



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
20.10.2021 Bulletin 2021/42

(51) Int Cl.:
H01Q 1/32 (2006.01) **H01Q 1/48** (2006.01)
H01Q 5/385 (2015.01) **H01Q 5/392** (2015.01)
H01Q 9/40 (2006.01) **H01Q 1/38** (2006.01)
H01Q 21/28 (2006.01)

(21) Application number: **21168966.6**

(22) Date of filing: **16.04.2021**

(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

(72) Inventors:
• **CORRÀ, Luigi**
20121 MILANO (IT)
• **INNOCENTE, Patrik**
20121 MILANO (IT)
• **CANALE, Matteo**
20121 MILANO (IT)
• **MESTRINER, Roberto**
20121 MILANO (IT)

(30) Priority: **16.04.2020 IT 202000008101**

(71) Applicant: **CALEARO ANTENNE S.P.A. CON SOCIO UNICO**
20121 Milano (IT)

(74) Representative: **Zamprogno, Bruno et al**
STUDIO TORTA S.p.A.
Via Viotti, 9
10121 Torino (IT)

(54) **ANTENNA DEVICE**

(57) A 5G antenna device (1) comprising a flat, plate-shaped supporting base (5) in an electrically insulating material, a first terminal (6a) for providing an antenna signal, a second terminal (6b) set at a pre-established reference potential, and a dipole antenna electrical circuit (7) comprising a first portion (10) positioned on the supporting base (5) and having a polygonal shape, a second portion (11) positioned on the supporting base (5) and comprises a first branch (11a) having an elongated

shape extending immediately alongside a first side (10a) of the first portion (10). The dipole antenna device (7) further comprises a plate-shaped element (12) made of electrically conductive material that lies on a plane transverse to the supporting base (5) and is electrically connected to the first branch (11a) of the second portion (11). The plate-shaped element (12) is adjacent to the first side (10a) of the first portion (10) and forms a capacitive antenna element therewith.

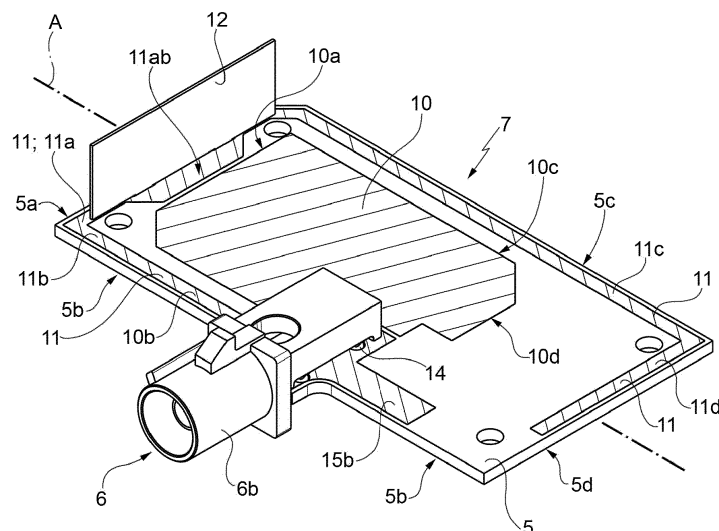


FIG. 6

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent application claims priority from Italian patent application no. 10202000008101 filed on 16/04/2020.

TECHNICAL FIELD

[0002] The present invention relates to an antenna device. Preferably, the present invention relates to an antenna device installable in a vehicle, conveniently a motor vehicle, such as a car or any similar vehicle which the following description refers to without by so doing detracting from its general application.

BACKGROUND ART

[0003] It is well known that there is currently a growing need on the part of manufacturers of motor vehicles, such as cars, trucks, buses, etc., to "connect" the vehicles both to communication networks/systems operating with fourth generation mobile phone technologies, so-called 4G communication networks/systems, and new/state-of-the-art broadband telecommunications networks/systems, such as in particular fifth generation networks/systems, i.e. 5G and/or LTE (acronym for Long Term Evolution) communication networks/systems.

[0004] The object of the present invention is therefore to provide an antenna device that is also capable of communicating with state-of-the-art broadband communication networks/systems, in particular mobile phone networks including the 5G network.

[0005] A further object of the present invention is to provide an antenna device having small dimensions, such that it can be installed in a vehicle, preferably in the dashboard thereof.

DISCLOSURE OF INVENTION

[0006] The object of the present invention is therefore to provide a solution to achieve the above-mentioned objectives.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The present invention will now be described with reference to the appended drawings, which illustrate a nonlimiting embodiment, wherein:

- Figure 1 schematically shows a wireless communication system fitted on board a vehicle made according to the dictates of the present invention,
- Figure 2 is an exploded view of an antenna device of the wireless communication system shown in Figure 1,
- Figures 3 and 4 are two perspective views showing

the antenna device being connected to the vehicle dashboard,

- Figure 5 is a plan view of the dipole antenna electronic circuit of the antenna device shown in Figure 2,
- Figure 6 is a perspective view of the supporting base and dipole antenna electronic circuit of the antenna device shown in Figure 2,
- Figure 7 shows a side elevation view of the supporting base and dipole antenna electronic circuit of the antenna device shown in Figure 2,
- Figure 8 shows a perspective view of the antenna device according to a first embodiment,
- Figure 9 shows a side elevation view of the supporting base and dipole antenna electronic circuit of the antenna device shown in Figure 8,
- Figure 10 shows a perspective view of an antenna device of the present invention according to a second embodiment,
- Figure 11 shows a plan view of the supporting base and dipole antenna electronic circuit of the antenna device shown in Figure 10,
- Figure 12 shows a perspective view of an antenna device of the present invention according to a third embodiment,
- Figure 13 shows a plan view of the supporting base and dipole antenna electronic circuit of the antenna device shown in Figure 12,
- Figure 14 shows a perspective view of an antenna device of the present invention according to a fourth embodiment,
- Figure 15 shows a plan view of the supporting base and dipole antenna electronic circuit of the antenna device shown in Figure 14,
- Figure 16 is a graph showing the efficiency trend as the frequency of the antenna device shown in Figure 5, made according to the dictates of the present invention, varies,
- Figure 17 shows a graph of the return loss as the frequency of the antenna device made according to the present invention varies.

BEST MODE FOR CARRYING OUT THE INVENTION

[0008] The present invention will now be described in detail with reference to the appended figures to enable a person skilled in the art to make and use it. Various modifications to the embodiments described will be immediately apparent to the person skilled in the art and the general principles described may be applied to other embodiments and applications while remaining within the sphere of protection of the present invention, as defined in the appended claims. The present invention should not therefore, be considered limited to the embodiments described and illustrated, but given the broadest scope of protection according to the principles and characteristics described, illustrated and claimed herein.

[0009] Figure 1 schematically shows a wireless communication system SA which is installed in a vehicle M1

and is suitable for performing a telematic communication with one or more wireless communication networks/systems (not shown).

[0010] It should be clarified that in the following description "telematic communication" means communication with LTE networks/systems, and/or networks operating according to mobile phone technology above 4G, preferably networks operating according to 5G mobile phone technology. It is understood, however, that telematic communication according to the present invention is not limited to the networks/systems listed above, and that the wireless communication system SA may be configured to conveniently perform communications with other types of communication networks/systems, such as networks/systems operating in wide-band with a bandwidth of less than 6GHz and/or operating in the ISM (acronym for Industrial, Scientific and Medical) band with a bandwidth of less than 6GHz.

[0011] It should also be noted that in the following description and in the appended figures, explicit reference will be made to a wireless communication system SA installed in a motor vehicle M1, preferably a car.

[0012] However, it is understood that the present invention is not limited to the above application and that the wireless communication system SA can be installed in any motor vehicle (car, truck, bus and the like).

[0013] With reference to Figure 1, the wireless communication system SA comprises an antenna device 1 and an electronic communication unit UC. The electronic communication unit UC is electrically connected to the antenna device 1 via a waveguide CV, comprising for example a coaxial cable, and is configured to perform wireless communication by means of the antenna device 1. The communication electronics unit UC can also be configured to perform radio frequency communication via the antenna device 1 so as to transmit/receive data in the form of signals in predetermined frequency bands described in detail in the description below.

[0014] With reference to Figures 1-4, the antenna device 1 is structured to be mounted in the vehicle M1. According to a preferred embodiment shown in Figures 3 and 4, the antenna device 1 is structured to be installed/mounted/integrated in a dashboard CP (only partially illustrated in Figures 3 and 4) of the vehicle M1. In the example illustrated, the dashboard CP is positioned inside the passenger compartment of the vehicle M1 and has a seat/pocket T1 in which the antenna device 1 is engaged. The antenna device 1 may be attached to the dashboard CP in the pocket T1 by means of fastening means, for example screws (not shown) or the like.

[0015] As shown in Figure 2, the antenna device 1 may comprise an outer protective shell or container 4, a board or supporting base 5 positioned inside the container 4, preferably, but not necessarily, an electrical connector 6 connected to the waveguide CV, and a dipole antenna electrical circuit 7 firmly connected (secured) to the supporting base 5.

[0016] In the example illustrated, the supporting base

5 is plate-shaped and is made of an electrically insulating material. The supporting base 5 has an approximately flat shape and has a reference axis A. Preferably, the supporting base 5 may be made from electrically insulating composite materials, and/or plastic materials (polyurethane) and/or resins (epoxy). A composite material conveniently used by the Applicant to make the supporting base 5 may be vetronite-based, for example FR4 or FR-4 type material.

[0017] According to a preferred embodiment shown in Figures 2, 5-8, the supporting base 5 has an approximately rectangular shape and has four sides indicated below and in the appended figures as 5a, 5b, 5c and 5d. Preferably, the mutually opposite sides 5a and 5d are parallel to each other and orthogonal to the axis A, and the other mutually opposite sides 5b and 5c are parallel to each other and to the axis A.

[0018] With reference to Figure 2, the container 4 may have an approximately parallelepiped box shape and comprises a cup-shaped body 4a, preferably having an approximately rectangular cross-section sized to hold the supporting base 5, and an approximately rectangular shaped closure plate 4b suitable for connecting, for example by means of snap mechanisms 4c with the side walls of the cup-shaped body 4a surrounding the opening thereof so as to close the cup-shaped body 4a.

[0019] With reference to Figure 5, the antenna device 1 may comprise a first terminal 6a suitable for providing an antenna signal and a second terminal 6b set at a predetermined reference potential. The predetermined potential of the second terminal 6b is preferably a ground potential.

[0020] With regard to the connector 6, if present, it may be coupled to a wall 4d of the container 4 so as to be accessible and connectable from outside the container 4 with the waveguide CV. In the example illustrated, the connector 6 is firmly coupled to the supporting base 5 so as to extend cantilevered from the side 5b thereof. The connector 6 preferably corresponds to a connector for coaxial antenna cables provided with two electrical terminals.

[0021] According to a possible embodiment shown in Figure 5, the first terminal 6a is preferably defined by a central internal pin of the connector 6. The second terminal 6b may preferably be defined by the cylindrical portion of the connector 6 surrounding the central internal pin of the first terminal 6a.

[0022] According to a preferred embodiment shown in Figure 5, the dipole antenna electrical circuit 7 comprises a first flat portion 10 made of electrically conductive material which is positioned on the supporting base 5 coplanar thereto. The first portion 10 may preferably comprise a layer of thin electrically conductive material (indicatively in the order of microns, e.g. a few tens of microns) deposited/printed on a first surface of the supporting base 5.

[0023] It is understood that the present invention is not limited to a first portion 10 formed of a layer of electrically

conductive material, but could comprise other solutions/variants, such as making the first portion 10 by means of a thin, flat sheet of conductive material shaped and firmly positioned (fixed) on the supporting base 5. The sheet of the first portion 10 may have a thickness in the order of one millimetre or fractions thereof, for example about 0.5 mm.

[0024] According to a preferred embodiment shown in Figure 5, the first portion 10 has a polygonal shape and is electrically connected to the first terminal 6a. According to a preferred embodiment shown in figure 5, the first portion 10 has a widened, approximately rectangular shape. It is understood that according to the present invention, a "widened" shape means that the area of the first portion 10 has a significant surface extension capable of covering a large area of the underlying first surface of the supporting base 5.

[0025] With reference to Figure 5, the first portion 10 is positioned approximately centrally on the first surface of the supporting base 5 and, having a rectangular shape, has its sides indicated by 10a, 10b, 10c and 10d approximately parallel to the sides 5a, 5b, 5c and 5d of the supporting base 5, respectively.

[0026] The first, widened, polygonal portion 10 made centrally on the supporting base 5 in the manner described above allows optimization of the communication bands in higher frequencies (e.g., starting from about 1.7GHz up to about 6GHz) while respecting the dimensional constraints of the supporting base 5. In this regard, it is to be noted that the supporting base 5 has dimensional limitations associated with the limit dimensions of the vehicle dashboard CP.

[0027] According to a preferred embodiment shown in Figure 5, the dipole antenna electrical circuit 7 further comprises a second flat portion 11 made of electrically conductive material which is positioned on the first surface of the supporting base 5 (coplanar therewith) alongside the first portion 10 and is electrically insulated therefrom.

[0028] The second portion 11 may preferably comprise a layer of thin electrically conductive material (indicatively in the order of microns, e.g. a few tens of microns) deposited/printed on the surface of the supporting base 5. It is understood that the present invention is not limited to a second portion 11 formed of a layer of electrically conductive material, but could comprise other solutions/variants such as making the second portion 11 by means of a flat sheet of conductive material shaped and firmly positioned (fixed) on the supporting base 5. The sheet of the second portion 11 may have a thickness in the order of one millimetre or fractions thereof, for example about 0.5 mm. The second portion 11 is electrically connected to the second terminal 6b.

[0029] With reference to the preferred embodiment shown in Figure 5, the second portion 11 comprises at least a first branch 11a having an elongated, preferably approximately rectangular shape. Preferably, the first rectangular branch 11a extends immediately alongside

the side 10a of the first portion 10, without any electrical connection thereto. Preferably, in the example illustrated, the first branch 11a extends over the supporting base 5 adjacent and parallel to the side/edge 5a of the supporting base 5.

[0030] The Applicant has found that the first elongated branch 11a of the second portion 11 placed alongside the first portion 10 conveniently allows for the creation of a low frequency resonance at, for example, below 1GHz.

[0031] With reference to the preferred embodiment shown in Figures 2 and 5-7, the dipole antenna electrical circuit 7 further comprises at least one plate-shaped element 12 made of electrically conductive material lying on a plane transverse to the placement plane of the supporting base 5. The plate-shaped element 12 is electrically connected to the first branch 11a of the second portion 11. According to a preferred embodiment shown in Figure 5, the plate-shaped element 12 is positioned on the surface of the supporting base 5 in a position adjacent/alongside the side 10a of the first portion 10 so as to form a capacitive antenna coupling between the first portion 10 and the second portion 11.

[0032] The Applicant has found that the capacitive coupling between the two portions 10 and 11 obtained by means of the plate-shaped element 12 has a technical effect of broadening the first two resonances of the dipole created by the dipole electrical circuit 7, one towards the other. The low-frequency resonance is broadened upward, and the highfrequency is broadened downward.

[0033] In other words, the Applicant has found that the capacitive coupling created by means of the plate-shaped element 12 connected electrically with the second portion 11, has the technical effect of increasing the maximum frequency of the low frequency band, and, at the same time, reducing the minimum frequency of the high frequency band until a union between the two bands is obtained.

[0034] Figure 16 shows a graph of the total antenna efficiency, while Figure 17 is a graph of the antenna return loss wherein: the curve RL1 shows the return loss (in the y-axis) of the dipole electrical circuit 7 in the different frequency bands (shown in the x-axis); the curve RL2 shows the return loss of a different circuit configuration of a test dipole electrical circuit (not illustrated) that differs from the dipole electrical circuit 7 in that it is devoid of the plate-shaped element 12; the curve RL3 shows the return loss of a different circuit configuration of a dipole electrical circuit (not illustrated) that differs from the dipole electrical circuit 7 in that it lacks both the plate-shaped element 12 and the capacitive coupling between the first portion 10 and the second portion 11.

[0035] In particular, in the graph in Figure 17, the grey columns correspond to respective predefined frequency bands associated with the 5G function, which are as follows: 617-960, 1427-1511, 1710-2170, 2496-2690, 3300-4200, 4400-5000 MHz.

[0036] From the comparison of the graphs RL1, RL2 and RL3, it is evident that the capacitive coupling be-

tween the first 10 and the second portions 11 present in the dipole electrical circuit 7 has the technical effect of causing a reduction of the return loss within the frequency band included between about 1427 and about 1511 MHz, while the plate-shaped element 12 substantially mitigates the increase of return loss due to the capacitive coupling itself in the frequencies included between about 2500 MHz and about 3300 MHz.

[0037] In the present case, the curve RL3 shown in Figure 17 was obtained by the Applicant by means of a first laboratory test performed on a first antenna circuit configuration, in which the dipole antenna element (not illustrated) differs from that shown in Figure 5 in that it is devoid of both the plate-shaped element 12 and the capacitive coupling between the first 10 and the second portions 11. The curve RL3 shows that the first configuration presents a return loss exceeding -6 dB both in the frequency range between about 700 MHz and about 960 MHz of the first band, and around about 1427 MHz of the second band where the curve RL3 exceeds the maximum allowed return loss threshold corresponding to -6 dB.

[0038] The curve RL2 is instead obtained by means of a second laboratory test performed on a second antenna circuit configuration, in which the dipole antenna element differs from the one shown in Figure 5 in that it is devoid of the plate-shaped element 12 but has the capacitive coupling between the first 10 and the second portions 11. The curve RL2 is indicative of the fact that the effect of the capacitive coupling between the first 10 and second portions 11 of the second configuration is of conveniently reducing the return loss in the first frequency band 617-960 MHz below the return loss threshold of -6 dB. However, the second test shows that the capacitive coupling between the first 10 and the second portion 11 also results in an undesirable increase of the return loss in the second band 1427-1511 MHz until exceeding the -6dB threshold, and also minor increases (which however remain below the threshold) in the first half of the third band 1710-2000 MHz, in the fourth band 2496-2690 MHz and at the beginning of the fifth band 3300 MHz.

The curve RL1 shown in Figure 17 is instead obtained by means of a third laboratory test performed by the Applicant on the dipole antenna element of the present invention made according to the embodiment shown in Figure 5 in which both the plate-shaped element 12 and the capacitive coupling between the portions 10 and 11 are provided.

The curve RL1 proves that the use of the plate-shaped element 12 results in a substantial reduction of the return loss in the critical frequency bands listed above and therefore attenuates the effect caused by the capacitive coupling of the portions 10 and 11, without altering the improved effect obtained by the same in the first band 617-960 MHz.

The curve RL1 thus demonstrates that the technical effect obtained through the combined use of the plate-shaped element 12 and the portions 10 and 11 is to achieve a substantial reduction in return loss to values

that are below its maximum threshold of -6 dB in all five frequency bands associated with 5G.

[0039] With reference to Figure 5, the first branch 11a of the second portion 11 is shaped so as to present approximately centrally a widened portion 11ab, which extends over the surface of the supporting base 5 towards the side 10a of the first portion 10 so as to form a central segment of the first branch 11a broadened along the axis A.

[0040] According to the embodiment shown in Figure 5, the portion 11ab has an approximately trapezoidal shape. The distance between the side of the portion 11ab facing the first portion 10 and the adjacent side 10a may be conveniently between 0.2 mm and 0.7 mm, preferably 0.5 mm. The first branch 11a may have a length (measured transverse to the axis A) between about 27 and about 29 mm, preferably about 28 mm.

[0041] The Applicant has found that the widened portion 11ab allows a further increase of the capacitive coupling between the second portion 11 and the first portion 10 and thus contributes to broadening the low frequency bands towards the high frequency bands and vice versa. Moreover, the widened portion 11ab allows the operation of fixing the plate-shaped element 12 to the supporting base 5 to be carried out, and the operation of electrically connecting the same with the first branch 11a, by means of a completely automatic process that carries out a single welding operation of the plate-shaped element 12 directly on the conductive material of the first branch 11a.

[0042] With reference to the preferred embodiment shown in Figure 5, the plate-shaped element 12 is formed by a flat fin. The fin is approximately rectangular and is rigidly connected to the supporting base 5. In the example illustrated in Figures 5-7, the fin is placed approximately orthogonal to the placement plane of the supporting base 5. In the example illustrated in Figure 5, the fin further extends parallel to the extension direction of the first branch 11a. The fin of the plate-shaped element 12 has a straight edge or bottom side which is positioned in abutment on the flat top surface of the first branch 11a of the second portion 11 so as to be electrically connected thereto.

[0043] It is understood that the present invention is not limited to the positioning of the fin of the plate-shaped element 12 on the surface of the first branch 11a, but alternative solutions may be provided. According to an alternative embodiment, the fin may be positioned resting on the surface in electrically insulating material of the supporting base 5, for example abutting against the side 5a, and be electrically connected with the first branch 11a via one or more wires or electrical tracks extending over the supporting base 5 from the plate-shaped element 12 to the first branch 11a. In this embodiment, the first branch 11a of the second portion 11 may be devoid of the widened portion 11ab, and the side 10a of the first portion 10 may be brought close to the side 5a towards the plate-shaped element 12 until it is positioned next to the first branch 11a.

[0044] In the example illustrated in Figures 5-7, the fin of the plate-shaped element 12 is made of a preferably rigid sheet of metallic material (e.g., copper or aluminium) having along its lower edge one or more protruding fasteners S1 which are firmly/rigidly engaged in respective slots/through-holes AS made on the supporting base 5 at the first branch 11a of the second portion 11. Preferably, the fin of the plate-shaped element 12 may have a height (measured orthogonally to the supporting base 5) of between about 7 and about 9 mm, preferably 8 mm.

[0045] With reference to the preferred embodiment shown in Figure 5, the second portion 11 further comprises an approximately straight elongated second branch 11b, preferably rectangular, extending over the supporting base 5 from a first longitudinal end of the first branch 11a towards the connector 6. The second branch 11b and the first branch 11a form an approximately L-shaped electrical track. The second branch 11b extends over the first surface of the supporting base 5 between the side 10b and the side 5b in a direction approximately parallel to the axis A, and is preferably positioned immediately alongside the side 5b. The second branch 11b of the second portion 11 has the end opposite the first branch 11a electrically connected to the second terminal 6b. Preferably, the minimum distance (measured transverse to the axis A) between the second branch 11b and the side 10b of the first portion may be between about 1 and about 3 mm, preferably 2 mm.

[0046] According to the preferred embodiment shown in Figure 5, the second portion 11 further comprises a third, approximately straight elongated branch 11c extending over the supporting base 5 from a second longitudinal end of the first branch 11a, in a direction approximately parallel to the axis A and the second branch 11b, towards the side 5d of the supporting base 5. The first branch 11a, second branch 11b and third branch 11c extend over the supporting base 5 so as to form an approximately U-shaped electrical track.

[0047] The third branch 11c extends over the supporting base 5 on the free surface between the side 10c and the side 5c in a direction approximately parallel to the axis A, and is preferably positioned immediately alongside the side 5c. Preferably, the minimum distance (measured transverse to the axis A) between the third branch 11c and the side 10c of the first portion 10 may be between about 1 and about 3 mm preferably 2 mm.

[0048] The third branch 11c may further be sized such that its length (measured parallel to the axis A) approximates by default approximately the length of the side 5c. For example, the third branch 11c may have a length between about 51 and about 53 mm, preferably about 52 mm.

[0049] According to the preferred embodiment shown in Figure 5, the second portion 11 further comprises a fourth approximately straight elongated branch 11d, extending on said supporting base 5 from a second longitudinal end of the third branch 11c, in a direction approximately transverse to the axis A, towards the side 5b.

Preferably, the first branch 11a, the second branch 11b, the third branch 11c and the fourth branch 11d extend over the supporting base 5 so as to form an approximately rectangular electrical track.

[0050] The fourth branch 11d extends over the supporting base 5 in a direction approximately orthogonal to the axis A on the first free surface between the side 10d and the side 5d, and is preferably positioned immediately adjacent to the side 5d. Preferably, the minimum distance (measured parallel to the axis A) between the fourth branch 11d and the side 10d of the first portion 10 is greater than about 5 mm.

[0051] The fourth branch 11d may further be sized such that its length orthogonal to the axis A is less than the length of the side 5d. For example, the fourth branch 11d may have a length of between about 20 and about 21 mm, preferably about 20.5 mm.

[0052] The Applicant has found that the branches 11b, 11c and 11d connected to the branch 11a elongate the portion 11 such that the low frequency band is obtained.

[0053] The Applicant has further found that the total length of the second portion 11 in the configuration comprising the first 11a, second 11b, third 11c and fourth branch 11d may advantageously be equal to about one-quarter $1/4$ of the wavelength ($\lambda/4$). For example, the total length of the second portion 11 in the configuration comprising the first 11a, the second 11b, the third 11c and the fourth branch 11d may be about 13 cm.

[0054] With reference to the preferred embodiment shown in Figure 5, the first portion 10 may be shaped to comprise an elongated, preferably rectangular, approximately straight connection branch 10k extending over the supporting base 5 from the side 10b of the first portion 10 approximately transverse to the axis A towards the side 5b of the supporting base 5 and having its free longitudinal end electrically connected to the first terminal 6a.

[0055] With reference to the preferred embodiment shown in Figure 5, the second portion 11 may further preferably comprise an elongated, approximately straight connection branch 11x extending over the supporting base 5 immediately alongside and parallel to the connection branch 10k of the first portion 10, without being in electrical contact therewith. In the example illustrated, the connection branch 11x is approximately rectangular in shape, extends approximately transverse to the axis A, and connects the second longitudinal end of the second branch 11b to the second terminal 6b of the connector 6. Preferably, the electrical connection between the second terminal 6b and the connection branch 11x may be made via one or more connection pins 13 that rigidly engage in respective holes/openings made through the connection branch 11x and the underlying supporting base 5.

[0056] With reference to the preferred embodiment shown in Figure 5, the dipole antenna electrical circuit 7 may further comprise a third portion 15 made of electrically conductive material which is positioned on the sup-

porting base 5 coplanar thereto approximately alongside the connection branch 10k of the first portion 10 and is electrically connected to the second terminal 6b. In the example illustrated, the third portion 15 is sized and structured to match the impedance in the higher frequency bands (e.g., 3.3GHz-4.2GHz, 4.4GHz-5GHz).

[0057] According to an embodiment shown in Figure 5, the third portion 15 comprises a branch extending over the supporting base 5 so as to approximately form a T. Preferably, the branch of the third portion 15 comprises a first segment 15a extending straight alongside and parallel to the connection branch 10k of the first portion 10 from the side opposite the connection branch 11x of the second portion 10. The third portion branch 15 further comprises a second segment 15b, which extends over the supporting base 5 orthogonal to the first segment 15a in a direction opposite to the straight connection branch 11x of the second portion 11. In the example illustrated, the second segment 15b of the third portion branch 15 extends approximately next to/adjacent to the side 5b so as to extend towards the side 5d. Preferably, the second segment 15b of the third portion 15 has a length (parallel to the axis A) between about 9 mm and about 11 mm, preferably 10 mm.

[0058] Preferably, the electrical connection between the second terminal 6b and the branch of the third portion 15 may be made through one or more connection points 14 that rigidly engage in respective holes/openings preferably made through the first segment 15a and the underlying supporting base 5.

[0059] Preferably, the dipole antenna electrical circuit 7 of the antenna device 1 made according to the above description is suitable for optionally communicating in the following frequency bands associated with the 5G function: 617-960 MHz, 1427-1511 MHz, 1710-2170 MHz, 2300-2400 MHz, 2496-2690 MHz, 3300-4200 MHz, 4400-5000MHz.

[0060] The Applicant has found it particularly advantageous to use the dipole antenna electrical circuit 7 of the antenna device 1 made as described above to carry out telephone communications.

[0061] In more detail, the Applicant has found that the antenna device 1, due to the presence of the plate-shaped element 12, has extremely small dimensions that allow it to be applied/installed in a vehicle dashboard.

[0062] Thanks to the configuration described above, it is possible to adapt the bandwidth, on the one hand, without affecting the compactness of the antenna device and, on the other, without the aid of a concentrated component adaptation network that would lead to the introduction of undesirable losses and costs.

[0063] Lastly it is clear that modifications may be made to, and variants derived from, the antenna device described and illustrated herein while remaining within the protective scope of the present invention, as defined by the appended claims.

[0064] The embodiment shown in Figures 8 and 9 relates to an antenna device 20, which is similar to the

antenna device 1 (shown in Figure 2), the constituent parts of which will be denoted, where possible, with the same reference numbers denoting corresponding parts of the antenna device 1.

[0065] The antenna device 20 differs from the antenna device 1 in that the plate-shaped element 12 is formed by a fin comprising a sheet folded into an L-shape. The plate-shaped element 12 has a first rectangular portion extending cantilevered from the supporting base 5 and lying on a plane approximately orthogonal thereto, and a second rectangular portion extending cantilevered from the upper end of the first rectangular portion so as to extend above the supporting base 5 towards the side 10a and lying on a plane approximately parallel to the supporting base 5.

[0066] The embodiment shown in Figures 10 and 11 relates to an antenna device 30, which is similar to the antenna device 1 (shown in Figure 2), the constituent parts of which will be denoted, where possible, with the same reference numbers denoting corresponding parts of the antenna device 1.

[0067] The antenna device 30 differs from the antenna device 1 in that the plate-shaped element 12 is made of a sheet folded at three points, along axes orthogonal to the supporting base, so as to form a substantially rectangular frame preferably open at one vertex. The frame has four walls 12a, 12b, 12c and 12d which are positioned at the sides 5a, 5b, 5c and 5d parallel thereto and extend cantilevered from the supporting base 5 so as to be approximately orthogonal to said supporting base 5. The walls 12a, 12b, 12c and 12d are preferably positioned with their lower sides resting on the branches 11a, 11b, 11c and 11d respectively.

[0068] The embodiment shown in Figures 12 and 13 relates to an antenna device 40, which is similar to the antenna device 1 (shown in Figure 2), the constituent parts of which will be denoted, where possible, with the same reference numbers denoting corresponding parts of the antenna device 1.

[0069] The antenna device 40 differs from the antenna device 1 in that it comprises a pair of dipole electrical circuits 41 positioned on the same supporting base 42 side by side.

[0070] According to the embodiment shown in Figures 12 and 13, the supporting base 42 is substantially rectangular and is sized to include the two dipole electrical circuits 41 side by side.

[0071] The supporting base 42 has a reference axis B and four sides indicated in Figures 12 and 13 as 42a, 42b, 42c. The mutually opposite sides 42a and 42d are parallel to each other and to the axis B, the mutually opposite sides 42c are parallel to each other and orthogonal to the axis B. The two dipole electrical circuits 41 are positioned on the supporting base 42 in such a way as to present the first sides 11a of the second portions facing/adjacent to the side 42a. Preferably, the first side 11a of a dipole electrical circuit 41 may be substantially parallel and aligned (coaxial) with the first side 11a of the

other dipole electrical circuit 41.

[0072] The two dipole electrical circuits 41 are further arranged on the supporting base 42 in such a way as to present the plate-shaped elements 12 facing/adjacent to the side 42a. Preferably, the plate-shaped element 12 of the dipole electrical circuit 41 may be substantially parallel and coplanar to the plate-shaped element 12 of the other dipole electrical circuit 41.

[0073] The two dipole electrical circuits 41 are also arranged on the supporting base 42 in such a way as to present the third branches 11c adjacent to the corresponding two sides 41c opposite each other and transverse to the axis B.

[0074] The two dipole electrical circuits 41 are also arranged on the supporting base 42 in such a way as to present the fourth branches 11d adjacent to the side 42b. Preferably, the fourth branch 11d of a dipole electrical circuit 41 may be parallel to and aligned with the fourth branch 11d of the other dipole electrical circuit 41.

[0075] The two dipole electrical circuits 41 are further arranged on the supporting base 42 such that the second branches 11b face and are parallel to each other in the central surface portion of the supporting base 42 at a given distance from each other. This distance may depend on the size of electronic components (not shown) centrally arranged on the supporting base 42.

[0076] According to the embodiment shown in Figures 12 and 13, the third portion 15 of each of the two dipole electrical circuits 41 has the segment 15b which extends parallel to the midplane V and has an end electrically connected to the end of the connection branch 11x adjacent to the midplane V.

[0077] According to the embodiment shown in Figures 12 and 13, the third portion 15 of each of the two dipole electrical circuits 41 further has the segment 15a which is connected to an intermediate segment of an inner side of the segment 15a and has a polygonal shape extending over the supporting base 42 towards the portion 10 such that it has a series of inner sides adjacent to the sides of the portion 10.

[0078] According to the embodiment shown in Figures 12 and 13, each of the two dipole electrical circuits 41 has a first terminal 6a, which is positioned approximately at the end portion of the connection branch 10k facing the midplane V and is connected to a pole of the waveguide CV associated with the antenna signal.

[0079] According to the embodiment shown in Figures 12 and 13, each of the two dipole electrical circuits 41 has the second terminal 6b which is positioned in the third portion 15, preferably at an area of the portion 15b adjacent to the first terminal 6a.

[0080] The Applicant has found this configuration to be particularly advantageous since, on the one hand, it integrates two dipole electronic circuits, thus greatly limiting their overall dimensions and making it possible to offer, in the passenger compartment of the vehicle, two telephone communication systems independent of each other and, on the other hand, it allows the two waveguides

CV to be arranged side by side. In the example illustrated in Figures 12 and 13, the two waveguides CV are side-by-side and parallel to each other and extend such that they cross the same side 42b of the supporting base 42.

[0081] The embodiment shown in Figures 14 and 15 relates to an antenna device 50, which is similar to the antenna device 40 (shown in Figures 12 and 13), the constituent parts of which will be denoted, where possible, with the same reference numbers denoting corresponding parts of the antenna device 1.

[0082] The antenna device 50 differs from the antenna device 40 in that one of the two dipole electrical circuits indicated by reference numeral 51 (positioned on the right in Figure 15) is positioned on the supporting base 42 so that it has a first terminal 6a and a second terminal 6b at the side 42c.

[0083] According to the embodiment shown in Figures 14 and 15, the first terminal 6a and the second terminal 6b of the dipole electrical circuit 51 are positioned on a side 42c and are connected to the first 6a and second terminal 6b.

[0084] According to the embodiment shown in Figures 14 and 15, the first portion 10 and the second portion 11 of the dipole electrical circuit 51 are identical to the first portion 10 and the second portion 11 of the dipole electrical circuit 7 shown in Figure 5.

[0085] The Applicant has found this configuration to be particularly advantageous since, on the one hand, it integrates two dipole electronic circuits, thus greatly limiting their overall dimensions and making it possible to offer, in the passenger compartment of the vehicle, two telephone communication systems independent of each other, and on the other hand, it allows the two waveguides CV to be arranged on two sides orthogonal to the supporting base 5.

Claims

1. A 5G dipole antenna device (1) comprising:

a flat plate-shaped supporting base (5) made of electrically insulating material,
a first terminal (6a) designed to provide an antenna signal, and a second terminal (6b) set at a pre-established reference potential,
and at least one dipole antenna electrical circuit (7) comprising:

at least a first flat portion (10) made of electrically conductive material which is arranged on said supporting base (5) coplanar to the same and is electrically connected to said first terminal (6a), said first portion (10) having an approximately polygonal shape,
at least one second flat portion (11) made of electrically conductive material which is

- arranged on said supporting base (5) coplanar to the same so as to be electrically insulated from the first portion (10) and is electrically connected to said second terminal (6b), said second portion (11) comprising at least one first branch (11a) having an elongated shape which extends immediately alongside a first side (10a) of said first portion (10), and at least one plate-shaped element (12) made of electrically conductive material that lies on a plane transverse to the placement plane of said supporting base (5) and is electrically connected to said first branch (11a) of said second portion (11), said plate-shaped element (12) being adjacent to said first side (10a) of said first portion (10) and forms, with said first adjacent side (10a) of said first portion (10), a capacitive antenna element.
2. The dipole antenna device according to claim 1, wherein said first branch (11a) of said second portion (11) has a widened portion (11ab) which extends on said supporting base (5) towards said first side (10a) of the first portion (10) and is shaped so as to have an approximately rectilinear inner edge arranged facing and adjacent to said first side (10a) of said first portion (10).
 3. The dipole antenna device according to any one of the preceding claims, wherein said first branch (11a) of said second portion (11) is rectilinear, said plate-shaped element (12) has an approximately rectangular shape and is firmly connected to said supporting base (5) so as to be arranged approximately orthogonal to the supporting base (5) and parallel to said first branch (11a) of said second portion (11), said plate-shaped element (12) has a lower side arranged in abutment on said first branch (11a) of said second portion (11) so as to be electrically in contact and connected with the same.
 4. The dipole antenna device according to any one of the preceding claims, wherein said supporting base (5) has a longitudinal axis (A), has an approximately rectangular shape and has an approximately rectilinear side edge (5a) adjacent and parallel to said first branch (11a) of said second portion (11).
 5. The dipole antenna device according to claim 4, wherein said second flat portion (11) has a second branch (11b) having an approximately rectilinear elongated shape which extends over said supporting base (5) parallel to said longitudinal axis (A) from a first end of the first branch (11a) so as to form an approximately L-shaped electrical track with the same; said second branch (11b) electrically connects said first branch (11a) to said second terminal (6b).
 6. The dipole antenna device according to claim 5, wherein said second portion (11) has a third branch (11c) having an approximately rectilinear elongated shape that extends over said supporting base (5) from a second end of the first branch (11a), opposite to said first end, along a direction approximately parallel to said longitudinal axis (A) so as to form an approximately U-shaped electrical track with said first branch and said second branch.
 7. The dipole antenna device according to claim 6, wherein said second flat portion (11) has a fourth branch (11d) having an approximately rectilinear elongated shape which extends over said supporting base (5) from an end of the third branch (11c) opposite to that of the latter connected with the first branch (11a), along a direction approximately orthogonal to said longitudinal axis (A) so as to form, with the first (11a), second (11b) and third (11c) branches, an approximately rectangular shaped electrical track.
 8. The dipole antenna device according to any one of the preceding claims, wherein said first flat portion (10) is approximately rectangular.
 9. The dipole antenna device according to any one of the preceding claims, wherein said plate-shaped element (12) is arranged adjacent to a first side (5a) of said supporting base (5), said first terminal (6a) and said second terminal (6b) are arranged adjacent to a second side (5b) of said supporting base (5) orthogonal to said first side (5a) of said supporting base (5).
 10. The dipole antenna device according to claim 9, wherein said first flat portion (10) comprises a rectilinear connection branch (10K) having an elongated rectangular shape which extends rectilinearly over said supporting base (5) from a second side (10b) of the first flat portion (10) approximately transverse to said first side (10a) towards said second side (5b) of said supporting base (5) and is electrically connected to said first terminal (6a).
 11. The dipole antenna device according to claim 10, wherein said second portion (11) comprises an approximately rectilinear elongated shaped connection branch which extends over said supporting base (5) immediately alongside and parallel to said rectilinear connection branch (10K) of the first portion (10) and is connected to said second terminal (6b).
 12. The dipole antenna device according to claim 11, comprising a third portion (15) made of electrically conductive material which is arranged over said sup-

porting base (5) coplanar to the same and is electrically connected to said second terminal (6b), said third portion (15) has an approximately T-shape wherein a first segment (15a) extends rectilinearly alongside and parallel to said rectilinear connection branch (10K) of the first portion (10) from the opposite side with respect to the connection branch (11X) of said second portion (11), and a second segment (15b) which extends over the supporting base (5) orthogonal to said longitudinal axis (A) in an opposite direction to the rectilinear connection branch (10K) of said first portion (10) .

13. The dipole antenna device according to any one of the preceding claims, wherein said dipole antenna electrical circuit is designed to operate in one or more of the following frequency bands: 617-960 MHz, 1427-1511 MHz, 1710-2170 MHz, 2300-2400 MHz, 2496-2690 MHz, 3300-4200 MHz, 4400-5000MHz.

14. The dipole antenna device according to any one of the preceding claims, wherein said dipole antenna electrical circuit (7) corresponds to a dipole antenna electrical circuit for a telephone.

15. The dipole antenna device according to any one of the preceding claims, wherein said plate-shaped element (12) comprises a flat sheet.

16. The dipole antenna device according to any one of the claims from 1 to 15, wherein said plate-shaped element (12) comprises a sheet folded in an L-shape.

17. The dipole antenna device according to any one of the preceding claims comprising:
at least two dipole antenna electrical circuits (7) which are arranged over said supporting base (5) approximately one beside the other and each comprises:

a first flat portion (10) made of electrically conductive material which is arranged over said supporting base (5) coplanar to the same and is electrically connected to the relative first terminal (6a), said first portion (10) having an approximately polygonal shape,

a second flat portion (11) made of electrically conductive material, which is arranged on said supporting base (5) coplanar to the same so as to be electrically insulated from the first portion (10) and is electrically connected to the relative second terminal (6b), said second portion (11) comprising at least one first branch (11a) having an elongated shape which extends immediately alongside a first side (10a) of the first portion (10),

a plate-shaped element (12) made of electrically conductive material that lies on a plane trans-

verse to the placement plane of said supporting base (5) and is electrically connected to said first branch (11a) of said second portion (11), said plate-shaped element (12) is adjacent to said first side of said first portion (10) and forms, with the first adjacent side of said first portion (10), a capacitive antenna element.

18. The dipole antenna device according to claim 17, wherein the two dipole antenna electrical circuits are arranged on said supporting base so as to mirror one another with respect to a vertical midplane (V) that extends at the centre towards said supporting base (5).

19. The dipole antenna device according to claim 18, wherein the two dipole antenna electrical circuits are arranged on said supporting base so as to each have the first terminal (6a) and the second terminal (6b) alongside and adjacent to said vertical midplane (V).

20. The dipole antenna device according to claim 17, wherein the two dipole antenna electrical circuits are arranged on said supporting base so that the first terminal (6a) and the second terminal (6b) of a dipole antenna electrical circuit are arranged adjacent to a first side of the supporting base, and wherein the first terminal (6a) and the second terminal (6b) of the other dipole antenna electrical circuit are arranged adjacent to a second side of the supporting base orthogonal to said first side of the supporting base.

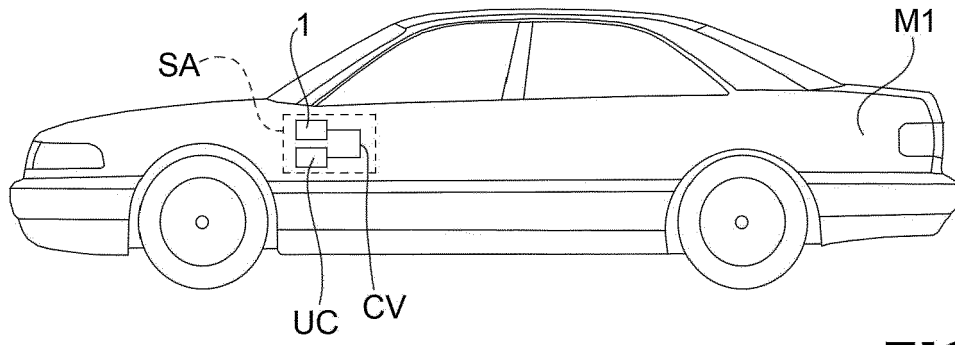


FIG. 1

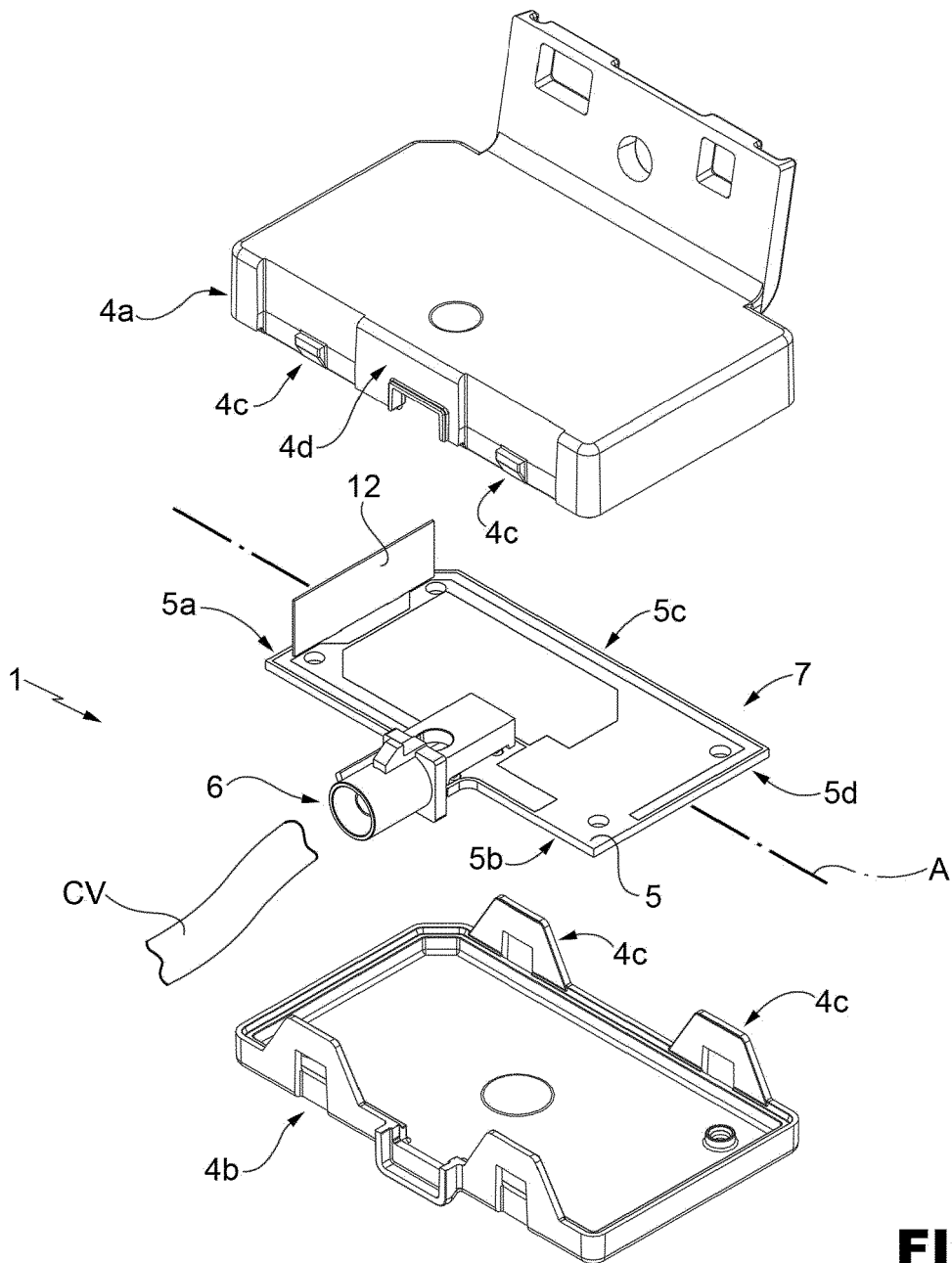


FIG. 2

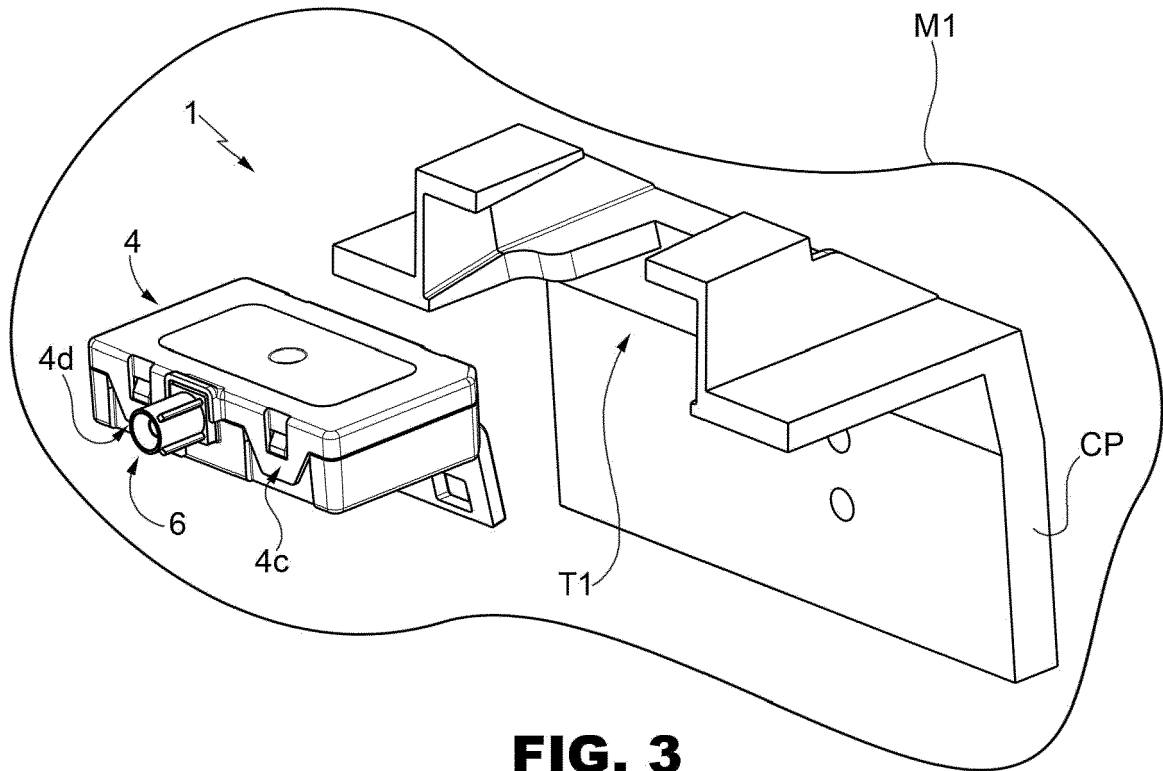


FIG. 3

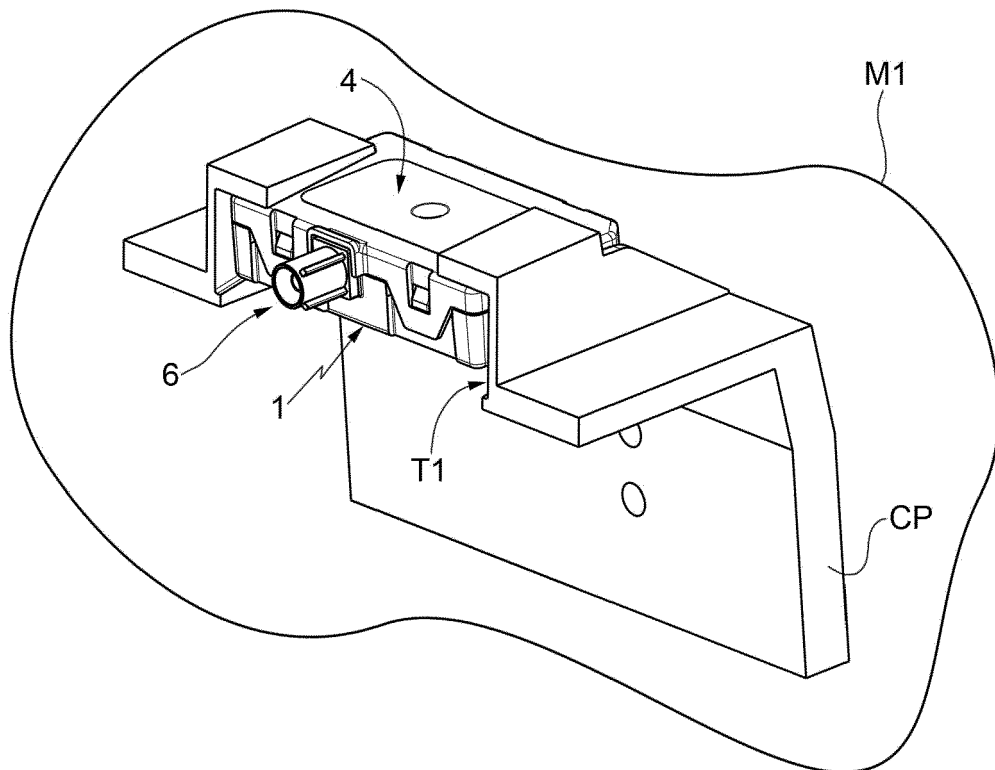


FIG. 4

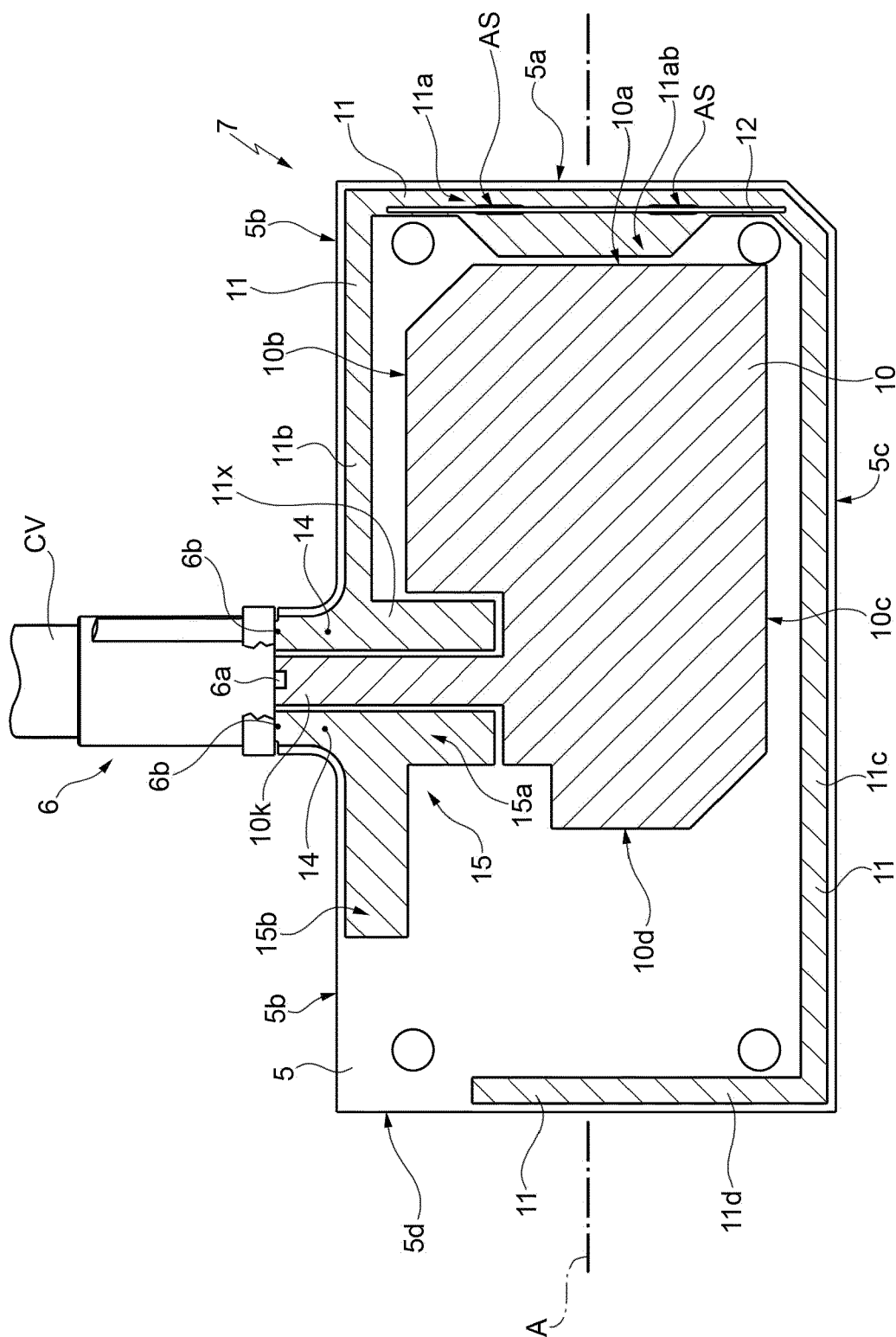


FIG. 5

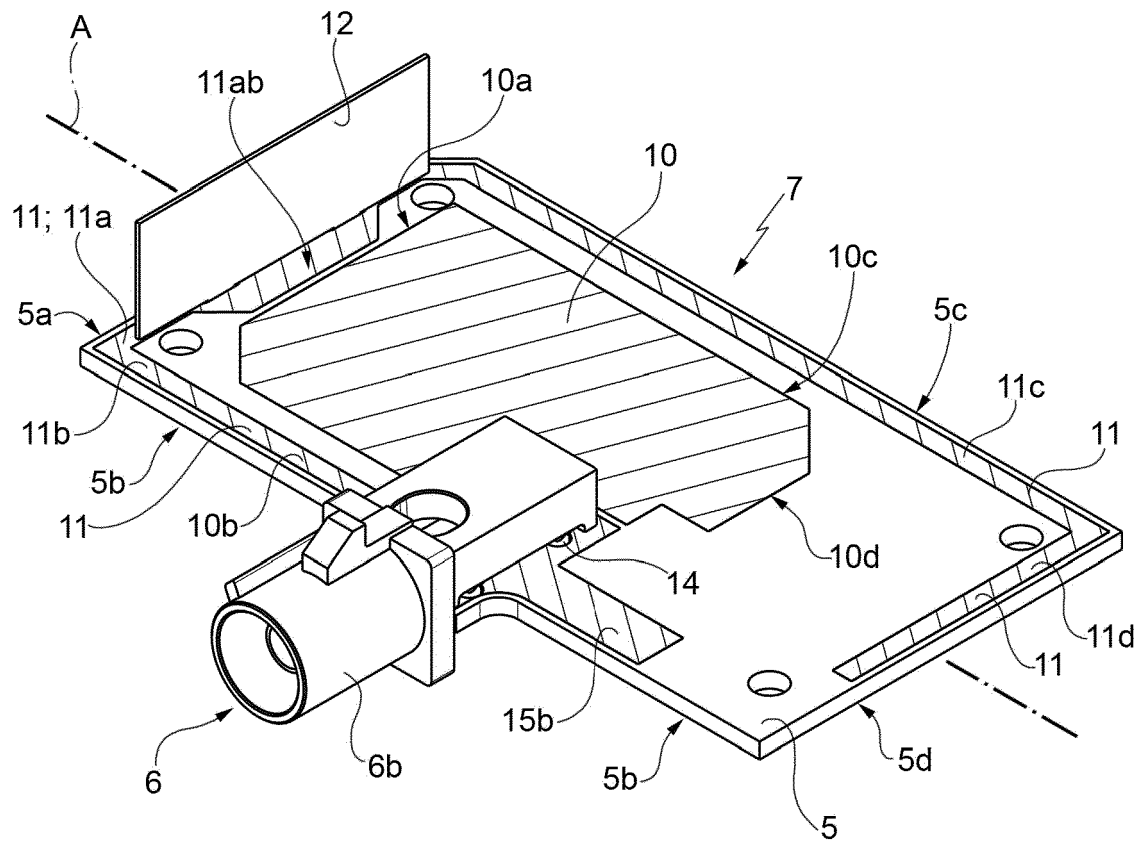


FIG. 6

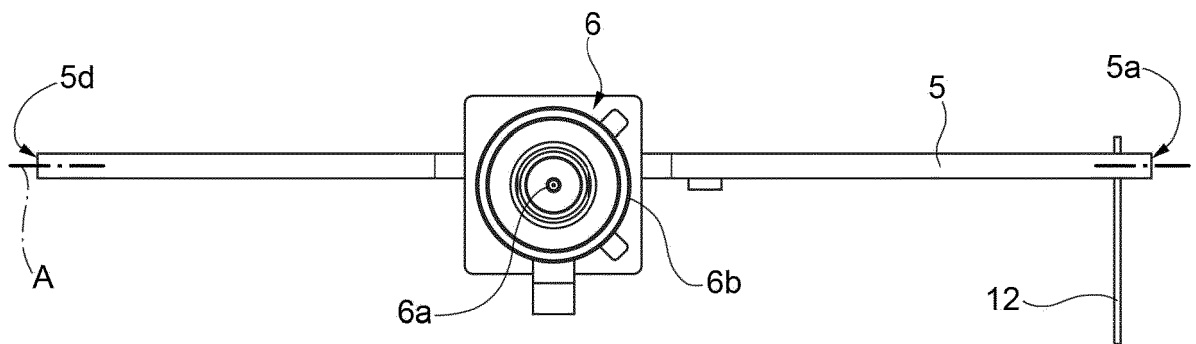


FIG. 7

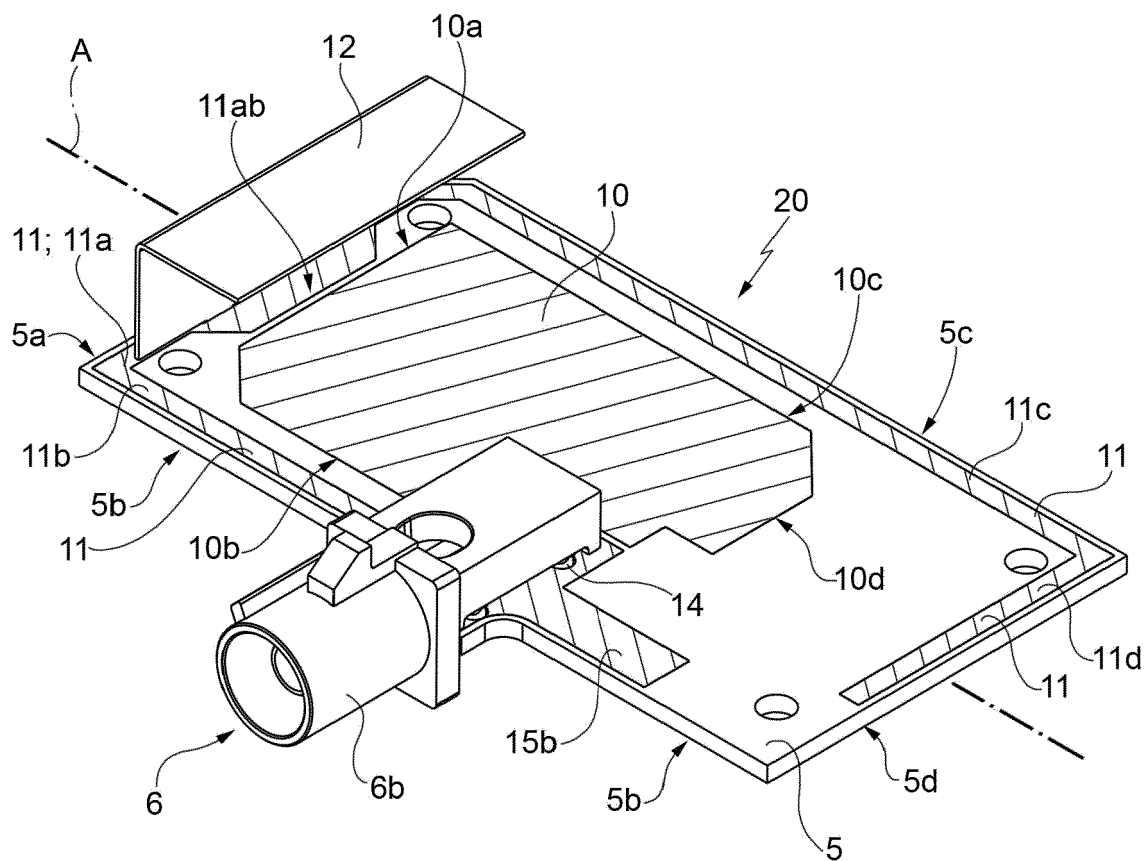


FIG. 8

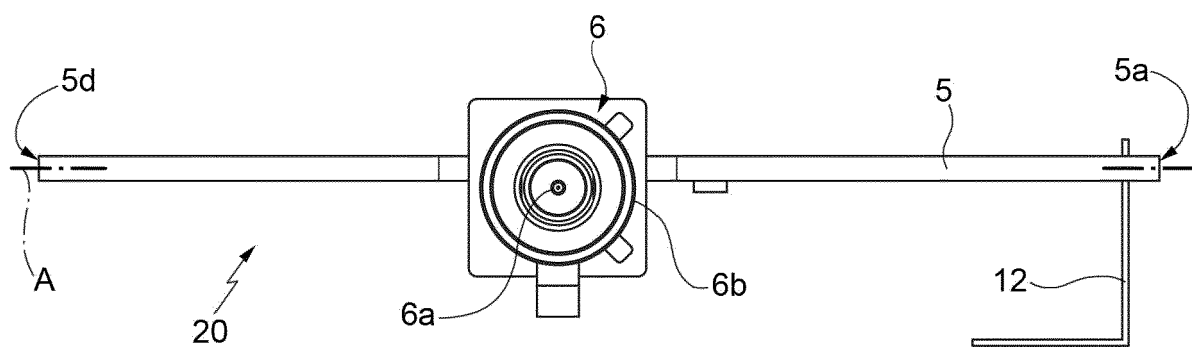


FIG. 9

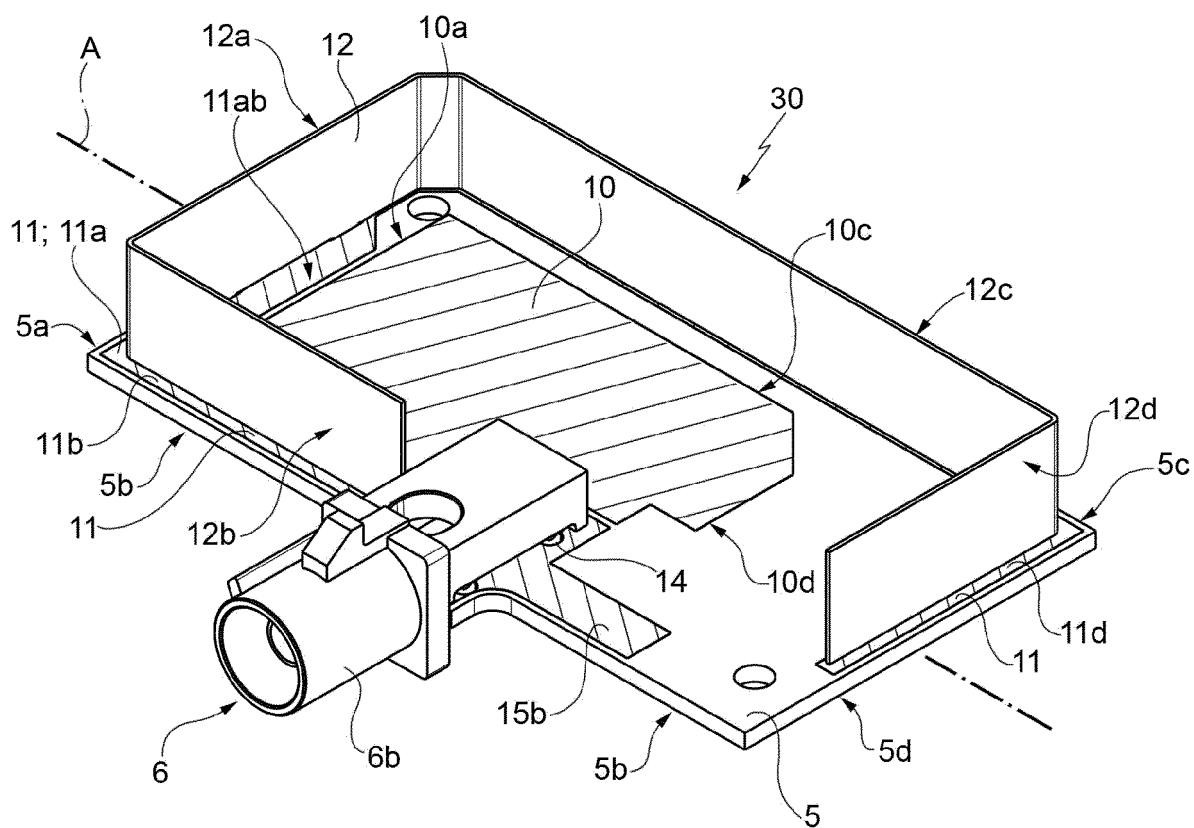


FIG. 10

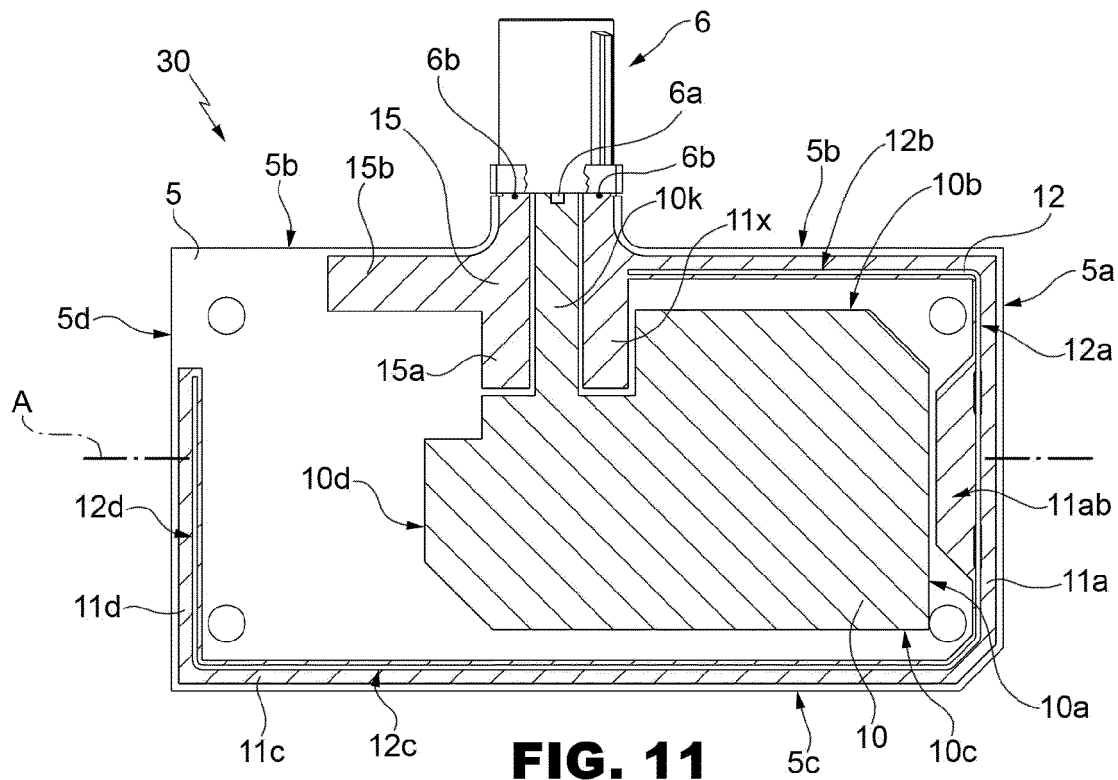


FIG. 11

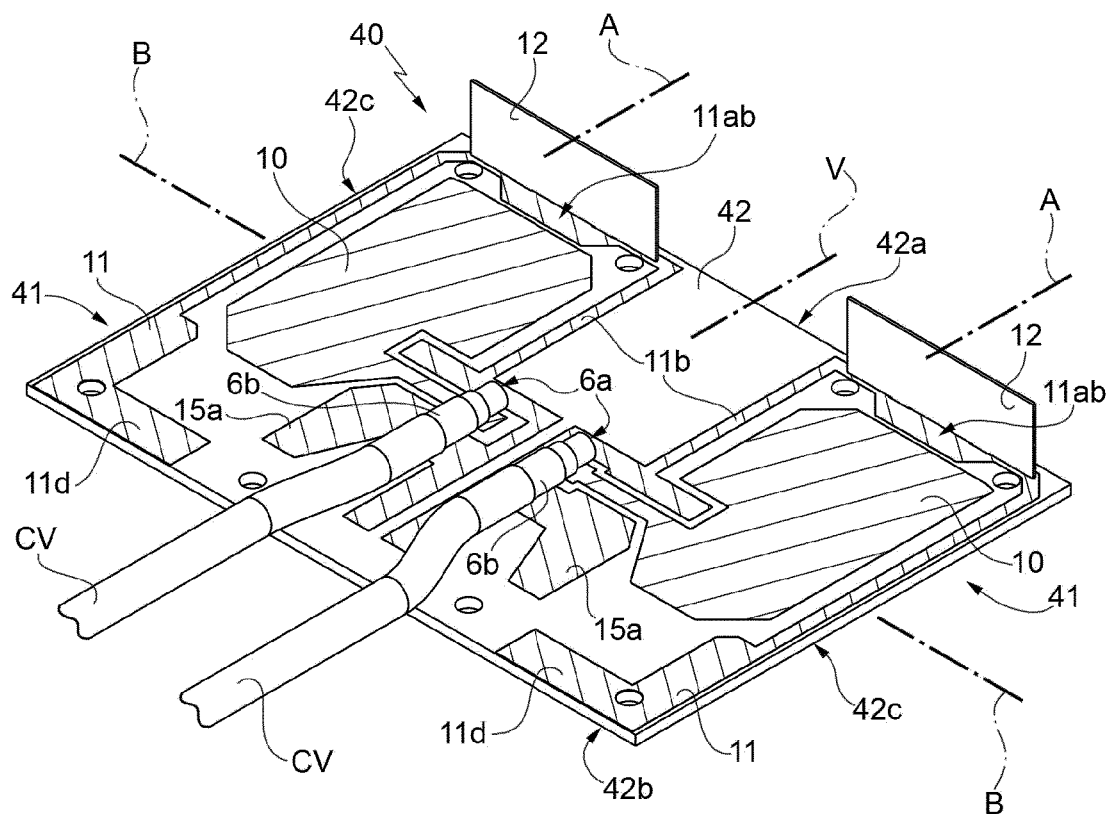


FIG. 12

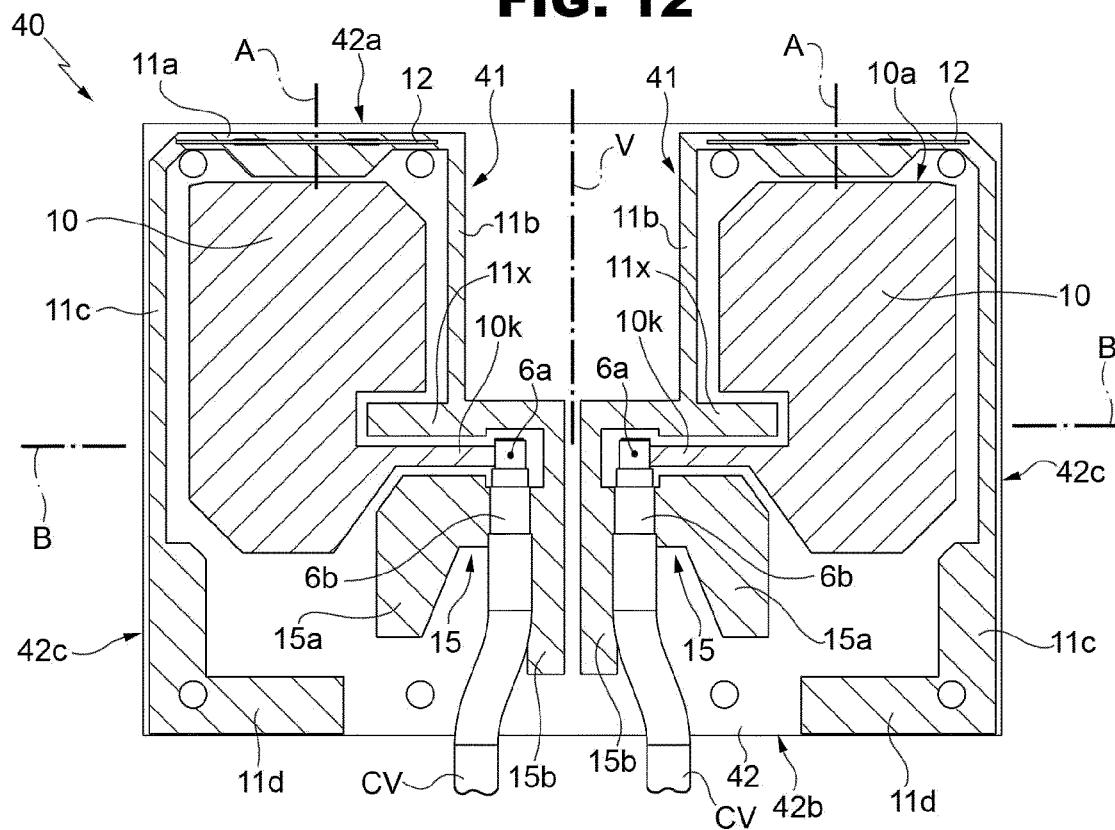


FIG. 13

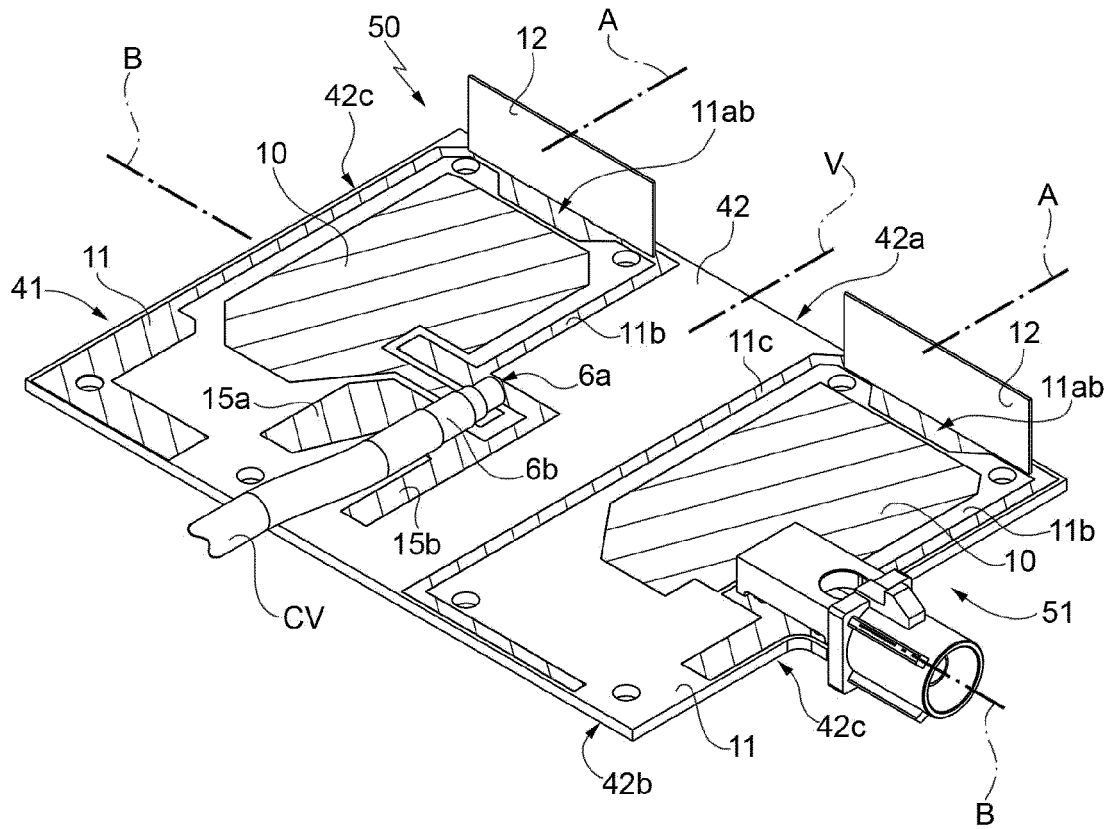


FIG. 14

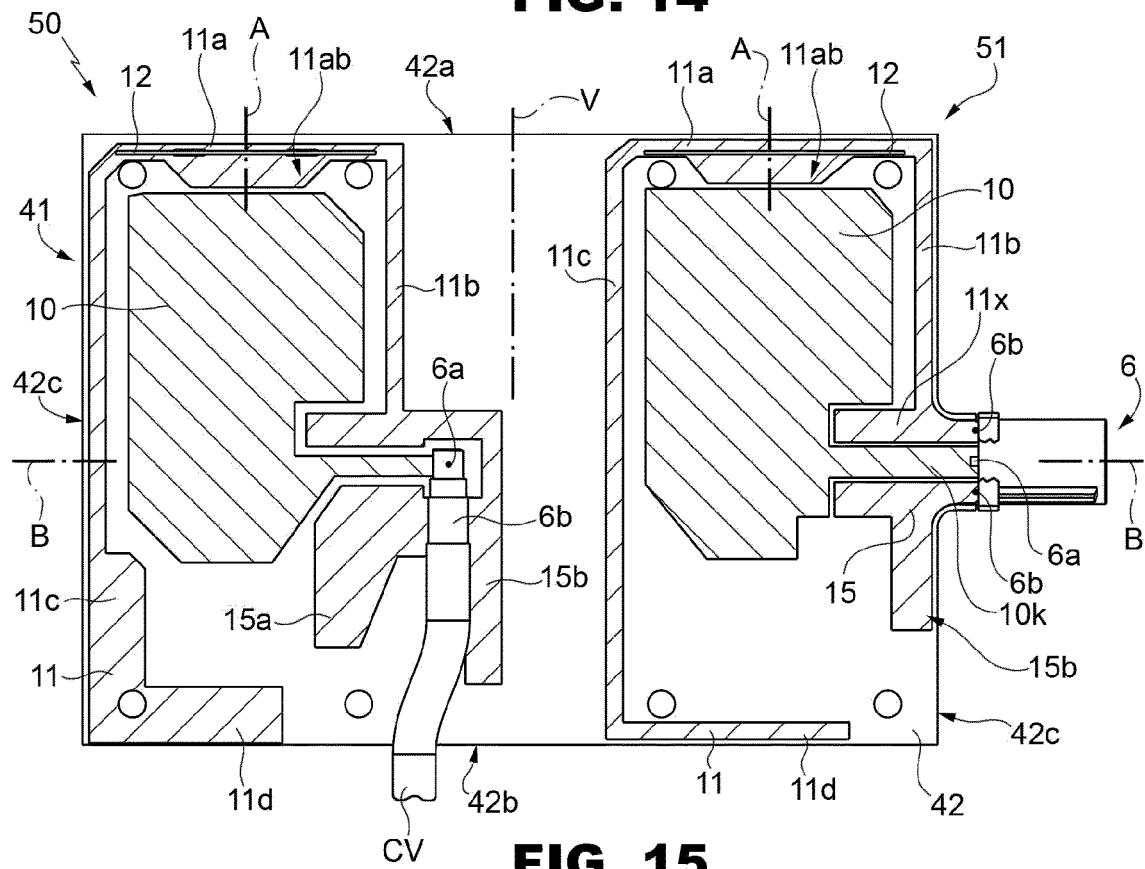


FIG. 15

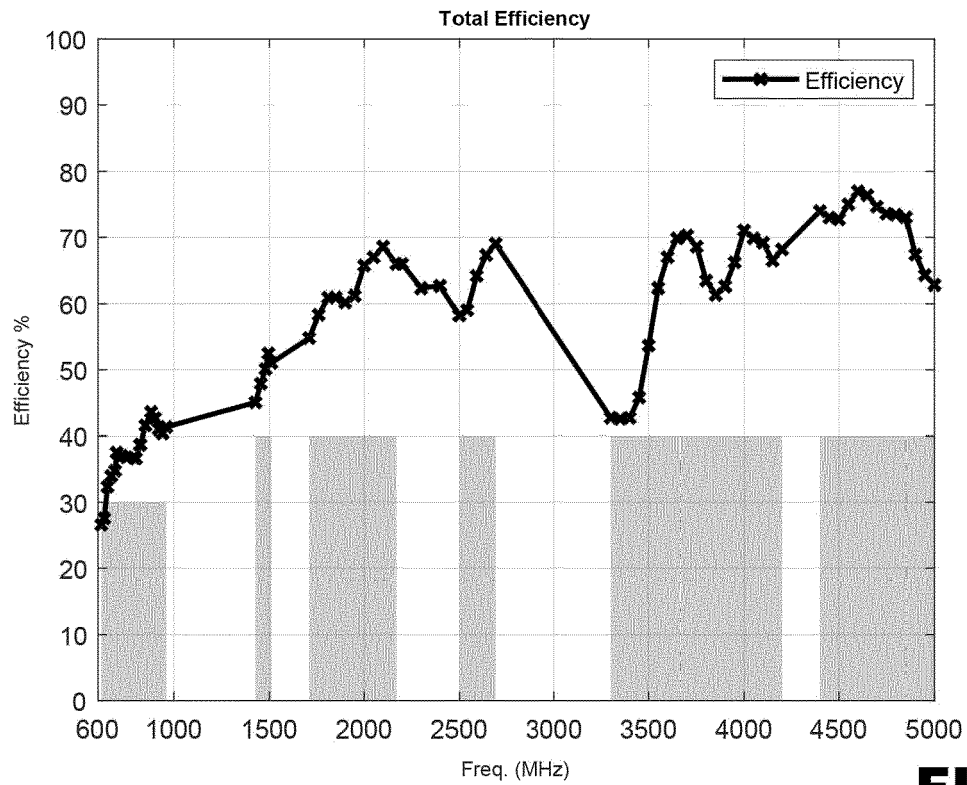


FIG. 16

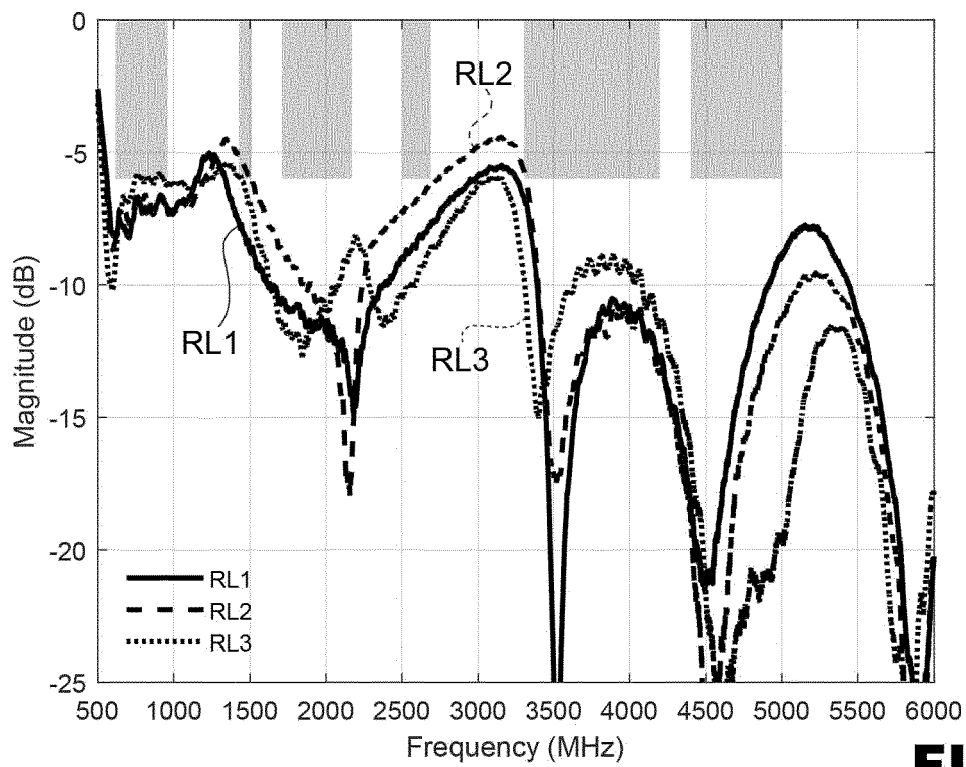


FIG. 17



EUROPEAN SEARCH REPORT

Application Number
EP 21 16 8966

5

10

15

20

25

30

35

40

45

50

55

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	EP 2 800 204 A1 (SONY CORP [JP]) 5 November 2014 (2014-11-05) * paragraphs [0001], [0011], [0015] - [0024], [0026] - [0034], [0040] - [0042], [0060] * * claim 3 * * figures 1,2a-2c,4,7 *	1-20	INV. H01Q1/32 H01Q1/48 H01Q5/385 H01Q5/392 H01Q9/40 H01Q1/38 H01Q21/28
A	EP 2 645 477 A1 (HUAWEI DEVICE CO LTD [CN]) 2 October 2013 (2013-10-02) * paragraphs [0002] - [0004], [0013], [0031], [0032]; figures 3,9 *	1-20	
A	EP 3 588 674 A1 (ADVANCED AUTOMOTIVE ANTENNAS S L U [ES]) 1 January 2020 (2020-01-01) * paragraphs [0001] - [0004], [0007], [0013] - [0027], [0034] - [0044]; figures 1a-1c *	1-20	
A	US 2014/320349 A1 (LEE YI-CHIEH [TW] ET AL) 30 October 2014 (2014-10-30) * paragraphs [0011] - [0016], [0018], [0020] - [0024]; figure 1 *	1-20	TECHNICAL FIELDS SEARCHED (IPC) H01Q
A	US 2010/188297 A1 (CHEN HUANG-CHIH [TW] ET AL) 29 July 2010 (2010-07-29) * paragraphs [0003], [0023], [0024], [0028] - [0031]; figures 2,3a,5a,5b *	1-20	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 13 August 2021	Examiner Wattiaux, Véronique
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 21 16 8966

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-08-2021

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2800204 A1	05-11-2014	BR 112014015168 A2	13-06-2017
		CN 104011936 A	27-08-2014
		EP 2800204 A1	05-11-2014
		JP 5861455 B2	16-02-2016
		JP 2013138380 A	11-07-2013
		KR 20140104968 A	29-08-2014
		RU 2014125273 A	27-12-2015
		TW 201330378 A	16-07-2013
		US 2014333493 A1	13-11-2014
		WO 2013099589 A1	04-07-2013

EP 2645477 A1	02-10-2013	CN 102136624 A	27-07-2011
		EP 2645477 A1	02-10-2013
		JP 5692685 B2	01-04-2015
		JP 2013543354 A	28-11-2013
		US 2013249741 A1	26-09-2013
		WO 2012068947 A1	31-05-2012

EP 3588674 A1	01-01-2020	EP 3588674 A1	01-01-2020
		US 2020006850 A1	02-01-2020

US 2014320349 A1	30-10-2014	TW 201442349 A	01-11-2014
		US 2014320349 A1	30-10-2014

US 2010188297 A1	29-07-2010	KR 20100086914 A	02-08-2010
		TW 201029266 A	01-08-2010
		US 2010188297 A1	29-07-2010

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- IT 102020000008101 [0001]