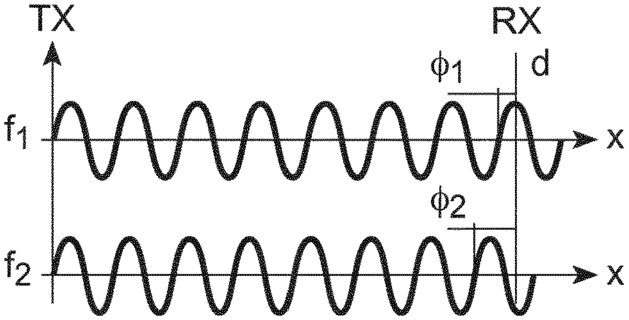


Fig.3

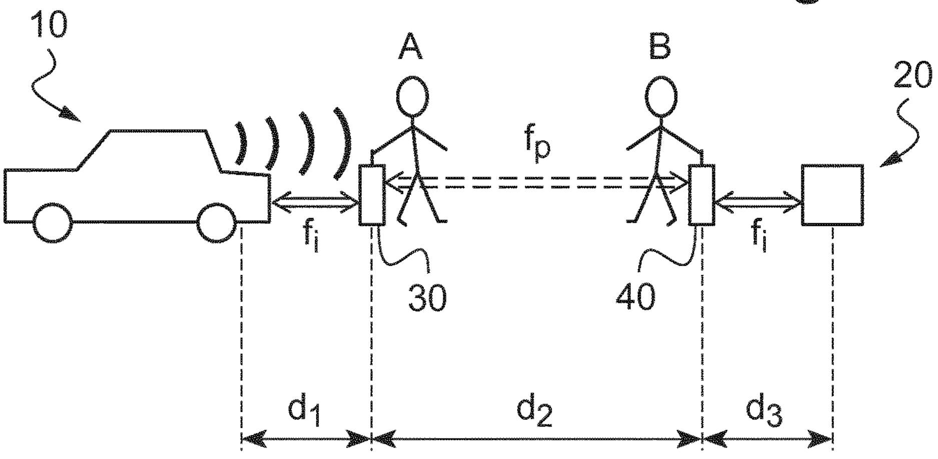
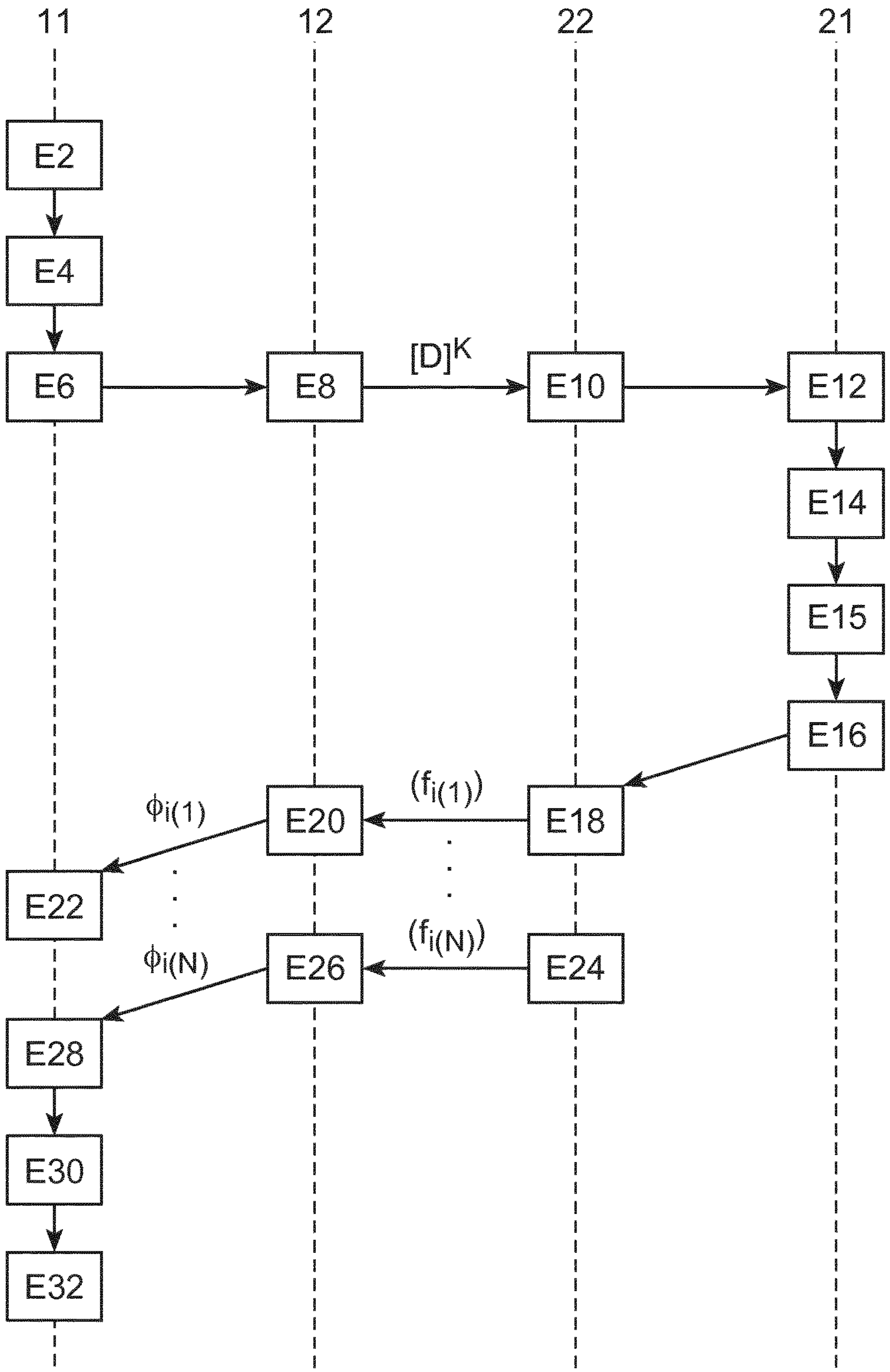


Fig.4


11
12
22
21
E2
E4
E6
E8
$[D]^K$
E10
E12
E14
E15
E16
$(f_{i(1)})$
E18
$\phi_{i(1)}$
E20
E22
$(f_{i(N)})$
E24
$\phi_{i(N)}$
E26
E28
E30
E32

METHOD FOR ESTIMATING A DISTANCE AND ELECTRONIC UNIT FOR A VEHICLE

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to estimating a distance between an identifier and a vehicle.

[0002] The invention more particularly relates to a method for estimating a distance and to an electronic unit for a vehicle.

[0003] The invention is particularly advantageously applicable to the case in which it is desired to protect the vehicle from relay attacks.

TECHNOLOGICAL BACKGROUND

[0004] PEPS (passive entry/passive start) systems are known in which the implementation of a function (such as unlocking the doors of a vehicle or starting such a vehicle) is conditional upon the presence of an identifier (generally carried by the user of the vehicle) in proximity to the vehicle.

[0005] Document US 2003/090 365 proposes measuring phases of reception of electromagnetic signals exchanged between the identifier and the vehicle for two different frequencies of the electromagnetic signals.

[0006] The distance separating the identifier and the vehicle may then be estimated on the basis of the difference between the measured phases.

SUBJECT MATTER OF THE INVENTION

[0007] In this context, the present invention provides a method for estimating a distance separating a vehicle provided with a first wireless communication module and an identifier provided with a second wireless communication module, comprising the following steps:

- **[0008]** generating a randomly ordered list;
- **[0009]** receiving, by at least one of the first and second wireless communication modules, electromagnetic signals having a frequency varying successively between a plurality of frequencies according to said list (in the order indicated in this list);
- **[0010]** for each frequency from the plurality of frequencies, measuring a phase of reception of the electromagnetic signal having the frequency in question;
- **[0011]** estimating said distance on the basis of the measured phases.

[0012] The frequency of the electromagnetic signals used to estimate the distance thus varies unpredictably and a relay attack such as described below with reference to FIG. **3** will therefore be ineffective.

[0013] According to features that are optional, and therefore nonlimiting:

- **[0014]** the method comprises a step of transmitting descriptive data of the list between the first wireless communication module and the second wireless communication module;
- **[0015]** the method comprises a step of encrypting the descriptive data of the list;
- **[0016]** the descriptive data of the list are transmitted under encryption between the first wireless communication module and the second wireless communication module;
- **[0017]** the method comprises a step of transmitting, by the other of the first and second wireless communication modules, said electromagnetic signals having a frequency varying successively between the plurality of frequencies according to said list;
- **[0018]** the step of estimating said distance comprises a step of determining a slope of a regression line linked to points that are each defined by a frequency from the plurality of frequencies and the associated measured phase;
- **[0019]** the reception step is implemented by the first wireless communication module.

[0020] The estimation method may further comprise one or more of the following steps:

- **[0021]** transmitting, by the first wireless communication module, electromagnetic signals having a frequency varying successively between the plurality of frequencies;
- **[0022]** receiving, by the second wireless communication module, electromagnetic signals having a frequency varying successively between the plurality of frequencies;
- **[0023]** for each frequency from the plurality of frequencies, measuring, at the second wireless communication module, a second phase of a received electromagnetic signal having the frequency in question;
- **[0024]** transmitting the second measured phases from the second wireless communication module to the first wireless communication module.

[0025] The transmitted second phases may then be used in the step of estimating said distance.

[0026] The aforementioned method may further comprise a step of potentially implementing a function of the vehicle according to the estimated distance.

[0027] The invention also provides an electronic unit for a vehicle, comprising:

- **[0028]** an element designed to generate a randomly ordered list;
- **[0029]** an element designed to control the reception (by a wireless communication module fitted to the vehicle), from an identifier, of electromagnetic signals having a frequency varying successively between a plurality of frequencies according to said list;
- **[0030]** an element designed to measure, for each frequency from the plurality of frequencies, a phase of reception of the electromagnetic signal having the frequency in question;
- **[0031]** an element designed to estimate a distance separating the vehicle and the identifier on the basis of the measured phases.

[0032] Such an electronic unit may also have at least one of the optional features presented above for the method.

[0033] When the electronic unit is produced on the basis of a microprocessor and at least one memory (such as described below), at least some of the aforementioned elements may be implemented by means of instructions stored in said memory and designed to carry out the function of the element in question when these instructions are run by the microprocessor.

DETAILED DESCRIPTION OF ONE EXEMPLARY EMBODIMENT

[0034] The following description with reference to the appended drawings, which are provided as nonlimiting examples, will facilitate understanding of the invention and how it may be carried out.

[0035] In the appended drawings:

[0036] FIG. **1** schematically shows the main elements of a system in which the invention is able to be implemented;

[0037] FIG. **2** schematically shows the propagation of two signals having frequencies that differ from one another;

[0038] FIG. **3** shows a possible relay attack on a system of the type of that of FIG. **1**; and

[0039] FIG. **4** is a flow chart showing a method for estimating the distance separating an identifier and a vehicle.

[0040] FIG. **1** schematically shows the main elements of a system in which the invention is able to be implemented.

[0041] Such a system comprises a vehicle **10**, here an automotive vehicle, and an identifier **20**, for example a key or badge for accessing the vehicle **10** (or, as a variant, a user terminal, such as a mobile telephone or a smartphone, provided with access rights to the vehicle **10**).

[0042] The vehicle **10** is provided with an electronic control unit **11** and with a communication module **12**.

[0043] The electronic control unit **11** comprises, for example, a microprocessor and at least one memory, for example a rewritable non-volatile memory. The memory stores, in particular, program instructions that allow, when they are run by the microprocessor, the electronic control unit **11** to implement the methods described below. The memory also stores values or parameters used in these methods, for example measured phase cl values (as explained below).

[0044] The memory of the electronic control unit **11** additionally stores a cryptographic key K (which has for example been written into the electronic control unit **11** during the manufacture thereof).

[0045] As a variant, the electronic control unit **11** could be embodied in the form of an application-specific integrated circuit (or ASIC).

[0046] The communication module **12** is designed to establish a wireless link with other electronic devices, in this case a link of Bluetooth Low Energy (or BLE) type. The communication module **12** is therefore in particular designed to transmit and receive electromagnetic signals (typically with a frequency higher than 1 MHz, or even 500 MHz), in this case in the 2.4 GHz band.

[0047] The identifier **20** is generally carried by a user of the vehicle **10**, and makes it possible to control certain functions of the vehicle **10** (for example unlocking the doors of the vehicle **10**), in particular when it is brought close to the vehicle **10**. The identifier **20** may potentially further include control buttons, by way of which the user is able to control at least some of the aforementioned functions or other functions of the vehicle **10**.

[0048] The identifier **20** comprises a control unit **21** and a communication module **22**.

[0049] The control unit **21** is, for example, embodied by means of a microprocessor and at least one memory, for example a rewritable non-volatile memory. The memory stores, in particular, program instructions that allow, when they are run by the microprocessor, the control unit **21** to implement the methods described below. The memory also stores values or parameters used in these methods.

[0050] The memory of the control unit **21** also additionally stores the cryptographic key K. In the case in which the identifier **20** is a badge (or key) for accessing the vehicle, the cryptographic key K has for example been written into the memory of the control unit **21** during the manufacture of the identifier **20**. In the variant mentioned above in which the identifier **20** is a user terminal, the cryptographic key K has for example been received from a remote server and stored during a phase of registration for a service for controlling vehicle functions by means of the user terminal.

[0051] As a variant, the control unit **21** could be embodied in the form of an application-specific integrated circuit.

[0052] The communication module **22** is designed to establish a wireless link (in this case of Bluetooth Low Energy or BLE type) with other electronic devices, in particular with the electronic control unit **11** of the vehicle **10** via the communication module **12** mentioned above. The communication module **22** is therefore also designed to transmit and receive electromagnetic signals (typically with a frequency higher than 1 MHz, or even 500 MHz), in this case in the 2.4 GHz band.

[0053] By virtue of the wireless link thus established between the communication module **12** of the vehicle **10** and the communication module **22** of the identifier **20**, data are able to be exchanged between the electronic control unit **11** of the vehicle **10** and the control unit **21** of the identifier **20**, as explained below.

[0054] The electromagnetic signals exchanged between the communication modules **12**, **22** may additionally be used to evaluate the distance d separating the identifier **20** and the vehicle **10**, on the basis of the principle now explained with reference to FIG. **2**.

[0055] Specifically, FIG. **2** schematically shows the propagation of two signals having respective frequencies f_1, f_2 (which differ from one another) between a transmitter module TX and a receiver module RX (and along an axis Ox passing through these two modules).

[0056] Measuring the phase ϕ_i of each of these signals at the receiver RX makes it possible to deduce the distance d separating the transmitter module TX and the receiver module RX according to the formula:

$$d=c.(\phi_2-\phi_1)/[2\pi.(f_2-f_1)],$$

[0057] where c is the speed of the electromagnetic waves.

[0058] It is possible to take such phase ϕ_i measurements for more than two signals having distinct frequencies f_i, which makes it possible to overcome the reflection or refraction phenomena that are liable to occur at certain frequencies.

[0059] FIG. 3 illustrates how a system operating on such a principle could be subject to an advanced relay attack.

[0060] A first attacker A is located in proximity to the vehicle **10** (specifically at a distance di from the vehicle **10**) and carries a first electronic module **30** which receives the signal transmitted by the vehicle **10** at a frequency f_i (it is assumed here that the transmitter module TX is the communication module **12** of the vehicle **10**).

[0061] The first electronic module **30** modulates the received signal by means of a carrier of frequency fp and transmits the obtained modulated signal to a second electronic module **40** carried by an attacker B located in proximity to the identifier **20**.

[0062] As can be seen in FIG. **3**, the electronic modules **30**, **40** are separated by a distance d**2**, while the second electronic module **40** is at a distance d**3** from the identifier **20**.

[0063] The second electronic module **40** demodulates the signal that it receives and hence obtains the signal of frequency f_i, which it transmits to the identifier **20**.

[0064] The value of the phase φ corresponding to the propagation of the electromagnetic signals from the vehicle **10** to the identifier **20** via the attackers A, B is:

$$\varphi=2\pi.(f_P-f_i).d_2/c+2\pi.f_i.(d_1+d_3)/c$$

[0065] Consequently, if the attackers know the successive frequencies of transmission f_i and design the electronic modules **30**, **40** so that the quantity (f_P-f_i) is constant (i.e. that the frequency f_P of the carrier is modified for each transmission frequency f_i so as to have: $f_P-f_i=\text{cte}$), the attack will go unnoticed since the distance estimate proposed above gives in this case:

$$d=c.[\varphi(f_2)-\varphi(f_1)]/[2\pi.(f_2-f_1)]=d_1+d_3.$$

[0066] Stated otherwise, since the quantity (f_P-f_i) is constant, the term $2\pi.(f_P-f_i).d_2/c$ is also constant from one measurement to the next and is cancelled out when differencing between the measured phases $\varphi(f_2)$, $\varphi(f_1)$.

[0067] A method for estimating the distance d which is not subject to such an attack is now described with reference to FIG. **4**.

[0068] This method begins with step E**2**, in which the electronic control unit **11** of the vehicle **10** generates a list of randomly ordered frequencies f_i.

[0069] In practice, the electronic control unit **11** stores for example a set of predefined frequencies $f_1, f_2, \ldots, f_N$ (where N is for example comprised between 50 and 100) and generates, by random sampling, an ordered list of indices i(1), i(2), . . . , i(N): the list of randomly ordered frequencies is then $f_{i(1)}, f_{i(2)}, \ldots, f_{i(N)}$.

[0070] The electronic control unit **11** then encrypts, in a step E**4**, descriptive data D of the ordered list by means of a cryptographic encryption algorithm using the cryptographic key K.

[0071] The descriptive data D of the ordered list represent for example the successive values of the frequencies f_i, in the order given by the ordered list generated in step E**2**. In the example given above, the descriptive data D of the ordered list may, as a variant, represent the list of indices i(1), i(2), . . . , i(N).

[0072] The electronic control unit **11** then orders the communication module **12** to transmit the encrypted descriptive data $[D]^K$ (step E**6**).

[0073] The communication module **12** thus transmits (step E**8**) the encrypted descriptive data $[D]^K$ via the wireless link established between the communication module **12** of the vehicle **10** and the communication module **22** of the identifier **20**.

[0074] It should be noted that it is possible to envisage, when establishing the wireless link or after the establishment thereof, a process of authenticating the identifier **20** by the electronic control unit **11** of the vehicle **10**, for example by checking (potentially by means of a challenge-response protocol) that the identifier **20** does indeed hold access rights to the vehicle **10** (i.e. in practice that the identifier **20** stores a given cryptographic key, for example the aforementioned cryptographic key K).

[0075] The communication module **22** of the identifier **20** receives the encrypted descriptive data $[D]^K$ in step E**10** and transmits these data $[D]^K$ to the control unit **21** (step E**12**).

[0076] The control unit **21** may thus decrypt, in step E**14**, the encrypted descriptive data $[D]^K$ by means of a decryption algorithm using the cryptographic key K (stored as already mentioned in the control unit **21**).

[0077] As mentioned above, the use of a symmetric key encryption system is proposed in the example described here. However, as a variant, it would be possible to use an encryption system in which the encryption key and the decryption key are different, for example a system using a public key (used for encryption) and a private key (used for decryption).

[0078] The control unit **21** is thus able to store, in step E**15**, the list of randomly ordered frequencies indicated by the descriptive data D. In the exemplary implementation described above, it is possible to envisage the control unit **21** storing the set of predefined frequencies $f_1, f_2, \ldots, f_N$ (which is identical to that stored in the electronic control unit **11**) and the control unit **21** then storing in practice, in step E**15**, the ordered list of indices i(1), i(2), . . . , i(N) defined by the descriptive data.

[0079] In the example described here, the ordered list of frequencies is generated randomly at the vehicle **10** (specifically by the electronic control unit **11**) and transmitted to the identifier **20** so that knowledge of this list is shared by these two entities. It is possible to envisage, as a variant, this ordered list of frequencies being generated at the identifier **20** and transmitted, for example in encrypted form, to the vehicle **10**, which also allows knowledge of the list to be shared.

[0080] The control unit **21** of the identifier **20** then orders (step E**16**) the communication module **22** to transmit electromagnetic signals successively having the frequencies f_i listed in the ordered list of frequencies.

[0081] For example, step E**18** of FIG. **4** shows an electromagnetic signal having a frequency $f_{i(1)}$ being transmitted by the communication module **22** of the identifier **20**.

[0082] This electromagnetic signal having a frequency $f_{i(1)}$ is received by the communication module **12** of the vehicle **10** in step E**20**, which makes it possible to obtain a measurement of the phase $\phi_{i(1)}$ of the received electromagnetic signal. Reference may be made in this regard to document U.S. Pat. No. 5,220,332.

[0083] The measured phase $\phi_{i(1)}$ is received by the electronic control unit **11** and stored in step E**22**.

[0084] Steps similar to steps E**18** to E**22** are carried out for each of the frequencies in the ordered frequency list, in the order established by this list.

[0085] FIG. **4** also shows the transmission, by the communication module **22**, of an electromagnetic signal having a frequency $f_{i(N)}$ (last frequency in the ordered list in the described example) in step E**24**.

[0086] This electromagnetic signal having a frequency $f_{i(N)}$ is received by the communication module **12** of the vehicle **10** in step E**26**, which makes it possible to obtain a measurement of the phase $\phi_{i(N)}$ of the received electromagnetic signal.

[0087] The measured phase $\phi_{i(N)}$ is received by the electronic control unit **11** and stored in step E**28**.

[0088] The electronic control unit **11** thus stores the measured phases ϕ_i for a plurality of frequencies f_i (regardless of the order in which these measurements have been taken) and may deduce therefrom in step E**30** an estimate of the distance d separating the identifier **20** and the vehicle **10**.

[0089] For example, by accounting for the fact that the various points of coordinates (f_i, ϕ_i) are in theory located on a straight line having a slope $c/(2\pi.d)$ according to the distance estimation principle recalled with reference to FIG. **2**, step E**30** comprises for example determining the slope of a regression line linked to the points of coordinates (f_i, ϕ_i) and determining the estimated distance according to this slope.

[0090] The electronic control unit **11** of the vehicle **10** may then potentially control, in step E**32**, a function of the vehicle **10** according to the estimated distance. For example, the electronic control unit **11** may control the unlocking of the doors of the vehicle **10** if the estimated distance is below a predetermined threshold.

[0091] In the example described above, the electromagnetic signals (successively having the frequencies f_i in the order indicated in the ordered list of frequencies) are transmitted by the communication module **22** of the identifier **20**.

[0092] As a variant, these electromagnetic signals could be transmitted by the communication module **12** of the vehicle **10**; the reception phases ϕ_i would then be measured at the communication module **22**. The measured phases ϕ_i associated with each frequency f_i could then be transmitted (via the wireless link established between the communication modules **12**, **22**, potentially in encrypted form) to the electronic control unit **11** for estimating the distance d (as in step E**30** described above); the measured phases ϕ_i could also be used within the identifier **20** to estimate the distance d (according to the principle recalled above), in which case the distance d estimated within the identifier **20** is transmitted to the electronic control unit **11** via the wireless link established between the communication modules **12**, **22** (potentially in encrypted form).

[0093] According to yet another variant, electromagnetic signals successively having the frequencies f_i (in the order indicated by the randomly ordered list) are transmitted by the communication module **22** of the identifier **20** and a phase ϕ_i measurement is taken at the vehicle **10** as described above with reference to figure **4**. Furthermore, electromagnetic signals successively having the frequencies f_i (in the order indicated by the randomly ordered list, or in another randomly defined order as explained above) are transmitted by the communication module **12** of the vehicle **10** and a phase ϕ'_i measurement is taken at the identifier **20**.

[0094] The phase ϕ'_i values measured at the identifier **20** are transmitted to the electronic control unit **11** via the wireless link established between the communication modules **12**, **22**.

[0095] According to this variant, the electronic control unit **11** determines, for each frequency f_i, the sum of the corresponding phase ϕ_i measured at the vehicle **10** and of the corresponding phase ϕ'_i measured at the identifier **20**, and estimates the distance d separating the identifier **20** and the vehicle **10** on the basis of these sums (which are each associated with a frequency f_i).

[0096] Such sums effectively corresponds to a return journey of the electromagnetic signal, i.e. to a distance equal to 2.d, and make it possible to overcome the difference in phase reference which may exist between the two communication modules **12**, **22**, as explained for example in document U.S. Pat. No. 5,220,332.

[0097] Specifically, the process of exchanging the signals and measuring the reception phases is then as follows for a given frequency f:

[0098] transmitting, by a first module (for example the communication module **12**), an electromagnetic signal having this given frequency f with a reference phase ϕ_{ref};

[0099] receiving the signal by the second module (here the communication module **22**) with an (absolute) phase $\phi'_{abs}=\phi_{ref}+2*\pi*d*f/c$;

[0100] measuring this phase by the second module using its own reference phase ϕ'_{ref}, the value of the measured phase therefore being:

$$\phi'=\phi'_{abs}-\phi'_{ref}=\phi_{ref}+2*\pi*d*f/c-\phi'_{ref};$$

[0101] transmitting, by the second module, an electromagnetic signal having this same given frequency f with its own reference phase ϕ'_{ref};

[0102] receiving, by the first module, this electromagnetic signal with an (absolute) phase $\phi_{abs}=\phi'_{ref}+2*\pi*d*f/c$;

[0103] measuring this phase by the first module using its reference phase ϕ'_{ref}, which gives a measured phase:

$$\phi=\phi_{abs}-\phi_{ref}=\phi'_{ref}+2*\pi*d*f/c-\phi_{ref}$$

[0104] The value of the sum ($\phi+\phi'$) of the measured phases is: $2*(2*\pi)*d*f/c$ and the phase offset between the two modules **12**, **22** is thus overcome.

[0105] In another possible embodiment, the reception of measured phases, the calculation of the aforementioned sums and the estimation of the distance on the basis of these sums could be carried out by the control unit **21** of the identifier **20** (the estimated distance could then potentially be transmitted from the control unit **21** to the electronic control unit **11** of the vehicle **10** via the established wireless link).

[0106] In all cases, the order in which the various frequencies f_i are used for the transmitted signals is random so that an attacker will not be able to predict this order and match the frequency of the carrier f_p to the frequency f_i of the transmitted signal (as explained above with reference to FIG. **3**). The attackers will therefore not be able to implement the attack described above with reference to FIG. **3**.

1. A method for estimating a distance separating a vehicle provided with a first wireless communication module and an identifier provided with a second wireless communication module, comprising:

generating a randomly ordered list;

receiving, by at least one of the first and second wireless communication modules, electromagnetic signals having a frequency varying successively between a plurality of frequencies according to said list;

for each frequency from the plurality of frequencies, measuring a phase of reception of the electromagnetic signal having the frequency in question; and

estimating said distance on the basis of the measured phases.

2. The estimation method as claimed in claim **1**, further comprising transmitting descriptive data of the list between the first wireless communication module and the second wireless communication module.

3. The estimation method as claimed in claim **2**, further comprising encrypting the descriptive data of the list, wherein the descriptive data of the list are transmitted under encryption between the first wireless communication module and the second wireless communication module.

4. The estimation method as claimed in claim **1**, further comprising transmitting, by the other of the first and second wireless communication modules, said electromagnetic signals having a frequency varying successively between the plurality of frequencies according to said list.

5. The estimation method as claimed in claim **1**, wherein estimating said distance comprises determining a slope of a regression line linked to points that are each defined by a frequency from the plurality of frequencies and the associated measured phase.

6. The estimation method as claimed in claim **1**, wherein receiving the electromagnetic signals is implemented by the first wireless communication module.

7. The estimation method as claimed in claim **6**, further comprising:

for each frequency from the plurality of frequencies, measuring, at the second wireless communication module, a second phase of a received electromagnetic signal having the frequency in question; and

transmitting the second measured phases from the second wireless communication module to the first wireless communication module.

8. The estimation method as claimed in claim **7**, wherein the transmitted second phases are used in estimating said distance.

9. The estimation method as claimed in claim **1**, further comprising potentially implementing a function of the vehicle according to the estimated distance.

10. An electronic unit for a vehicle, comprising:

an element for generating a randomly ordered list;

an element for controlling the reception, from an identifier, of electromagnetic signals having a frequency varying successively between a plurality of frequencies according to said list;

an element for measuring, for each frequency from the plurality of frequencies, a phase of reception of the electromagnetic signal having the frequency in question; and

an element for estimating a distance separating the vehicle and the identifier on the basis of the measured phases.

* * * * *