(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 040 598 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
10.08.2022 Bulletin 2022/32

(21) Application number: **22151929.1**

(22) Date of filing: **18.01.2022**

(51) International Patent Classification (IPC):
H01Q 1/32 *(2006.01)* ***H01Q 3/26*** *(2006.01)*
H01Q 21/08 *(2006.01)* ***H01Q 9/30*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
H01Q 21/08; H01Q 1/3233; H01Q 3/2623; H01Q 9/30

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **19.01.2021 IT 202100000887**

(71) Applicant: **Ask Industries Societa' per Azioni**
60037 Monte San Vito (AN) (IT)

(72) Inventors:
- **CERRETELLI, Matteo**
  50019 SESTO FIORENTINO (IT)
- **NOTARI, Andrea**
  42030 VIANO (IT)
- **FACCHINI, Paolo**
  42123 REGGIO EMILIA (IT)
- **LENZINI, Stefano**
  41126 MODENA (IT)

(74) Representative: **Lavoix**
62, rue de Bonnel
69448 Lyon Cedex 03 (FR)

(54) DIRECTIONAL ANTENNA, AND VEHICLE COMPRISING SUCH DIRECTIONAL ANTENNA

(57) Directional antenna (100), comprising at least:
- a first radiating element (1) and a second radiating element (2) arranged spaced apart from each other at a predetermined first distance (D1);
- a supply circuit (5) which is connected to and is adapted to supply said first and second radiating elements (1, 2) with a feeding signal to be radiated, wherein said supply circuit (5) comprises at least one conducting element (5a) having a first end (5b) connected to the first radiating element (1) and a second end (5c) connected to the second radiating element (2), said at least one conducting element (5a) having, with reference to the nominal operating frequency of the antenna (100), a predefined electrical length (d) measured between said first and second ends (5b, 5c) which is comprised between one fifth of a wave and three quarters of a wave, said supply circuit (5) being configured so that the signal fed in input into the first radiant element (1) is out of phase in time with respect to the signal fed in input into the second radiant element (2) by a first value comprised between thirty and one hundred and twenty sexagesimal degrees.

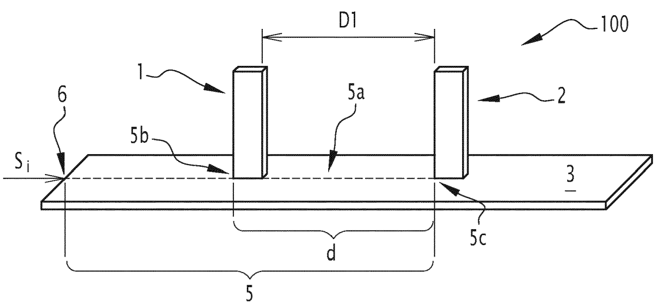

FIG.1

EP 4 040 598 A1

Description

[0001] The present invention relates in general to a directional antenna, in particular for a vehicle, and to a vehicle comprising such directional antenna.

[0002] The directional antenna according to the present invention is especially suitable for use in vehicles, in particular to realize V2X (Vehicle to Everything) communications preferably operating at frequencies around 5.9Ghz, and will be described in the following making reference to such applications without intending to limit in any way the possible fields of application.

[0003] As is well known, over recent years there has seen the commercialization of increasingly connected vehicles that integrate many services ranging from entertainment, for example radio and/or television, to driver assistance, typically via satellite navigation systems.

[0004] In this regard, in the field of telecommunications, in relation to vehicles it is indicated with V2V (Vehicle to Vehicle) the communication between vehicles, with V2I (Vehicle to Infrastructure) the communication between vehicles and infrastructure, and with V2P (Vehicle to Pedestrian) the communication between vehicles and pedestrians, and with the acronym V2X it is indicated the communication between a vehicle and everything that can be relevant.

[0005] For this type of V2X communications, which can take place according to different standards (IEEE802.11p or CV2X), an international frequency band around 5.9 GHz has been allocated with small differences depending on the standardization body.

[0006] As a consequence, it is necessary to install on modern vehicles antennas capable of operating at this frequency.

[0007] Moreover, given the possible use of V2X communications for applications also related to security, it is often necessary that the antennas on the vehicle have a range of coverage as wide and adequate as possible.

[0008] This coverage can be obtained either with a single antenna or by placing several antennas in different positions of the vehicle. In fact, since the vehicle itself is composed mainly of metal parts that by their nature interact with the electromagnetic waves emitted by the antenna, depending on the position of an antenna, the radiation pattern can be differently deformed.

[0009] For example, depending on the curvature of the roof, an antenna positioned towards the rear of a car may not be able to radiate electromagnetic power towards the front of the car itself and to compensate for this effect it is often necessary to install a second antenna on the front of the car, for example at the rear-view mirrors.

[0010] To make the antennas positioned in different points of the vehicle more efficient, it is possible to manipulate the radiation pattern of the antennas to avoid dispersing electromagnetic power in directions not of interest, or, in the case of an antenna installed inside the car in positions such as the rearview mirror, to make sure to correctly transmit the electromagnetic field towards the outside of the vehicle (forward and towards the sides) where it is more likely there are devices with which to exchange communications, and not towards its occupants (rear).

[0011] In this regard, on the market there are antennas that, in order to obtain the desired deformation of the radiation pattern, use a single radiating element combined with the directing effect of a screen of conductive material placed at a controlled distance from the radiating element itself.

[0012] The solutions nowadays known, while achieving appreciable results, are susceptible of further improvements.

[0013] For example, the use of several antennas installed in different positions of a vehicle negatively affects the costs of production and installation.

[0014] On the other hand, an antenna coupled to a shield presents a control of the radiation pattern not entirely optimal, in particular with regard to the coverage of intermediate angles transversal to the ideal axis that joins the direction of the maximum radiation to the direction of the minimum.

[0015] Therefore, a main aim of the present invention is to provide a directional antenna, in particular for V2X type communications, which, compared to known solutions, enables improving the control of the radiation pattern and is easy to be realized.

[0016] Within this main aim, another scope of the present invention is to provide a directional antenna that allows ensuring a greater bandwidth with respect to known solutions, in particular greater than those using a shielded antenna.

[0017] A further scope of the present invention is to provide a solution for a directional antenna that is easy to implement and relatively inexpensive, and that can be easily installed in the most varied types of vehicles both of road type, such as cars, buses, commercial vehicles of various types, and railway type, such as trams, trains, et cetera.

[0018] This main aim, as well as the aforementioned additional scopes and others that will result more from the following description, are achieved by a directional antenna whose characteristics are defined in claim 1.

[0019] This main aim, as well as the aforementioned additional scopes, are also achieved by a vehicle according claim 10.

[0020] Particular embodiments are the subject of the dependent claims, the contents of which are intended to form an integral part of this description.

[0021] Further characteristics and advantages of the invention will appear from the following detailed description, made by way of non-limiting examples only, with reference to the accompanying drawings, in which:

Figure 1 schematically illustrates a possible embodiment of a directional antenna according to the present invention;

Figure 2 schematically illustrates another possible embodiment of the antenna of figure 1;

Figures 3 and 4 schematically illustrate another possible embodiment of a directional antenna according to the present invention;

Figure 5 schematically illustrates a further embodiment a directional antenna according to the present invention;

Figure 6 shows the horizontal radiation pattern obtained using the antenna of figures 3 and 4;

Figure 7 shows the vertical radiation pattern obtained using the antenna of figures 3 and 4;

Figure 8 shows the reflection coefficient obtained using the antenna of figures 3 and 4;

Figure 9 illustrates a possible horizontal radiation angle θ obtainable using a directional antenna according to the invention positioned at the front of a vehicle;

Figure 10 illustrates a possible vertical radiation angle φ obtainable using a directional antenna according to the invention positioned at the front of a vehicle.

[0022] It should be noted that in the detailed description that follows, identical or similar components, either from a structural and/or functional point of view, have the same reference numerals, regardless of whether they are shown in different embodiments of the present disclosure.

[0023] It should also be noted that in order to clearly and concisely describe the present invention, the drawings may not necessarily be to scale and certain features of the description may be shown in somewhat schematic form.

[0024] Further, when the term "adapted" or "arranged" or "configured" or "shaped", or a similar term is used herein while referring to any component as a whole, or to any part of a component, or to a combination of components, it has to be understood that it means and encompasses correspondingly either the structure, and/or configuration and/or form and/or positioning.

[0025] In addition, when the term "substantial" or "substantially" is used herein, it has to be understood as encompassing an actual variation of plus or minus 5% with respect to an indicated reference value or position, and when the terms transversal or transversally are hereby used, they have to be understood as encompassing a direction non-parallel to the reference part(s) or direction(s)/axis they refer to, and perpendicularity has to be considered a specific case of transverse direction.

[0026] Finally, in the following description and claims, the numeral ordinals first, second, et cetera, will be used only for the sake of clarity of description and in no way they should be understood as limiting for whatsoever reason; in particular, the indication for example of a "first value..." or of a "first distance" does not imply necessarily the presence or strict need that there is a further "second distance" or "second value" or vice versa, unless such presence is clearly evident for the correct functioning of the embodiments described, nor that the order should be exactly the one described with reference to the illustrated exemplary embodiments.

[0027] Figures 1-5 schematically illustrate a possible embodiment of a directional antenna according to the invention, indicated globally by the reference number 100.

[0028] The antenna 100 according to the invention comprises a plurality of radiating elements, i.e. at least two, and a supply circuit which is connected to the radiating elements and is suitable for feeding them appropriately with a feed signal to be radiated.

[0029] In particular, according to the realization embdiments that will result more in detail from the following description, said first and second radiating elements and said supply circuit are configured and operatively connected among them so as to generate a combined irradiation pattern which presents, on a horizontal plane, a signal reduction in a selected direction substantially equal to one quarter of a round angle and an increase distributed in a substantially uniform manner in the remaining three quarters of the round angle.

[0030] In practice, the antenna 100 according to the invention allows, once the directions where the maximum and minimum of the irradiated signal is desired have been selected, for example forward and respectively backward relative to a vehicle on which the antenna 100 is installed, to widen the irradiated beam as much as possible towards the intermediate directions.

[0031] More in details, as for example illustrated in the embodiments of figures 1, 3, 4 and 5, the antenna 100 comprises at least:

- a first radiating element 1 and a second radiating element 2 arranged spaced apart from each other at a predetermined first distance D1; and
- a supply circuit or network 5 which is connected to and is suitable to supply said first and second radiating elements 1, 2 with a feeding signal to be radiated S_i.

[0032] In particular, the supply circuit 5 is configured so that the signal to be radiated fed in input to the first radiating element 1 is offset in time by a first predefined value $\Delta\phi$ with respect to the same signal to be radiated fed in input to the second radiating element 2.

[0033] In a possible embodiment of the directional antenna 100 according to the invention, the supply circuit 5 is configured so that the signal fed in input into the first radiant element 1 is out of phase in time with respect to the signal fed in input into the second radiant element 2 by a first value comprised between thirty and one-hundred-and-twenty sexagesimal degrees.

[0034] In particular, according to a possible embodiment, the supply circuit 5 is conveniently configured so that the signal fed in input into the first radiant element 1 is out of phase in time with respect to the signal fed in input into the second radiant element 2 of a first value comprised between fifty and seventy sexagesimal degrees, preferably equal to sixty sexagesimal degrees.

[0035] Usefully, according to a possible embodiment illustrated in the figures, the supply circuit 5 comprises at least one conducting element 5a having a first end 5b connected to the first radiating element 1 and a second end 5c connected to the second radiating element 2, said at least one conducting element 5a having, with reference to the nominal operating frequency of the antenna 100, a predefined electrical length "d" measured between said first and second ends 5b, 5c.

[0036] In practice, the supply circuit 5 carries the electromagnetic waves in input/output at a connection 6, for example from/to the electronics of a vehicle on which the antenna 100 is installed, indicated in the figures 9 and 10 by the reference number 200. In particular, in the case of a wave coming from the input connetion 6 of the antenna 100 and traveling through the supply network 5, thanks to the combination of the appropriately sized physical distance D1 between the two radiating elements 1 and 2 and the configuration of the supply circuit 5, and in particular of its part 5a included between the two radiating elements 1 and 2, the transported wave will reach first the nearest radiating element, that is the first radiating element 1, and then the most distant one, that is the second radiating element 2, with a phase difference defined by the following equation:

$$\Delta\varphi = d \cdot \frac{2\pi}{\lambda_{lt}}$$

wherein, $\Delta\varphi$ is the phase difference between the signal of the transported wave fed in input to the first radiating element 1 and the signal of the same wave fed in input to the second radiating element 2, "d" is the electrical length of the part of the supply network or circuit 5 comprised between the two ends connected respectively to the first and second radiating elements 1 and 2, and λ_{lt} is the wavelength of the electromagnetic wave within the supply circuit 5.

[0037] In one possible embodiment, the predefined electrical length "d" is comprised between one fifth of a wave and three quarters of a wave, of the signal S_i carried by the circuit 5.

[0038] More in particular, according to a possible embodiment, the predefined electrical length "d" is comprised between two fifths of a wave and three fifths of a wave, more preferably it is equal to one half of a wave.

[0039] In the embodiments illustrated in Figures 3-4 and 5, the conductor element 5a is formed by a broken line having three substantially straight sections forming an overall U- or C-shaped path, wherein the electrical distance is substantially given by the sum of the electrical lengths of the three rectilinear sections di, d_2, d_3.

[0040] In practice, by imposing a different phase to the radiating elements 1 and 2, a desired deformation of the radiation pattern is obtained, as illustrated for example in figures 7 and 8, which can be suitably calibrated according to the needs.

[0041] Clearly, the supply circuit 5, and in particular its part 5a that interconnects the two radiating elements 1 and 2, can be differently configured in order to obtain similarly the same technical results in terms of modification of the radiation pattern of the antenna 100.

[0042] For example, in a possible embodiment, the supply circuit 5 comprises at least one conducting element 5a having a first end 5b connected to the first radiating element 1, a second end 5c connected to the second radiating element 2, and a supporting element, for example a strip made of a dielectric material, which is mechanically connected at least to said conducting element 5a and acts as a mechanical support for the same, also contributing to obtain the desired phase shift $\Delta\phi$.

[0043] This support element can be shaped for example replicating the shape and following the physical path of the supply circuit 5 or only of its part 5a, or even have a different shape as long as suitable to support the circuit 5 itself, and in particular its part 5a, and to contribute to the achievement of the desired phase shift $\Delta\phi$.

[0044] For example, if the signal supply circuit 5 is realized by means of a microstrip, the support element may be realized by a body made of a dielectric material that replicates at least in part the path of the microstrip, in particular with respect to at least its part 5a. If instead the signal supply circuit 5, and in particular at least its part 5a, is made for example by a coaxial cable, then the cable can also be mechanically released from the support that holds the radiating elements and have as its only points of contact the ends 5b and 5c.

[0045] In a further possible embodiment of the directional antenna 100 according to the invention, the supply circuit 5 comprises at least one lumped constants component (altenrative defined as component with concentrated constants) disposed between said first and second radiating elements 1 and 2. Such component, schematically illustrated in figure 2 by the dashed box 30, may be consititited for example by a capacitor or an inductance.

[0046] In particular, according to this embodiment, the supply circuit 5, or at least its part interposed between and interconnecting the two radiating elements 1 and 2, may comprise or be constituted by a "T" or "pi"(pi greek) network of combinations of inductors or capacitors, which realize the desired phase shift, without having to resort to a binding physical spacing between the input ports of the radiating elements 1 and 2. In this way, there is a greater degree of freedom regarding the spacing between the same radiating elements 1 and 2, which can thus be chosen to a degree less dependent on the physical architecture of the supply network 5 itself.

[0047] In a possible embodiment, and as illustrated in the examples of Figures 1-5, the directional antenna 100 further comprises a support element 3 on which said first and second radiating elements 1 and 2 and the supply circuit 5 are at least partially arranged or connected to.

[0048] In the illustrated examples, said support element 3 has a substantially planar development and the radiating elements 1 and 2 and the supply circuit 5 may be arranged on opposite faces of said planar element 3, as in the examplary embodiment illustrated by figures 3 and 4, or on the same face as illustrated in the examplary embodiments of figures 1, 2 and 5.

[0049] In a possible embodiment, one or more of said power supply circuit 5, and first and second radiating elements 1 and 2, preferably each of them, comprises a respective metal conductor connected to a grounding element fixed to the support element 3 or formed by the support element 3 itself.

[0050] In particular, depending on the applications, such grounding element can be formed then by the same support element 3 which in this case is substantially made of conductive material.

[0051] Alternatively, the support member 3 may be made of a dielectric material and the grounding element comprises at least one conductive surface, that covers at least partially one face of the support member 3 (see Figure 5), or is arranged on both faces of the support member 3 so as to at cover least partially them (see Figures 3 and 4).

[0052] In the embodiments illustrated, each grounding element comprises a conducting foil made of copper having a substantially planar development and indicated in Figures 3-5 by the reference number 4.

[0053] This grounding element 4 is sized to have a surface suitably greater than that of the radiating elements so as to modify, typically for lowering or for raising, the elevation of the maximum of the radiated signal illustrated in figure 7.

[0054] In particular, in the examplary embodiment of Figures 3 and 4, the radiating elements 1 and 2 are realized using PCB (from the English Printed Circuit Board) technology and are formed, for example, of copper traces deposited on a dielectric support 7.

[0055] The shape and size of the copper traces forming the two radiating elements 1 and 2 are selected to obtain a resonance of the antenna 100 around the operating frequency, for example around 5.9GHz. Furthermore, in order to improve the adaptation of the antenna, in such examplary embodiment a corresponding branch 8 and respectively 9 is provided for each radiating element 1 and 2, the two branches 8 and 9 being connected to a common grounding element 4.

[0056] In turn, the supply circuit 5 is realized in this example on the face of the support element 3 opposite to that where there are the radiating elements 1 and 2, and may also be implemented using PCB technology. For example, the circuit 5 may comprise a waveguide known as a microstrip. Such a waveguide is formed by a copper trace and a grounding element divided by a dielectric thickness. The width of the copper trace is appropriately sized to have, for example, a characteristic impedance of the microstrip equal to 50Ω. Narrowed or widened parts 11 of the microstrip may be made to improve the overall adaptation of the antenna 100. To secure the radiating elements 1 and 2 to the support element 3, holes 10 may be drilled inside which the PCBs of the radiating elements 1 and 2 are inserted to be subsequently connected by soldering to the supply circuit 5.

[0057] In the example shown in Figure 5, the radiating elements 1 and 2 are made from folded sheets. Compared to PCB technology, this solution allows, for example, to exploit more efficiently the available space by developing the radiating elements three-dimensionally, and in many cases allows to optimize, i.e. to reduce, the production cost of the radiating elements themselves. In this case the supply circuit 5 is realized on the same side of the radiating elements 1 and 2 always using for example a microstrip. In order to obtain a better adaptation of the antenna 100, two connection points to the grounding plane 4 have been added to the radiating elements 1 and 2, indicated by the reference numbers 12 and 13 respectively.

[0058] In yet a further embodiment, similar to that of figures 3 and 4 (and not illustrated in details in the figures), the dielectric support 7 is positioned directly over the grounding element 4, i.e. it is formed by one single dieletric substantially planar area or by two separated planar areas laid within the grounding element 4; in this embodiment, the radiating elements 1 and 2 with their respective metal connectors or connecting branches 8 and 9 are shaped like in figure 3 and are positioned over the dielectric area (or over the respective dieletric areas) and connected to the supply circuit 5 which is placed on the opposite face of the support 3, as shown in figure 4.

[0059] Clearly, depending on the applications, in the antenna 100 according to the invention it is possible to use radiating elements differently configured, as well as a larger number of radiating elements.

[0060] For example, as schematically illustrated in the examplary embodiment of figure 2, there is foreseen the use of at least a third radiating element 20 spaced from the first radiating element 1 of a predetermined second distance D2, and spaced from the second radiating element 2 of a predetermined third distance D3. Said third radiating element 20 may be suitably arranged to realize a triangular configuration, as for example illustrated in figure 2, or may be arranged aligned with the two radiating elements 1 and 2 so as to form a linear configuration.

[0061] In turn, the supply circuit 5 is connected to and is suitable for supplying also the third radiating element 20 with the feed signal S_i to be radiated. In particular, the supply circuit 5 is configured so that the signal to be radiated S_i fed at the input of the third radiating element 20 is time-shifted by a second predefined value with respect to the signal fed at the input of the first radiating element 1 and by a third predefined value with respect to the signal fed at the input of the second radiating element 2.

[0062] What has been previously described regarding the embodiments with only the two radiant elements 1 and 2, is equally applicable in the presence of the third radiant element 20, as well as for any further radiant element.

[0063] In particular, the values indicated for the electrical distance "d" and the phase shift between the first radiating element 1 and the second radiating element 2, are applicable to each pair of radiating elements, and therefore in the case of the third radiating element 20 to the pair first-third radiating elements 1 and 20, and respectively to the pair second-third radiating elements 2 and 20.

[0064] Furthermore, in the illustrated examples, each of the physical distances D1, D2 and D3 between pairs of elements is illustrated measured between two nearest surfaces facing each other; alternatively, it is possible to define each distance in another way, for example in the case of radiating elements of symmetrical shape, by calculating it as the distance between the respective axes of symmetry, or in another way still suitable for sizing the antenna according to the invention.

[0065] In a further possible embodiment, the antenna 100 comprises for example a housing made of dielectric material, schematically illustrated only in Figure 2 by the reference number 50. Such housing 50 allows to further deform and in a controlled manner the overall radiation pattern.

[0066] In practice, it has been ascertained that the directional antenna 100 according to the invention allows to fulfill the predetermined aim as it allows to obtain a control of the radiation pattern significantly improved compared to known solutions, and in particular to expand to the maximum the azimuthal angle of coverage that with the known solutions does not reach three quarters of the angle circle, obtaining a greater coverage of the intermediate angles transversal to the ideal axis that joins the direction of the maximum radiation to the direction of the minimum.

[0067] An example to this end is illustrated in Figures 6, 7 and 8, where the results shown are obtained by means of the embodiment of the antenna 100 illustrated in Figures 3 and 4. In particular, these results were obtained by imposing a phase shift of 60° and a physical distance D1 of about 12.7mm, consequently sizing the length of the suppy circuit 5 according to the previously indicated equation. In particular, the figures 6 and 7 refer respectively to the irradiation diagram on the horizontal and vertical planes; with the definition of horizontal and vertical planes is meant, for example, those illustrated in figures 9 and 10 where are highlighted the sectors, angle θ for the horizontal and angle φ for the vertical, in which is radiated most of the power. Figure 8 also shows the reflection coefficient obtained for the antenna 100 taken as an example.

[0068] The antenna 100 thus conceived also allows to guarantee a greater bandwidth thanks to the particular feeding technique, allowing, if necessary, to use the same antenna also for transmissions in bands close to the one allocated to V2X communication, such as the WiFi band.

[0069] To achieve this, as previously illustrated, there are used components of easy construction and assembly and at low cost, which allow to properly calibrate the operation of the antenna itself, in particular playing appropriately on the mutual distance between the radiating elements and the electrical length of the part of the supply circuit or network that interconnects them and feeds them with the signal to be radiated.

[0070] With further advantage, the antenna 100 according to the invention can be used in principle in any type of vehicle, both road and rail, and can be easily installed both in new vehicles and, if desired, in vehicles already in use. Therefore, a further object of the present invention relates to a vehicle characterized by the fact that it comprises at least one directional antenna 100 according to what has been described above, and more particularly as defined in the appended claims.

[0071] Of course, without prejudice to the principle of the invention, the embodiments and details of realization may be widely varied with respect to what has been described and illustrated by way of preferred but not limiting examples only, without thereby departing from the scope of protection of the present invention as defined in particular by the appended claims. For example, the previously described embodiments can be combined, even partially, by selecting for this purpose one or more of the features described with reference to a possible embodiment and using, where useful or possible each feature selected in one of the other described embodiments.

[0072] For example, the device 30 or the housing 50 could be used in all or only in some of the embodiments disclosed. The shape of the described components or portions thereof may be suitably modified so long as it is compatible with the purpose and functionalities for which such components were conceived within the scope of the present invention. For example, the radiating elements 1, 2 and 20, and/or the supply circuit 5 or part thereof may be made by metallization on dielectric materials, for example, plastics; such radiating elements may be shaped differently with respect to what illustrated in the examples and may be arranged in a position other than the substantially vertical position shown in the accompanying figures; the supply circuit 5 may have at least partially a path curved or mixed; there may be a single grounding element 4 for all the radiating elements, or one ground element may be used for each radiating element used, and the groundin elements may be electrically connected or not connected to each other; each ground element may be constituted by an element having not necessarily a planar development; the housing of dielectric material 50 may be replaced by bulky mechanical components, i.e. of dimensions comparable or larger than those of the radiating elements; et cetera.

Claims

1. Directional antenna (100), **characterized in that** it comprises at least:

    - a first radiating element (1) and a second radiating element (2) arranged spaced apart from

each other at a predetermined first distance (D1);
- a supply circuit (5) which is connected to and is adapted to supply said first and second radiating elements (1, 2) with a feeding signal to be radiated, wherein said supply circuit (5) comprises at least one conducting element (5a) having a first end (5b) connected to the first radiating element (1) and a second end (5c) connected to the second radiating element (2), said at least one conducting element (5a) having, with reference to the nominal operating frequency of the antenna (100), a predefined electrical length (d) measured between said first and second ends (5b, 5c) which is comprised between one fifth of a wave and three quarters of a wave, said supply circuit (5) being configured so that the signal fed in input into the first radiant element (1) is out of phase in time with respect to the signal fed in input into the second radiant element (2) by a first value comprised between thirty and one hundred and twenty sexagesimal degrees.

2. Directional antenna (100) according to claim 1, wherein said first and second radiating elements (1, 2) and said supply circuit (5) are configured and operatively connected among them so as to generate a combined irradiation pattern which presents, on a horizontal plane, a signal reduction in a selected direction substantially equal to one quarter of a round angle and an increase distributed in a substantially uniform manner in the remaining three quarters of the round angle.

3. Directional antenna (100) according to claim 1 or 2, wherein said supply circuit (5) comprises a support element mechanically connected at least to said conducting element (5a).

4. Directional antenna (100) according to any one of the preceding claims, wherein said supply circuit (5) comprises at least one lumped constants component (30) arranged between said first and second radiating elements (1, 2).

5. Directional antenna (100) according to any one of the preceding claims, wherein said predefined electrical length (d) is comprised between two fifths of a wave and three fifths of a wave.

6. Directional antenna (100) according to any one of the preceding claims, wherein said supply circuit (5) is configured so that the signal fed in input into the first radiant element (1) is out of phase in time with respect to the signal fed in input into the second radiant element (2) of a first value comprised between fifty and seventy sexagesimal degrees.

7. Directional antenna (100) according to any one of the preceding claims, further comprising at least one support element (3) on which said first and second radiating elements (1, 2) and said supply circuit (5) are at least partially arranged or connected to.

8. Directional antenna (100) according to claim 7, wherein one or more of said supply circuit (5), first and second radiating elements (1, 2) comprises a metal conductor connected to a grounding element (4) fixed to the support element (3) or constituted by the support element (3) itself.

9. Directional antenna (100) according to any one of the preceding claims, comprising at least a third radiating element (20) arranged spaced apart from said first radiating element (1) at a predetermined second distance (D2) and from said second radiating element (2) at a predetermined third distance (D3), and in which said supply circuit (5) is connected to and is adapted to supply said third radiating element (20) with said feeding signal to be radiated, in which said supply circuit (5) is configured in such a way that the signal to be radiated fed in input into the third radiant element (20) is out of phase in time by a second predefined value with respect to the signal fed in input into the first radiant element (1) and by a third predefined value with respect to the signal fed in input into the second radiant element (2).

10. Vehicle (200) **characterized in that** it comprises at least one directional antenna (100) according to any one of claims 1 to 9.

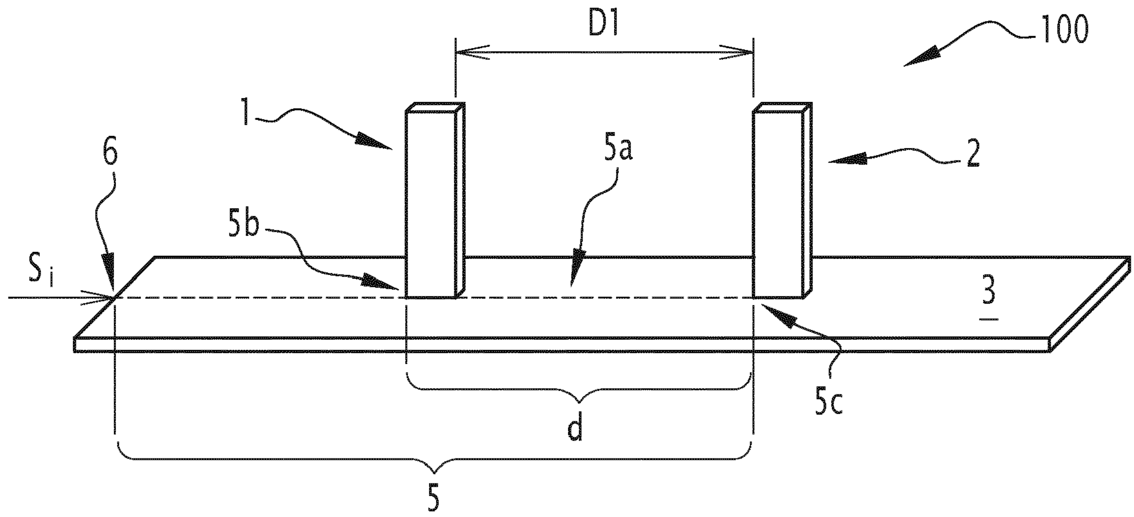

FIG.1

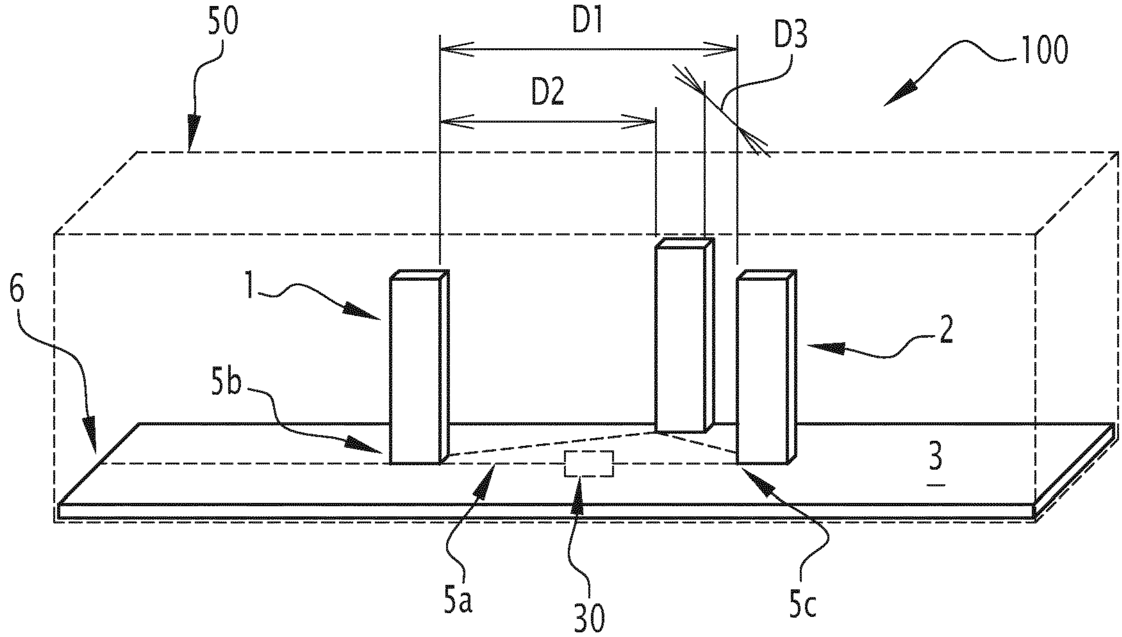

FIG.2

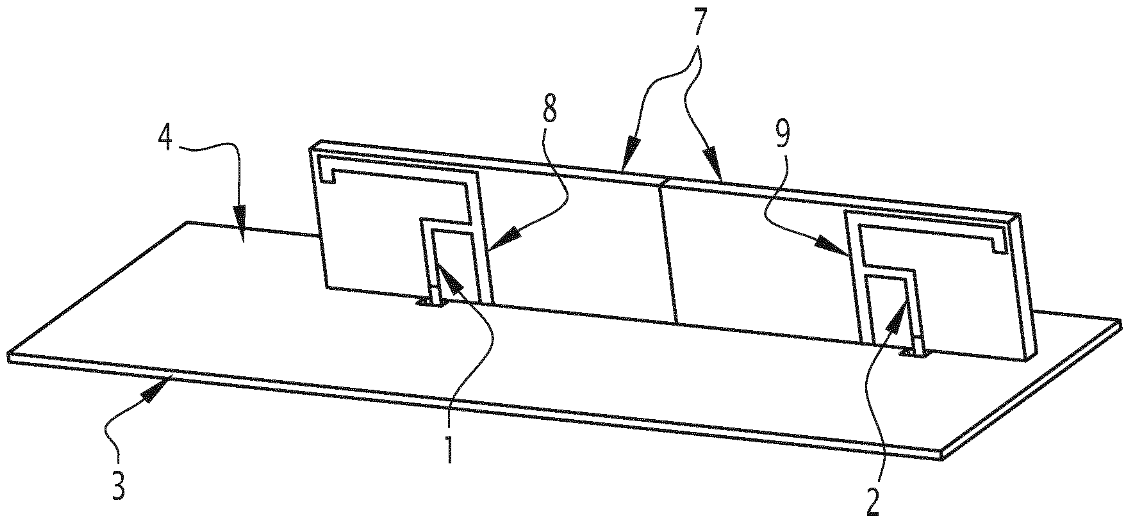

FIG.3

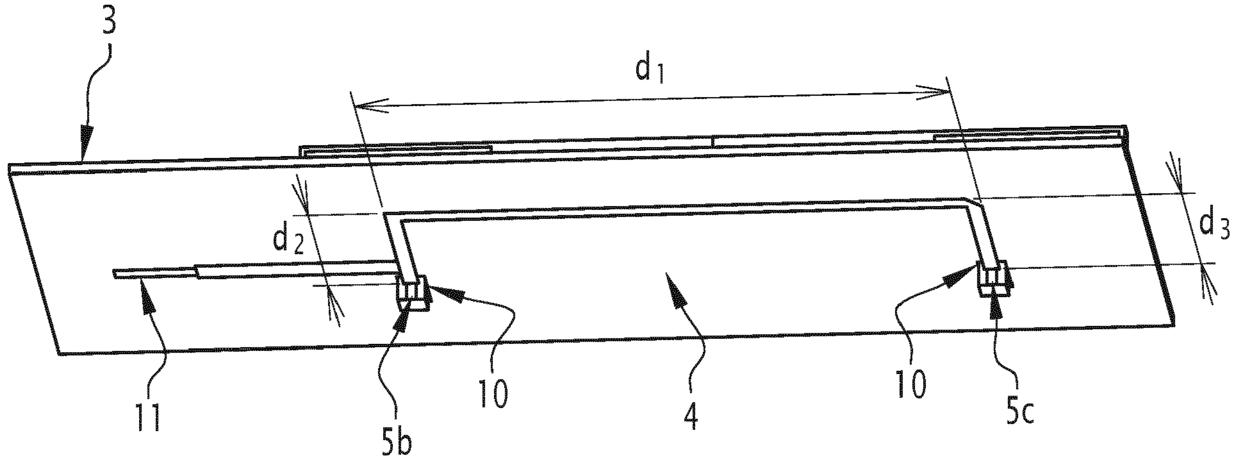

FIG.4

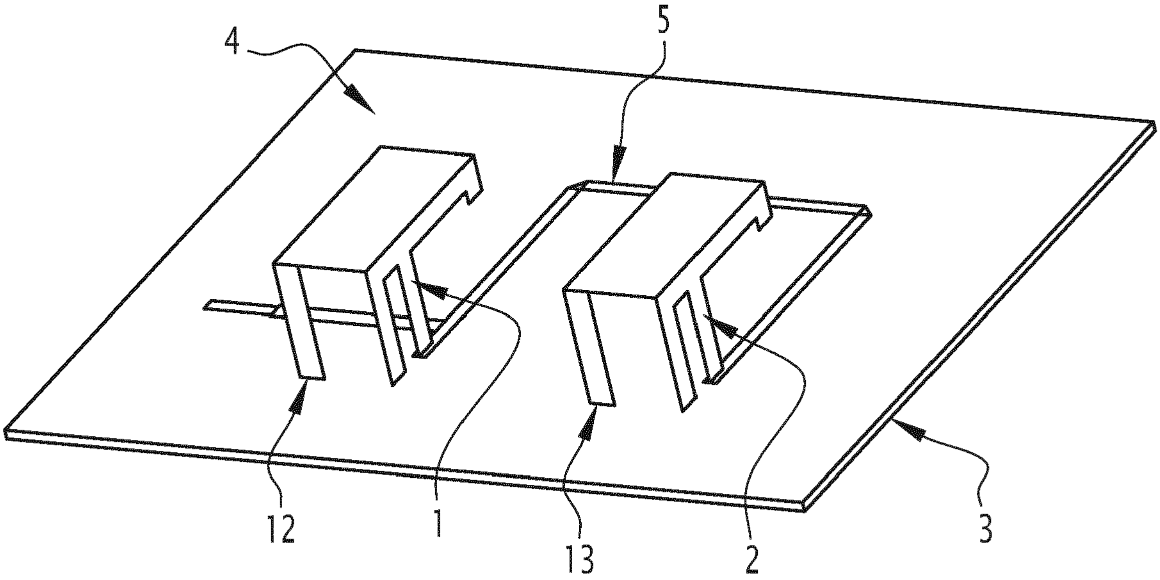

FIG.5

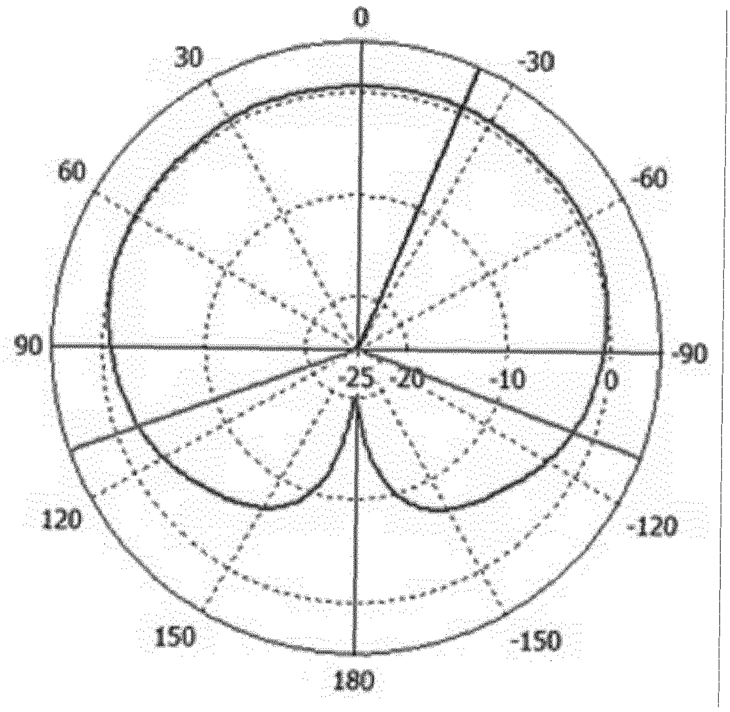

FIG.6

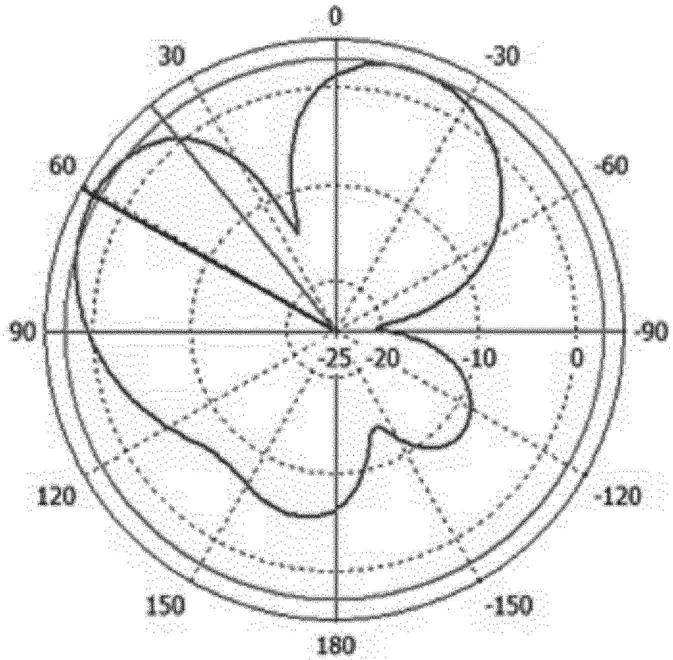

FIG.7

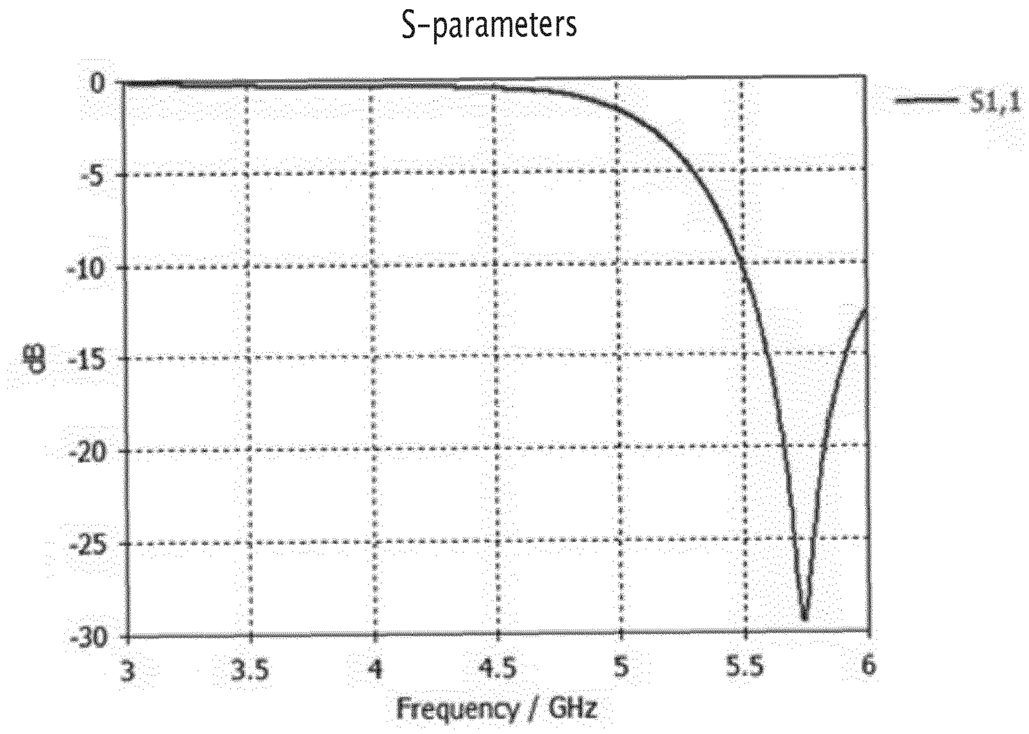
S-parameters
0
-5
-10
-15
-20
-25
-30
dB
3
3.5
4
4.5
5
5.5
6
Frequency / GHz
S1,1

FIG.8

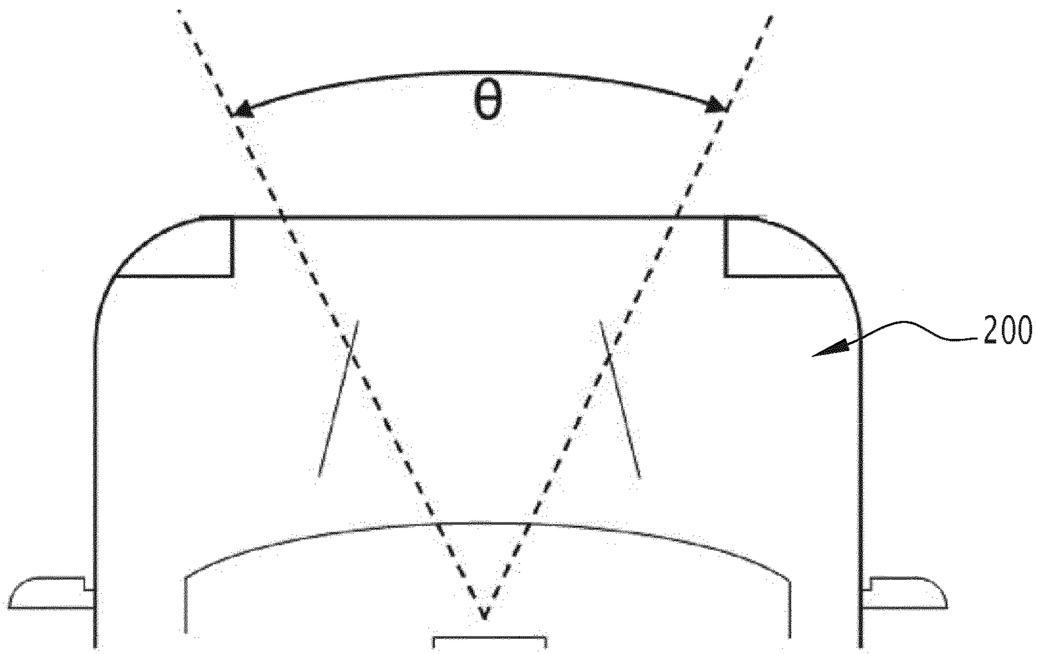

FIG.9

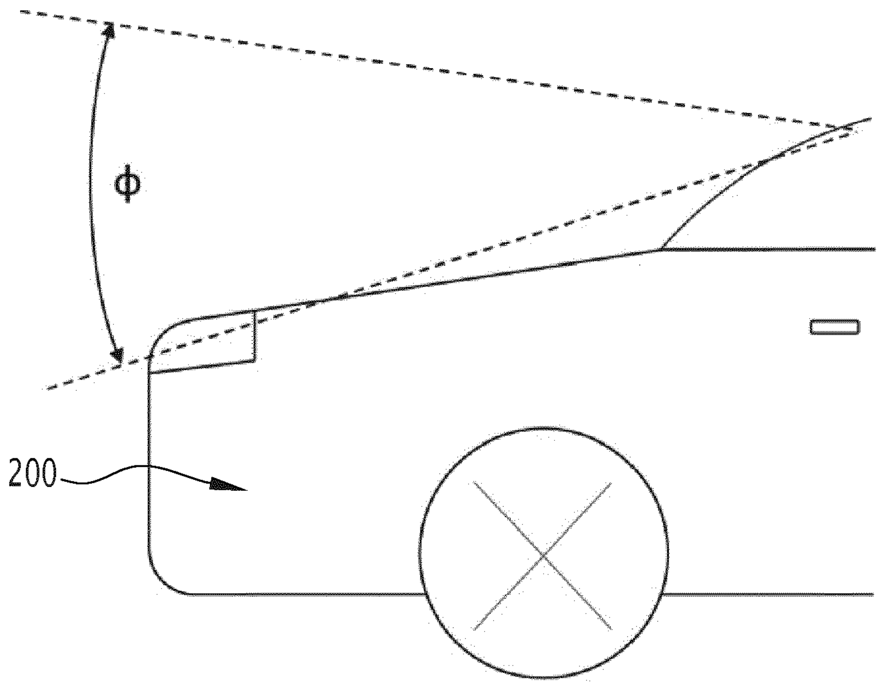

FIG.10

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	30 June 2022	Mitchell-Thomas, R

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30-06-2022

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