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(71) Applicant: **Continental Automotive GmbH**
30165 Hannover (DE)

(72) Inventors:
- **Bejinaru, Razvan c/o Continental Automotive GmbH**
  81737 München (DE)
- **Maritescu-Lungocea, Manuel-Ciprian**
  81737 München (DE)

(74) Representative: **Continental Corporation**
c/o Continental Automotive GmbH
Intellectual Property
Postfach 83 01 16
81701 München (DE)

(54) **ANTENNA ARRANGEMENT FOR ELECTRONIC VEHICLE KEY**

(57) An antenna arrangement comprises a large loop antenna (32), an antenna circuitry (21) electrically coupled to the large loop antenna (32), a first capacitance (C1) coupled in series with the large loop antenna (32) and between the large loop antenna (32) and a ground potential (GND), and a second capacitance (C2) coupled between the ground potential (GND) and a common node between the large loop antenna (32) and the antenna circuitry (21).

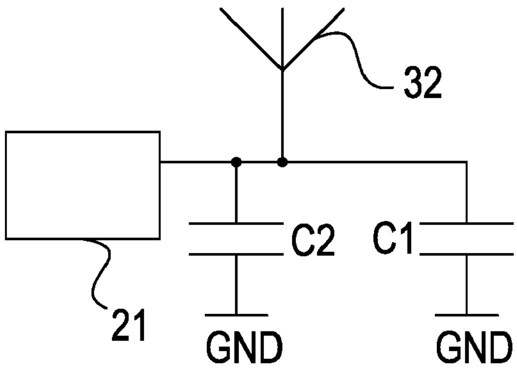

FIG 4

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Description

[0001] The current invention relates to an antenna arrangement, in particular an antenna arrangement for an electronic vehicle key.

[0002] Most vehicles today may be unlocked and remotely started using an electronic vehicle key. Some "start and stop" access systems are well known in which the user needs to press an unlocking button from the electronic remote key to unlock or lock the vehicle, start the engine of the vehicle, or open a trunk of the vehicle, for example. Such an electronic vehicle key usually has to be inserted into an immobilizer station located inside the vehicle which recognizes the vehicle key and allows the user to start the vehicle. Such systems replace the originally known ignition switch systems. Other "start and stop" access systems do not require the user to press a button or to insert the key in an immobilizer in order to unlock or lock the vehicle or to start the engine. Such a "start and stop" access system is called a passive start and entry system. With passive start and entry systems, the vehicle may be unlocked automatically when the key is detected within a certain range from the vehicle. In order to start the vehicle, a start button within the vehicle usually has to be pressed.

[0003] Such an electronic vehicle key communicates with the vehicle using wireless technology. For this reason, an electronic vehicle key usually comprises two or more different antennas. For example, an electronic vehicle key may comprise at least one low frequency (LF) antenna and at least one radio frequency (UHF, ultra-high frequency) antenna. At least one of the antennas may be implemented as a loop antenna. Small-loop antennas generally have certain advantages over large-loop antennas. However, the behavior of a small-loop antenna may shift to a large-loop behavior if certain conditions arise. This may negatively affect the performance of the antenna.

[0004] There is a need to provide an antenna arrangement for an electronic vehicle key which provides a satisfactory performance and the advantages of a small-loop antenna.

[0005] This problem is solved by an antenna arrangement according to claim 1 and an electronic vehicle key with an antenna arrangement according to claim 11. Configurations and further developments of the invention are the subject of the dependent claims.

[0006] An antenna arrangement includes a large loop antenna, an antenna circuitry electrically coupled to the large loop antenna, a first capacitance coupled in series with the large loop antenna and between the large loop antenna and a ground potential, and a second capacitance coupled between the ground potential and a common node between the large loop antenna and the antenna circuitry.

[0007] This antenna arrangement allows to maintain the electrical length of a large loop antenna, while at the same time benefiting from the advantages of a small loop antenna.

[0008] The antenna arrangement may further include a substrate or printed circuit board, wherein the antenna circuitry and the large loop antenna are arranged on the substrate or printed circuit board.

[0009] When an antenna is printed on a substrate or printed circuit board, the electric length of the antenna is multiplied by the square root of the relative permittivity of the substrate or printed circuit board. Arranging the capacitances accordingly, however, still allows to benefit from the advantages of a small loop antenna design.

[0010] The substrate or printed circuit board may include a ceramic substrate.

[0011] The relative permittivity of a ceramic is generally comparably high. The advantages of a small loop antenna, however, may still be maintained by arranging the capacitances accordingly.

[0012] The substrate or printed circuit board with the antenna circuitry and the large loop antenna arranged thereon may be molded into a potting material.

[0013] This increases the relative permittivity even further. The advantages of a small loop antenna, however, may still be maintained by arranging the capacitances accordingly.

[0014] The potting material may include polyurethane. The advantages of a small loop antenna, however, may still be maintained by arranging the capacitances accordingly.

[0015] The antenna arrangement may further include a third capacitance coupled in series with the large loop antenna and between the large loop antenna and the antenna circuitry.

[0016] This allows a satisfactory antenna impedance matching.

[0017] The antenna arrangement may further include a fourth capacitance coupled between the ground potential and a common node between the large loop antenna and the third capacitance.

[0018] This allows a satisfactory antenna impedance matching.

[0019] The large loop antenna may include an electrical length of between 9/10 and 11/10 of the wavelength of the operating frequency of the large loop antenna. The antenna circuitry may be configured to control the antenna and transmit and/or receive data sent or received by the antenna.

[0020] The antenna arrangement may further include a microcontroller coupled to the antenna circuitry.

[0021] An electronic vehicle key may include an antenna arrangement as described above.

[0022] Examples are now explained with reference to the drawings. In the drawings the same reference characters denote like features.

Figure 1 , including Figures 1A and 1B, schematically illustrates a small-loop antenna (Figure 1A) and a large-loop antenna (Figure 1B) arranged on a printed circuit board.

Figure 2 , including Figures 2A and 2B, schematically illustrates in smith diagrams an antenna impedance of a small-loop antenna (Figure 2A) and of a large-loop antenna (Figure 2B).

Figure 3 schematically illustrates an antenna arrangement according to one example.

Figure 4 schematically illustrates an antenna arrangement according to another example.

Figure 5 schematically illustrates in a smith diagram an antenna impedance of a large-loop antenna arranged in the antenna arrangement of Figure 3.

Figure 6 schematically illustrates in a smith diagram an antenna impedance of a large-loop antenna arranged in the antenna arrangement of Figure 4.

Figure 7 schematically illustrates an antenna arrangement according to another example.

Figure 8 schematically illustrates an antenna arrangement according to an even further example.

Figure 9 schematically illustrates in a smith diagram an antenna impedance of a small-loop antenna arranged in the antenna arrangement of Figure 7.

Figure 10 schematically illustrates in a smith diagram an antenna impedance of a large-loop antenna arranged in the antenna arrangement of Figure 8.

[0023] In the following Figures, only such elements are illustrated that are useful for the understanding of the present invention. The antenna arrangement and the electronic vehicle key described below may comprise more than the exemplary elements illustrated in the Figures. However, any additional elements that are not needed for the implementation of the present invention have been omitted for the sake of clarity.

[0024] Figure 1 illustrates an antenna arrangement that may be arranged in an electronic vehicle key. Signals may be sent between a vehicle and the electronic vehicle key (vehicle not illustrated in Figure 1). For example, the electronic vehicle key may send inquiry signals to the vehicle to indicate the desire of a user to unlock/lock the vehicle. Further, authentication signals may be sent between the electronic vehicle key and the vehicle, for example, in order to prevent unauthorized users (unauthorized keys) from unlocking or starting the vehicle. Many other signals may be sent between the electronic vehicle key and the vehicle for many different applications.

[0025] An electronic vehicle key, therefore, may comprise different antennas. A first antenna may be a low frequency (LF) antenna, for example. Low frequency signals may be sent at frequencies in the range between 30 to 300kHz, for example. A second antenna may be a radio frequency (RF) or ultra-high frequency (UHF) antenna, for example. Radio frequency signals may be sent at frequencies in the range between 20kHz to 300GHz. In Figure 1 only a radio frequency or ultra-high frequency antenna 31, 32 is schematically illustrated. The antenna 31, 32 may be coupled to corresponding antenna circuitries 21. The antenna circuitry 21 may be configured to control the antenna 31, 32, and transmit and/or receive data sent or received by the antenna 31, 32. The antenna arrangement may further comprise a microcontroller as well as other necessary components. The microcontroller may be coupled to the antenna circuitry 21. The antenna 31, 32 and corresponding circuitry 21 are arranged on a printed circuit board 10.

[0026] In the example illustrated in Figure 1A, the antenna is a small-loop antenna 31, while in the example illustrated in Figure 1B, the antenna is a large-loop antenna 32. An antenna is generally considered a small-loop antenna if an overall perimeter or (electrical) length of the antenna loop is small as compared to the wavelength of the antenna. Small in this context generally means that the perimeter is shorter than 1/10 of the wavelength of the antenna. On the other hand, antennas are considered large-loop antennas if the overall perimeter or (electrical) length of the antenna loop is large as compared to the wavelength of the antenna. Large in this context generally means that the perimeter is significantly larger than 1/10 of the wavelength of the antenna, e.g., between 9/10 and 11/10 of the wavelength or, in other words, close to a full wavelength of the antenna.

[0027] Small-loop antennas generally have several advantages such as, e.g., the influence of foreign objects and human bodies close to the antenna have a comparably small influence on the performance of the antenna, the antenna shows little sensitivity to electro-magnetic noise, the antenna has an omni-directional pattern in the loop lane, and the antenna is comparably small and easy and cheap to realize.

[0028] An antenna can generally be realized in metal (metal loop) or may be printed on a printed circuit board 10, as is exemplarily illustrated in Figure 1. At a working frequency of the antenna, generally no natural resonances arise and the antenna can be matched to a specific impedance comparably easy. Impedance matching is generally an important aspect when an antenna arrangement is assembled to allow the antenna to operate in the desired frequency band with maximum efficiency. An optimized efficiency results in a maximum range, minimal power consumption, reduced heating and a reliable data throughput. In most cases today, an antenna is matched to an impedance of 50Ω. Matching the input impedance of an antenna to 50Ω (or any other desired impedance) is a prerequisite in order to ensure maximum power transfer from the circuitry 21 to the antenna 31, 32 with a negligible amount of power being reflected back.

[0029] When an antenna is printed on a substrate or printed circuit board 10, e.g., on a FR4 PCB, or integrated in a plastic molding or carrier, the electronic length of the antenna is multiplied by the square root of the relative permittivity of the substrate or PCB 10. When the permittivity of the substrate or PCB 10 is high, this may result in a significant increase of the electrical length of the antenna. The substrate or printed circuit board 10 with the antenna circuitry 21 and the antenna 32 arranged may be molded into a potting material. The potting material may comprise polyurethane, for example. This may increase the electrical length even further while at the same time introducing losses in the total power radiated by the antenna. The resulting electrical length of a small-loop antenna may increase to such an extent that the electrical length is shifted more and more towards the desired wavelength. A small-loop antenna, therefore, may behave more like a large-loop antenna in such a case and the advantages of small-loop antennas may be lost.

[0030] The small-loop antenna 31 of Figure 1A and the large-loop antenna 32 of Figure 1B may have different disadvantages such as a strong resonance and high antenna impedance (large-loop antenna) or no resonance close to the working frequency and a small antenna impedance (small-loop antenna). A matching between a radio frequency antenna 31, 32 and a corresponding radio frequency circuitry 21 (e.g., RF IC) may lead to a reduced radiated power due to an in-band resonance with a high real part of the large-loop impedance (e.g., hundreds of ohms compared to a few ohms for a small-loop design). This is schematically illustrated in Figure 2, wherein Figure 2A illustrates in a smith diagram an exemplary antenna impedance of the small-loop antenna 31 of Figure 1A, and Figure 2B illustrates in a smith diagram an exemplary antenna impedance of the large-loop antenna 32 of Figure 1B.

[0031] As can be seen, the small-loop antenna 31 shows no resonance in the desired frequency band (Figure 2A), while the large-loop antenna 32 shows a resonance in the desired frequency band (Figure 2B). The resonance is highlighted by the bold arrow in Figure 2B which points towards the resonance. The design of the large-loop antenna 32, therefore, is very sensitive to external influence (e.g., foreign objects, human bodies, noise, etc.) and the input impedance may not be stable and may cause problems with reflections and may be prone to drops in signal quality.

[0032] For this reason, generally a small-loop antenna may 31 be preferred over a large-loop antenna 32 for many applications. However, in some cases the overall design of the antenna arrangement cannot be adapted to reduce the electrical length of the antenna from a large-loop antenna to a small-loop antenna. This may be the case, for example, when a potting material is used to fill an inside volume of the electronic module (e.g., electronic vehicle key), or when materials having a high permittivity are used within the electronic module. A substrate or printed circuit board 10 including a ceramic material, for example, may have a high permittivity due to the low-loss properties of ceramic materials.

[0033] An antenna arrangement according to an example allows maintaining the electrical length of a large-loop antenna 32 while, at the same time, benefiting from the advantages of a small-loop antenna 31. This may be achieved by electrically loading the large-loop antenna 32 using at least one discrete component. The at least one discrete component artificially shifts the electrical behavior of the large-loop antenna 32 to a resonance-free area. A matching may be implemented which adapts this impedance at the working frequency (e.g., 433.92MHz) close to a desired value (e.g., 50Ω). The value of the at least one discrete component may be chosen to match the working frequency of the specific application.

[0034] In the antenna arrangement illustrated in Figure 3, a first capacitance C1 is coupled in series with a large loop antenna 32. In particular, the first capacitance C1 is coupled between the large loop antenna 32 and a ground potential GND. The corresponding smith diagram in Figure 5 shows the corresponding antenna impedance. As can be seen, the resonance in the desired frequency band which is present in Figure 2B, is no longer present in the antenna arrangement of Figure 3. The first capacitance C1 moves the impedance towards point M1, as indicated with the dashed arrow in Figure 5.

[0035] Figure 4 shows an antenna arrangement according to another example. The antenna arrangement also comprises a large-loop antenna 32. The large-loop antenna 32 is coupled in series with a first capacitance C1. A second capacitance C2 (shunt capacitor) is coupled between a ground potential GND and a common circuit node between the antenna 31 and the antenna circuitry 21. The second capacitance C2 moves the impedance towards point M2, as indicated with the dashed arrow in the smith diagram illustrated in Figure 6.

[0036] Figure 7 schematically illustrates a further example of an antenna arrangement. A first capacitance C1 is coupled in series with the antenna 31. In particular, the first capacitance C1 is coupled between the antenna 31 and a ground potential GND. In this arrangement, a third capacitance C3 is coupled in series with the antenna 31. In particular, the third capacitance C3 is coupled between the antenna 31 and the antenna circuitry 21. A second capacitance C2 is coupled between a ground potential GND and a common node between the antenna circuitry 21 and the third capacitance C3. The antenna 31 in this case is a small-loop antenna. Figure 9 in a smith diagram exemplarily illustrates the corresponding antenna impedance.

[0037] Figure 8 schematically illustrates an even further example of an antenna arrangement. The antenna 32 in this arrangement is a large loop antenna. In this arrangement, a first capacitance C1 is coupled in series between the large loop antenna 32 and a ground potential GND, similar to the arrangement of Figure 3. A third capacitance C3 is coupled in series between the large loop antenna 32 and the antenna circuitry 21. A second capacitance C2 is coupled between a ground potential GND and a common node between the antenna circuitry 21 and the third capacitance C3. A fourth capacitance C4 is coupled between a ground potential GND and a common node between the large loop antenna 32 and the third capacitance C3. Figure 10 in a smith diagram exemplarily illustrates the corresponding antenna impedance.

[0038] With the described antenna arrangements, a large loop antenna 32 does not have a directional pattern anymore. When using a large loop antenna 32, an antenna gain is generally larger (e.g., approximately +4dBi) as compared to a small loop design. At the same output power, therefore, the antenna arrangement with the large-loop antenna 32 as described above may radiate up to 4dB more, or even more than 4dB. That is, that the current consumption of the antenna arrangement may be reduced in the large-loop antenna arrangement while obtaining a similar performance as with a small-loop antenna arrangement.

Claims

1. An antenna arrangement comprising
a large loop antenna (32);
an antenna circuitry (21) electrically coupled to the large loop antenna (32);
a first capacitance (C1) coupled in series with the large loop antenna (32) and between the large loop antenna (32) and a ground potential (GND); and
a second capacitance (C2) coupled between the ground potential (GND) and a common node between the large loop antenna (32) and the antenna circuitry (21).

2. The antenna arrangement of claim 1, further comprising a substrate or printed circuit board (10), wherein the antenna circuitry (21) and the large loop antenna (32) are arranged on the substrate or printed circuit board (10).

3. The antenna arrangement of claim 2, wherein the substrate or printed circuit board (10) comprises a ceramic substrate.

4. The antenna arrangement of claim 2 or 3, wherein the substrate or printed circuit board (10) with the antenna circuitry (21) and the large loop antenna (32) arranged thereon is molded into a potting material.

5. The antenna arrangement of claim 4, wherein the potting material comprises polyurethane.

6. The antenna arrangement according to any of the preceding claims, further comprising a third capacitance (C3) coupled in series with the large loop antenna (32) and between the large loop antenna (32) and the antenna circuitry (21).

7. The antenna arrangement according to claim 6, further comprising a fourth capacitance (C4) coupled between the ground potential (GND) and a common node between the large loop antenna (32) and the third capacitance (C3).

8. The antenna arrangement of any of the preceding claims, wherein the large loop antenna (32) comprises an electrical length of between 9/10 and 11/10 of the wavelength of the operating frequency of the large loop antenna (32).

9. The antenna arrangement of any of claims 1 to 8, wherein the antenna circuitry (21) is configured to control the antenna (32), and transmit and/or receive data sent or received by the antenna (32).

10. The antenna arrangement of any of claims 1 to 9, further comprising a microcontroller.

11. An electronic vehicle key comprising an antenna arrangement of any of claims 1 to 10.

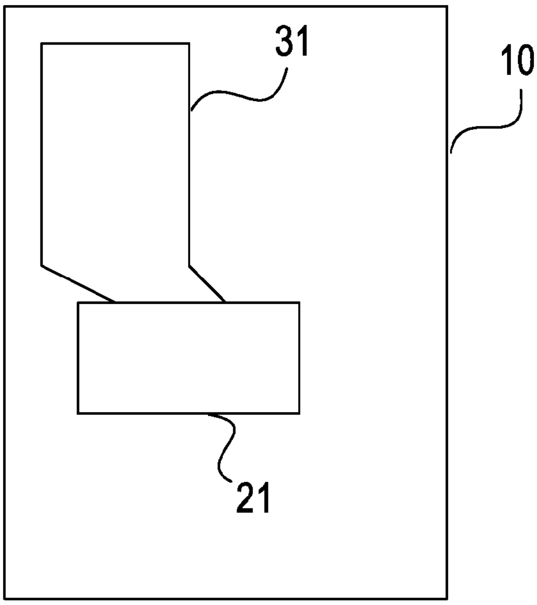

FIG 1A

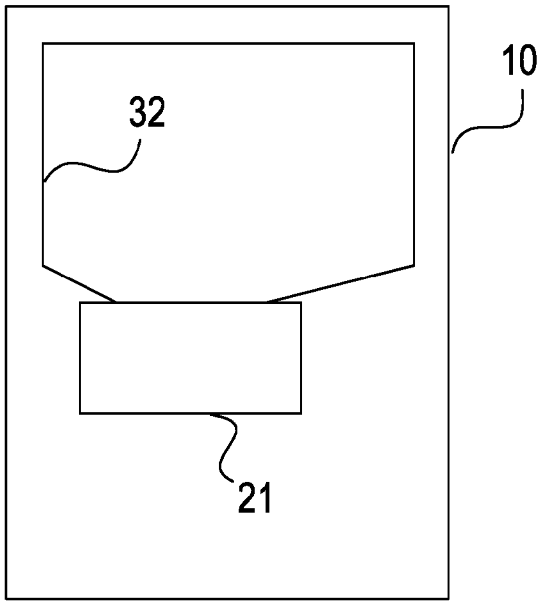

FIG 1B

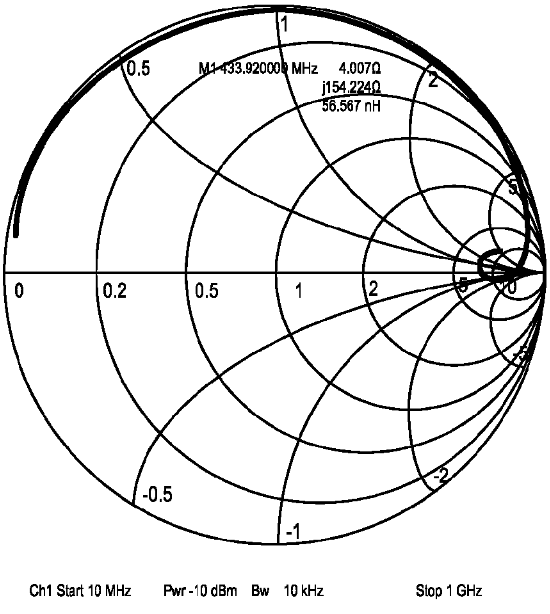

FIG 2A

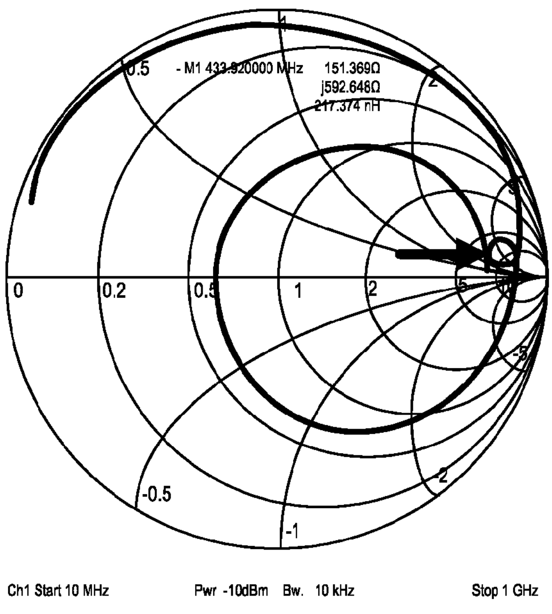

FIG 2B

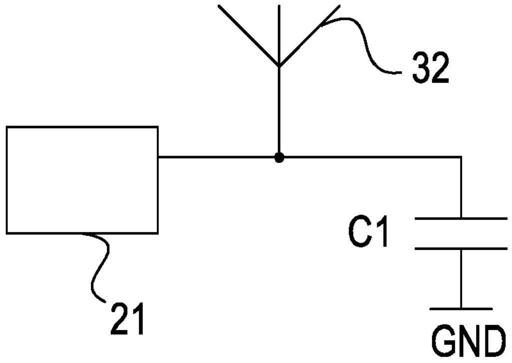

FIG 3

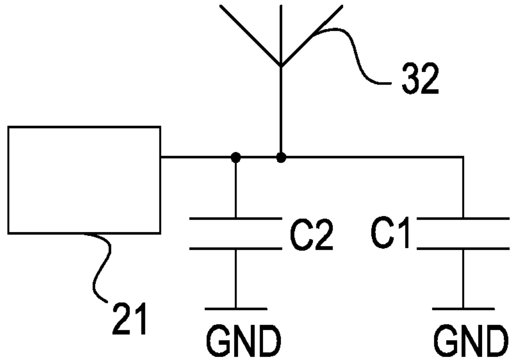

FIG 4

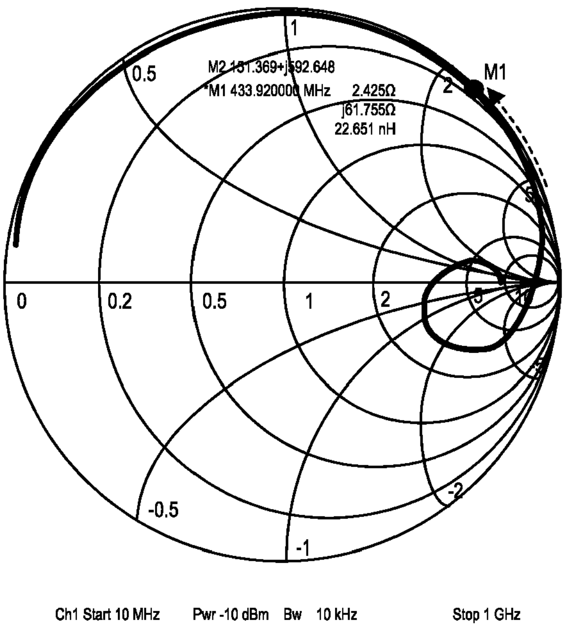

FIG 5

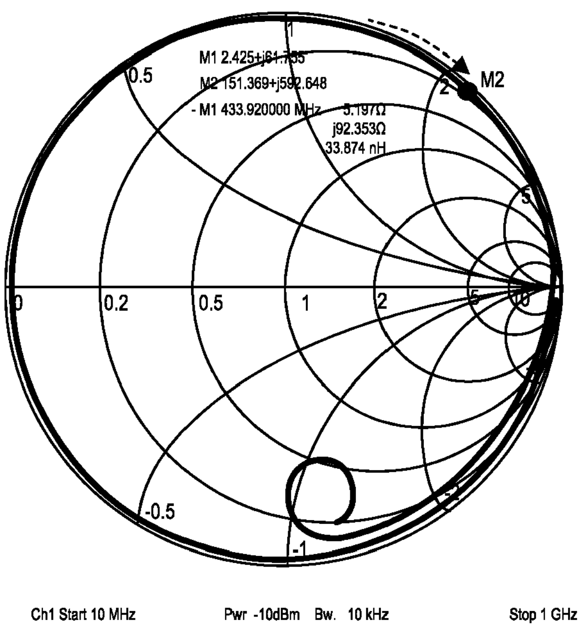

FIG 6

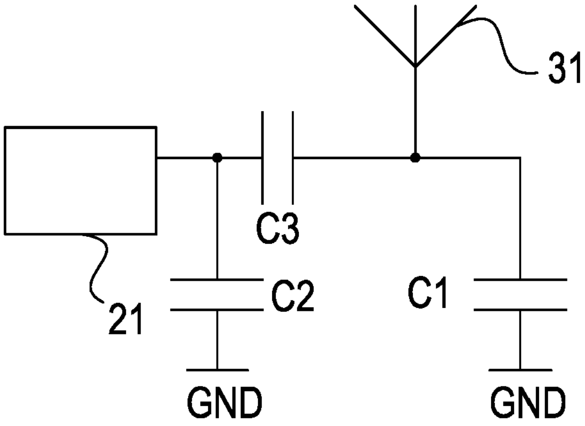

FIG 7

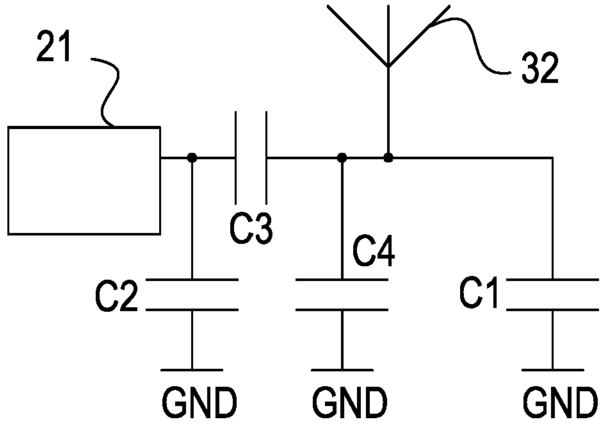

FIG 8

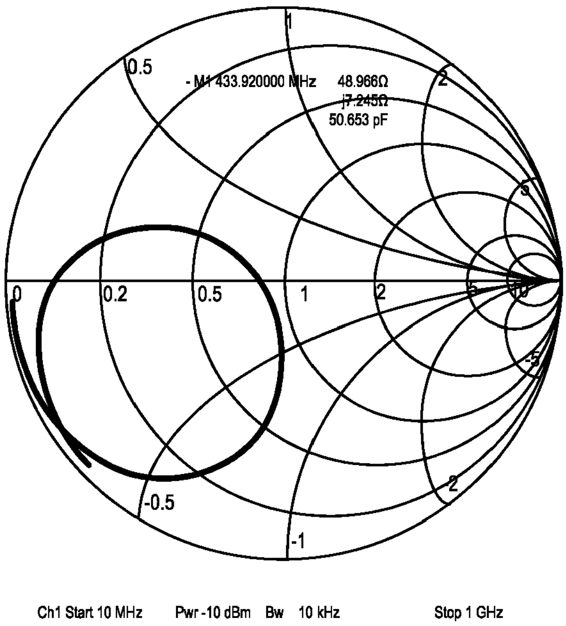

FIG 9

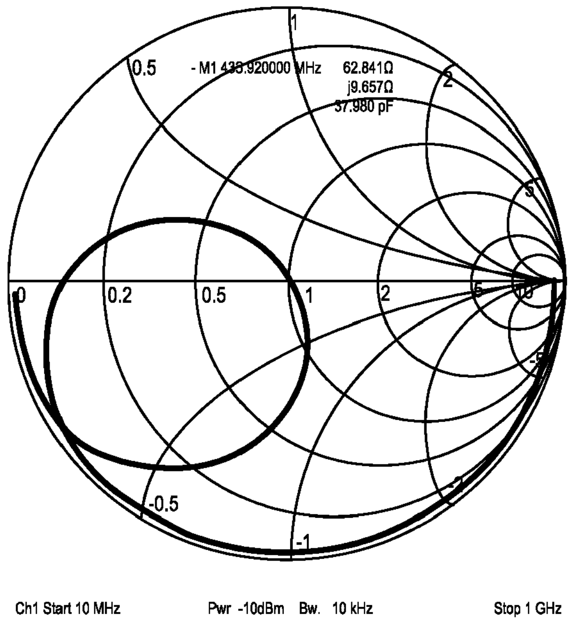

FIG 10

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EUROPEAN SEARCH REPORT

Application Number
EP 20 46 5532

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	2 November 2020	Kalialakis, Christos

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EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	G.-A. CHAKAM ET AL: "Comparison of key-FOB antennas for vehicle access system", EUROPEAN CONFERENCE ON ANTENNAS AND PROPAGATION : EUCAP 2007 ; 11 - 16 NOVEMBER 2007, EICC, EDINBURGH, UK, 11 November 2007 (2007-11-11), pages 610-610, XP055745862, DOI: 10.1049/ic.2007.1137 ISBN: 978-0-86341-842-6 * figure 1 * * figure 3a * * page 4, right-hand column, paragraph first * -----	11	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

1

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