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**Intellectual Property**
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(54) **ANTENNA ARRANGEMENT FOR AN ELECTRONIC KEY**

(57) An antenna arrangement for an electronic key comprises a printed circuit board (202) arranged inside a housing (200) of the electronic key, an antenna (208) arranged on the printed circuit board (202) and inside the housing (200), a processing unit (204) arranged on the printed circuit board (202) and inside the housing (200), and configured to control the antenna (208), a power source (206) arranged on the printed circuit board (202) and inside the housing (200), and configured to provide power to the antenna arrangement, and a conductive layer (210) arranged on the outside of the housing (200) and capacitively coupled to the antenna (208).

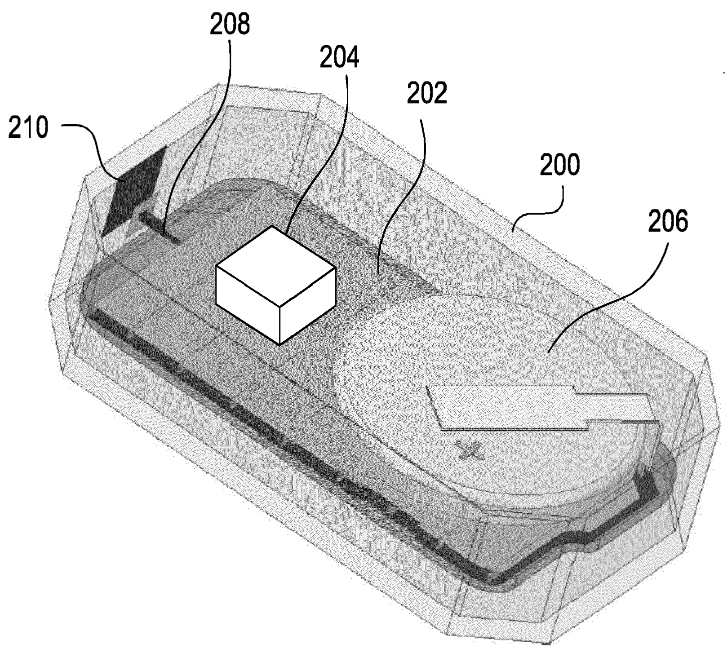


FIG 6

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## Description

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

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

**[0003]** Such an electronic vehicle key communicates with the vehicle using wireless technology. For this reason, an electronic vehicle key usually comprises one or more antennas. For example, an electronic vehicle key may comprise a low frequency (LF) antenna, an ultra-high frequency (UHF) antenna, an ultra-wide band (UWB) antenna, and/or an antenna for Bluetooth communication. Bluetooth or Bluetooth Low Energy (BLE) communication may be used, for example for transmitting all kind of information (e.g., tire pressure, fuel status, etc.) from the vehicle to the vehicle key or to a portable electronic device (e.g., smartphone). Each antenna requires space within the vehicle key. Further, for each antenna usually an antenna circuit needs to be provided. The different elements are often rather costly and require a certain amount of space.

**[0004]** There is a need to provide an antenna arrangement for an electronic key which has comparably small space requirements and can be implemented at comparably low costs.

**[0005]** This problem is solved by an antenna arrangement according to claim 1 and an electronic key according to claim 14. Configurations and further developments of the invention are the subject of the dependent claims.

**[0006]** An antenna arrangement for an electronic key includes a printed circuit board arranged inside a housing of the electronic key, an antenna arranged on the printed circuit board and inside the housing, a processing unit arranged on the printed circuit board and inside the housing, and configured to control the antenna, a power source arranged on the printed circuit board and inside the housing, and configured to provide power to the antenna arrangement, and a conductive layer arranged on the outside of the housing and capacitively coupled to the antenna.

**[0007]** Such an antenna arrangement can be formed in a small and cost-effective way, as the conductive layer on the outside of the housing does not require space on the printed circuit board inside the housing and is usually already present as a logo or decorative object. The conductive layer acts as a capacitance, thereby matching the impedance of the antenna more closely to a desired impedance of, e.g., 50Ohm.

**[0008]** The antenna arrangement may be configured to transmit and receive ultra-wide band signals.

**[0009]** Ultra-wide band signals are generally transmitted at comparably high frequencies. The effect of the conductive layer may be particularly good for antennas transmitting at high frequencies.

**[0010]** The antenna may comprise a conducting path formed on the printed circuit board.

**[0011]** The antenna, therefore, may be implemented in a space saving and cost effective way.

**[0012]** The antenna may have a length of 5mm or less, or 3mm or less.

**[0013]** Short antennas may be particularly suitable for high frequency transmission.

**[0014]** The antenna may be a monopole antenna.

**[0015]** The antenna, therefore, may be implemented in a space saving and cost effective way.

**[0016]** A maximum dimension of the conductive layer may be 8mm or less, or 5mm or less.

**[0017]** Such sizes are common for manufacturer logos on an electronic key and already lead to comparably good results.

**[0018]** The conductive layer may comprise a metallic material.

**[0019]** Many manufacturer logos on the outside of an electronic key are metallic or comprise metallic components. A metallic layer may be formed on the outside of the housing in a simple and cost-effective way.

**[0020]** The conductive layer may provide a manufacturer logo on the outside of the housing.

**[0021]** Such manufacturer logos are usually already present on the outside of electronic keys. The desired effect of the conductive layer, therefore, can be implemented in a very cost-effective way, as the conductive layer fulfills two different functions.

**[0022]** The conductive layer and the antenna may be arranged at a distance of 1mm or less from each other.

**[0023]** In this way, the desired capacitive coupling can be achieved.

**[0024]** The conductive layer and the antenna may both be in direct contact with the housing such that the distance between the conductive layer and the antenna is defined by a thickness of the housing.

**[0025]** No additional components are generally needed in such an arrangement to achieve the desired capacitive coupling.

**[0026]** The antenna, however, can also be arranged distant from the housing, and the antenna arrangement may further comprise a conducting element extending from the antenna to the housing, thereby bridging the distance between the antenna and the housing.

**[0027]** The conducting element may be a metallic spring element.

**[0028]** In this way, the capacitive coupling can be achieved in a simple and cost effective way, even if the antenna is not in direct contact with the housing for whatever reason.

**[0029]** The conductive layer may have a square, round, oval, triangular, polygonal, or irregular shape.

**[0030]** Many different shapes are generally possible when the conductive layer is used to present a manufacturer logo on the outside of the housing.

**[0031]** An electronic key comprises an antenna arrangement.

**[0032]** Examples are now explained with reference to the drawings. In the drawings the same reference characters denote like features.

Figure 1 schematically illustrates a three-dimensional view of a conventional electronic key.

Figure 2 schematically illustrates a three-dimensional view of different components arranged inside a housing of an electronic key.

Figure 3 schematically illustrates in a diagram an antenna input impedance as a function of frequency for a conventional electronic key.

Figure 4 schematically illustrates in a diagram a resulting bandwidth for a conventional electronic key.

Figure 5 schematically illustrates in a diagram a nominal antenna radiation efficiency as a function of frequency for a conventional electronic key.

Figure 6 schematically illustrates a three-dimensional view of different components arranged inside a housing of an electronic key according to one example.

Figure 7 schematically illustrates a three-dimensional view of a housing of an electronic key according to one example.

Figure 8 schematically illustrates in a diagram an antenna input impedance as a function of frequency for an electronic key according to one example.

Figure 9 schematically illustrates in a diagram a resulting bandwidth for an electronic key according to one example.

Figure 10 schematically illustrates in a diagram a resulting antenna radiation efficiency as a function of frequency for an electronic key according to one example.

**[0033]** In the following Figures, only such elements are illustrated that are useful for the understanding of the present invention. The antenna arrangement and the electronic key described below may comprise more than the exemplary elements illustrated in the Figures. However, any additional elements that are not needed for the implementation of the present invention have been omitted for the sake of clarity.

**[0034]** Figure 1 illustrates an electronic key 10. The electronic key 10 may be a key for a vehicle or for any other kind of object, e.g., a building or a gate. The electronic key 10 comprises a housing 200. The housing 200 may comprise or may be formed of a plastic material, for example. Any electronic components that are required for the function of the electronic key 10 are arranged inside and protected by the housing 200.

**[0035]** Generally, an antenna arrangement may be implemented in the housing 200 of an electronic key 10. Signals may be sent between a vehicle (or object) and the electronic key 10. For example, the electronic key 10 may send inquiry signals to the vehicle (or object) to indicate the desire of a user to unlock/lock the vehicle (or object). Further, authentication signals may be sent between the electronic key and the vehicle (or object), for example, in order to prevent unauthorized users (unauthorized electronic keys) from unlocking or starting the vehicle (or object). Many other signals may be sent between the electronic key 10 and the vehicle (or object) for many different applications.

**[0036]** An electronic key 10, therefore, comprises at least one antenna 208. One antenna 208 and a corresponding antenna circuit are schematically illustrated in Figure 2. The antenna 208 can be an ultra-wide band (UWB) antenna, for example. Ultra-wide band is a radio technology that can use a very low energy level for short-range, high bandwidth communications over a large portion of the radio spectrum. The electronic key 10, however, may also comprise additional antennas that are configured to transmit and receive signals according to a Bluetooth standard at a frequency of 2.4GHz, for example. The antenna 208 can also be an antenna for communicating according to any other suitable standard instead.

**[0037]** The antenna arrangement illustrated in Figure 2 comprises an antenna circuit, the antenna circuit comprising a processing unit 204, and a power source 206. The processing unit 204 may be or may comprise a microcontroller, for example. The power source 206 may be a battery or accumulator, for example, and may be configured to provide power to the antenna arrangement. The antenna circuit may further comprise a matching circuit (not specifically illustrated) configured to match an input impedance of the antenna 208 to an output impedance of the antenna circuit. Such a matching circuit may comprise capacitors and inductances, for example. The antenna circuit may further comprise a filter arrangement (not specifically illustrated) configured to filter signals received and signals to be sent by the antenna 208. Such a filter arrangement may comprise a front-end band pass filter, for example, to reduce or even avoid spurious emissions during transmission of signals, and to reduce or even avoid in-band noise that might negatively affect the demodulation during reception of signals. The processing unit 204 is configured to process the received signals and/or the signals to be sent via the antenna 208, and to control the function of the (optional) antenna circuit.

**[0038]** The antenna 208, the processing unit 204 and the power source 206 may be arranged on a printed circuit board 202. The printed circuit board 202 with the different elements arranged thereon in arranged inside the housing 200. That is, the printed circuit board 202 and the elements arranged thereon are well protected by the housing 200. The antenna 208 may comprise or may be formed by a conducting path formed on the printed circuit board 202, for example. In the example illustrated in Figure 2, the antenna 208 is a comparably short monopole antenna. Short in this context refers to an antenna 208 having a length of 5mm or less, or 3mm or less. A short antenna 208 may be easily formed on the printed circuit board 202 without requiring a lot of space on the printed circuit board 202. A short antenna may be used for an ultra-wide band (UWB) communication, for example.

**[0039]** UWB generally offers improved features and increased security especially for short range devices such as electronic keys 10 that are used for granting access to vehicles or other objects by localizing a user and communicating with the vehicle (or object).

**[0040]** A corresponding antenna circuit usually comprises a dedicated UWB transceiver with a corresponding antenna, and matching and filtering circuits tuned for the required UWB channels (usually between about 5.25GHz and 9.25GHz). Usually, further components such as a microcontroller with required peripherals, buttons, battery, etc. are also arranged inside the housing of the electronic key 10. All component are arranged on a comparably small printed circuit board arranged inside the housing, in order to keep the electronic key 10 small. As a comparably large amount of elements is required for the function of the electronic key 10, the space inside the housing 200 is limited and only little space remains to arrange the antenna 208 and required matching circuit inside the housing 200. In many cases, a compromise needs to be made between performance and size. A smaller size of the electronic key 10 generally results in a decreased performance, and vice versa. However, users generally prefer to carry smaller keys instead of large and bulky keys.

**[0041]** Using a comparably short antenna 208 (e.g, having a length of 5mm or less, or even 3mm or less) results in a comparably low antenna input impedance, as is schematically illustrated in Figure 3 (dashed line). However, an antenna input impedance of about 50Ohm is usually required for a satisfactory performance. As can be seen, the antenna input impedance of the antenna 208 as illustrated in Figure 2 is far below the required 50Ohm impedance. This comparably low antenna input impedance results in a poor input reflection coefficient and small bandwidth, as is schematically illustrated in Figure 4. Therefore, a matching circuit is generally required in conventional antenna circuits, as has been discussed above. Such a matching circuit introduces additional losses, requires space inside the housing 200 of the electronic key 10, and increases the manufacturing costs of the electronic key 10.

**[0042]** Figure 5 schematically illustrates the nominal antenna radiation efficiency without considering any mismatch losses. In order to increase the antenna input impedance to close to 50Ohm, the losses introduced by the required matching circuit have to be subtracted from those values as illustrated in Figure 5.

**[0043]** Now referring to Figure 6, an antenna arrangement according to one example is schematically illustrated. The antenna arrangement essentially corresponds to the antenna arrangement as illustrated in Figure 2. In this example however, the antenna performance is increased by means of a conductive layer 210 arranged on the outside of the housing 200 and capacitively coupled to the antenna 208. The conductive layer 210 may comprise a metallic material, for example. According to one example, the conductive layer 210 is thin, that is, a thickness of the conductive layer 210 may be 1mm or less, or 0.5mm or less. The conductive layer 210 may be formed by a metallic paint, for example. The conductive layer 210 may provide a manufacturer logo on the outside of the housing 200. Providing a manufacturer's logo on the outside of an electronic key is very common. Many manufacturer's logos already include conductive (e.g., metallic) parts, or may be easily made from conductive (metallic) parts. By capacitively coupling the antenna 208 to such a manufacturer logo that is already present on the outside of the housing 200 of an electronic key 10, the invention may be implemented in a very simple and cost effective way.

**[0044]** The conductive layer 210 and the antenna 208 may be capacitively coupled to each other through the housing 200. As is schematically illustrated in Figure 6, the antenna 208 and the conductive layer 210 are arranged in the same area of the housing 200, the antenna 208 being arranged on the inside, and the conductive layer 210 being arranged on the outside of the housing 200. That is, a distance between the antenna 208 and the conductive layer 210 is short, e.g., 1mm or less. According to one example, the distance between the antenna 208 and the conductive layer is defined by a thickness of the housing 200. That is, the antenna 208 may directly contact the housing 200 from the inside, while the conductive layer 210 directly contacts the housing 200 from the outside. In this case, the printed circuit board 202 with the antenna 208 arranged thereon may directly contact the inside of the housing 200. This, however, is only an example. It is also possible that the printed circuit board 202 and therefore also the antenna 208 which is arranged thereon do not directly contact the inside of the housing 200. In this latter case, a distance between the antenna 208 and the conducting layer 210 may be too large in order to allow sufficient capacitive coupling. Therefore, the arrangement may comprise an additional conductive element (not specifically illustrated) which extends from the antenna 208 to the housing 200, thereby bridging the distance between the antenna 208 and the housing 200 to allow sufficient capacitive coupling between the antenna 208 and the conducting layer 210. The conductive element may be a metallic element, e.g., a metallic spring element.

**[0045]** The conductive layer 210 may have a square, round, oval, triangular, polygonal, or irregular shape. A maximum dimension (e.g., length, diameter, etc.) of the conductive layer 210 may be 8mm or less, or even 5mm or less. A conductive layer 210 having a square shape (see Figure 7, for example) may have a length of 5mm, and a width of 5mm, for example. Other dimensions are generally also possible.

**[0046]** The conductive layer 210 may act as a capacitance, thereby matching the impedance of the antenna 208 more closely to the desired 50Ohm. In this way, the performance of the antenna 208 may be increased in a very simple and cost effective manner. This is schematically illustrated in the diagrams of Figures 8, 9 and 10. Figure 8 exemplarily illustrates a resulting antenna input impedance (dashed line) for an exemplary arrangement. The increased antenna input impedance results in an increased input reflection coefficient and bandwidth (Figure 9). Figure 10 schematically illustrates the nominal radiation efficiency for an exemplary antenna arrangement, which may be increased to a theoretical maximum limit of 0dB. The plotted values illustrated in Figure 10 which are above 0dB merely result from numerical software limitations. If a minimal matching circuit is used, additional losses of about 0.5dB, up to about 1dB may be considered.

**[0047]** The diagrams illustrated herein are merely examples and are meant to very generally illustrate the effects that may be achieved with the antenna arrangement as described.

**[0048]** The increase of antenna input impedance, input reflection coefficient, bandwidth, and radiation efficiency results in an increased performance of the antenna arrangement as described herein. In the specific examples described herein, a significant improvement, especially for high frequencies (such as UWB), of about 1.5 to 3dB can be achieved. By increasing the size of the conductive layer 210, even better results may be achieved. The exact values generally depend on many different factors such as, e.g., size of the antenna 208, size of the conductive layer 210, thickness of the housing 200 (distance between the antenna 208 and the conductive layer 210), etc.

**[0049]** Specific values for an exemplary arrangement with and without the conductive layer 210 are presented in the following to illustrate the improvement that can be achieved with minimal effort:

| Small UWB antenna without conductive layer | | | |
|---|---|---|---|
| Frequency | Nominal radiation frequency | Estimated matching circuit losses | Total realized efficiency |
| 6.5GHz | -0.35 dB | -2 dB | -2.35 dB |
| 7.5GHz | -0.5 dB | -2 dB | -2.5 dB |
| 8.5GHz | -1 dB | -2 dB | -3 dB |
| 9.5GHz | -2.1 dB | -2 dB | -4.1 dB |

| Small UWB antenna with conductive layer | | | | |
|---|---|---|---|---|
| Frequency | Nominal radiation frequency | Estimated matching circuit losses | Total realized efficiency | Overall efficiency improvement |
| 6.5GHz | 0 dB | -1 dB | -1 dB | 1.35 dB |
| 7.5GHz | 0 dB | -1 dB | -1 dB | 1.5 dB |
| 8.5GHz | 0 dB | -1 dB | -1 dB | 2 dB |
| 9.5GHz | 0 dB | -1 dB | -1 dB | 3.1 dB |

List of reference signs

**[0050]**

| | |
|---|---|
| 10 | electronic key |
| 200 | housing |
| 202 | printed circuit board |
| 204 | processing unit |
| 206 | power source |
| 208 | antenna |
| 210 | conducting layer |

## Claims

1. An antenna arrangement for an electronic key comprises

   a printed circuit board (202) arranged inside a housing (200) of the electronic key (10);
   an antenna (208) arranged on the printed circuit board (202) and inside the housing (200);
   a processing unit (204) arranged on the printed circuit board (202) and inside the housing (200), and configured to control the antenna (208);
   a power source (206) arranged on the printed circuit board (202) and inside the housing (200), and configured to provide power to the antenna arrangement; and
   a conductive layer (210) arranged on the outside of the housing (200) and capacitively coupled to the antenna (208).

2. The antenna arrangement of claim 1, wherein the antenna arrangement is configured to transmit and receive ultra-wide band signals.

3. The antenna arrangement of claim 1 or 2, wherein the antenna (208) comprises a conducting path formed on the printed circuit board (202).

4. The antenna arrangement of any of claims 1 to 3, wherein the antenna (208) has a length of 5mm or less, or 3mm or less.

5. The antenna arrangement of any of claims 1 to 4, wherein the antenna (208) is a monopole antenna.

6. The antenna arrangement of any of claims 1 to 5, wherein a maximum dimension of the conductive layer (210) is 8mm or less, or 5mm or less.

7. The antenna arrangement of any of claims 1 to 6, wherein the conductive layer (210) comprises a metallic material.

8. The antenna arrangement of any of claims 1 to 7, wherein the conductive layer (210) provides a manufacturer logo on the outside of the housing (200).

9. The antenna arrangement of any of the preceding claims, wherein the conductive layer (210) and the antenna (208) are arranged at a distance of 1mm or less from each other.

10. The antenna arrangement of any of the preceding claims, wherein the conductive layer (210) and the antenna (208) are both in direct contact with the housing (200) such that the distance between the conductive layer (210) and the antenna (208) is defined by a thickness of the housing (200).

11. The antenna arrangement of any of claims 1 to 9, wherein the antenna (208) is arranged distant from the housing (200), and wherein the antenna arrangement further comprises a conducting element extending from the antenna (208) to the housing (200), thereby bridging the distance between the antenna (208) and the housing (200).

12. The antenna arrangement of claim 11, wherein the conducting element is a metallic spring element.

**13.** The antenna arrangement of any of the preceding claims, wherein the conductive layer (210) has a square, round, oval, triangular, polygonal, or irregular shape.

**14.** An electronic key (10) comprising an antenna arrangement of any of claims 1 to 13.

**15.** The electronic key (10) of claim 14, wherein the electronic key (10) is a key for a vehicle.


FIG 1

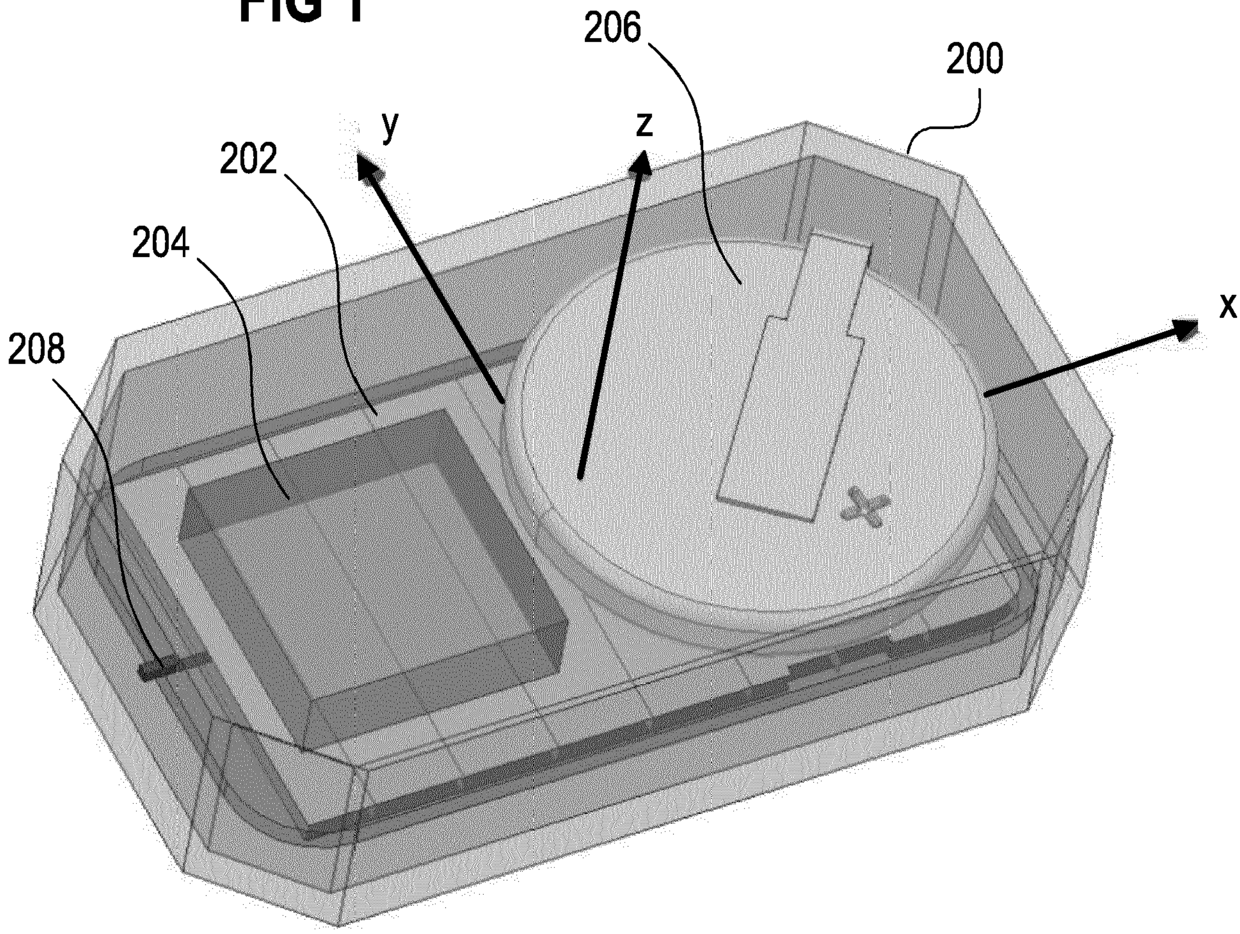
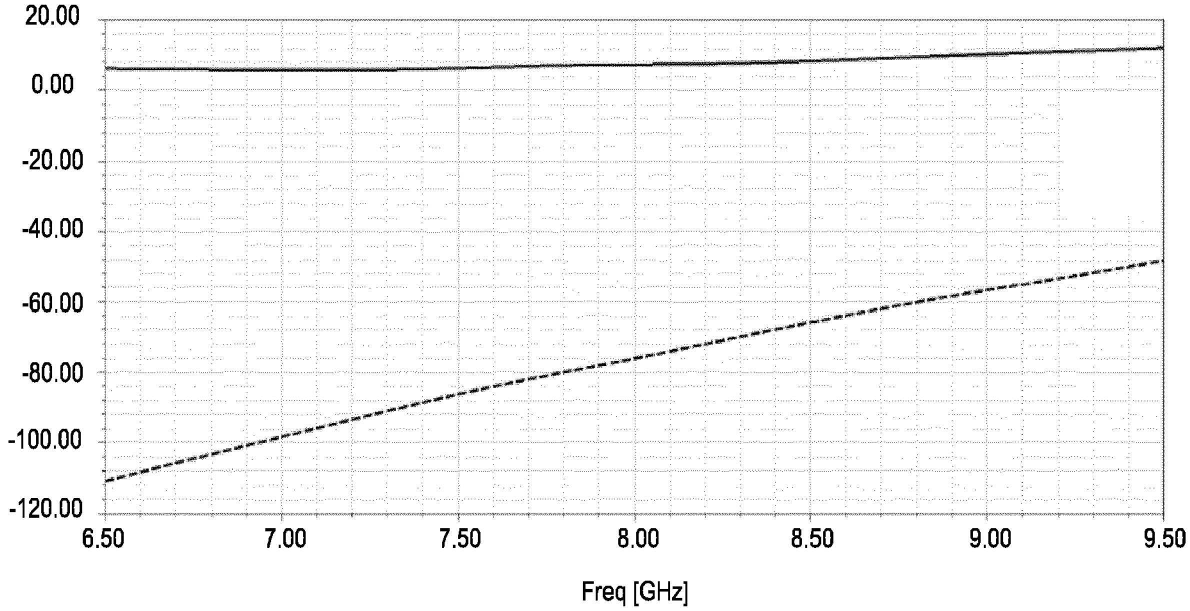



FIG 2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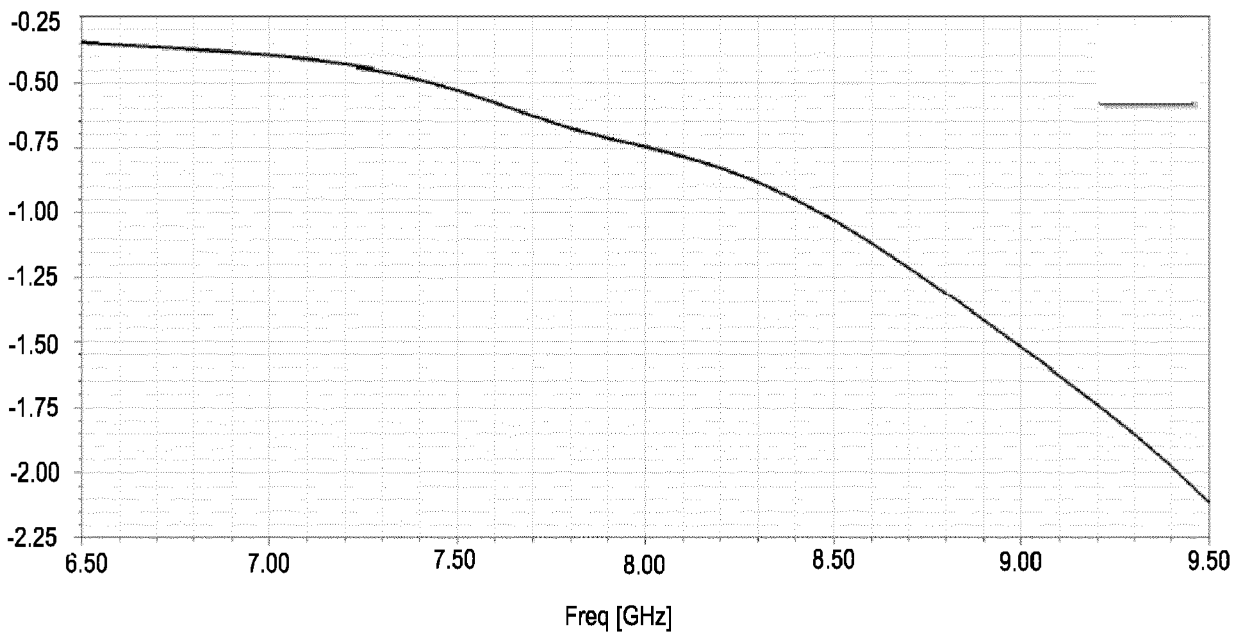
9.00
9.50
Freq [GHz]

# FIG 3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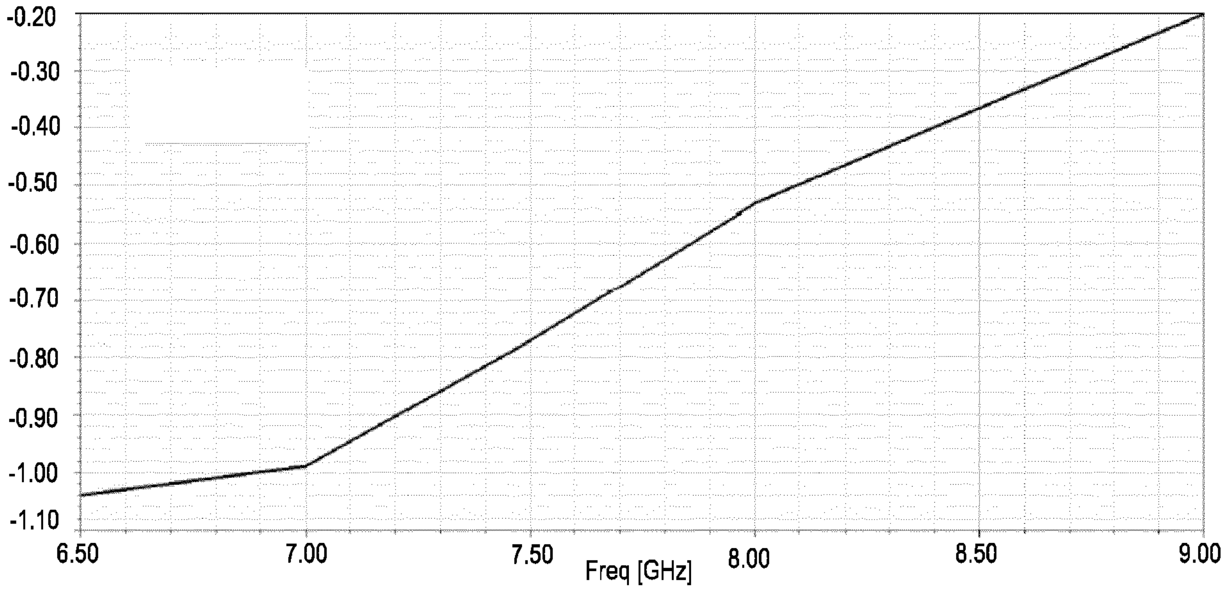
9.50
Freq [GHz]

# FIG 4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-0.80
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6.50
7.00
7.50
Freq [GHz]
8.00
8.50
9.00

FIG 5

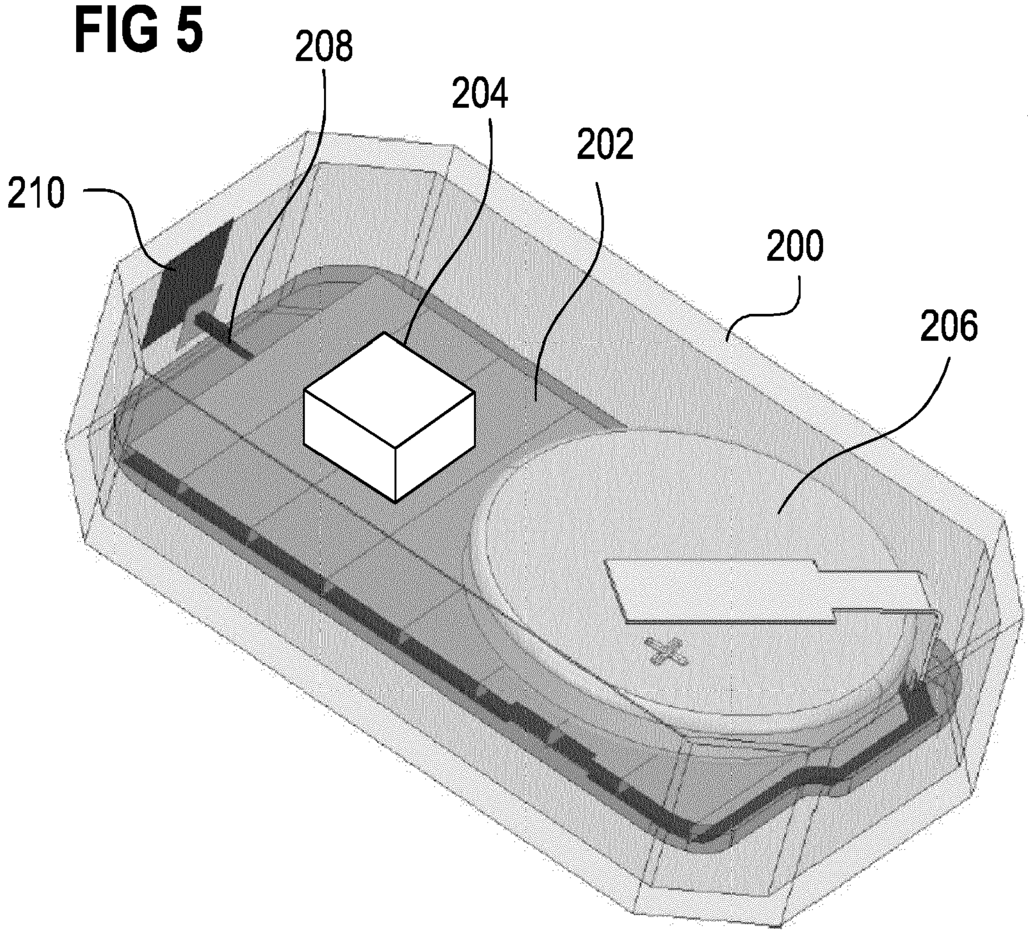

208
204
202
210
200
206

FIG 6

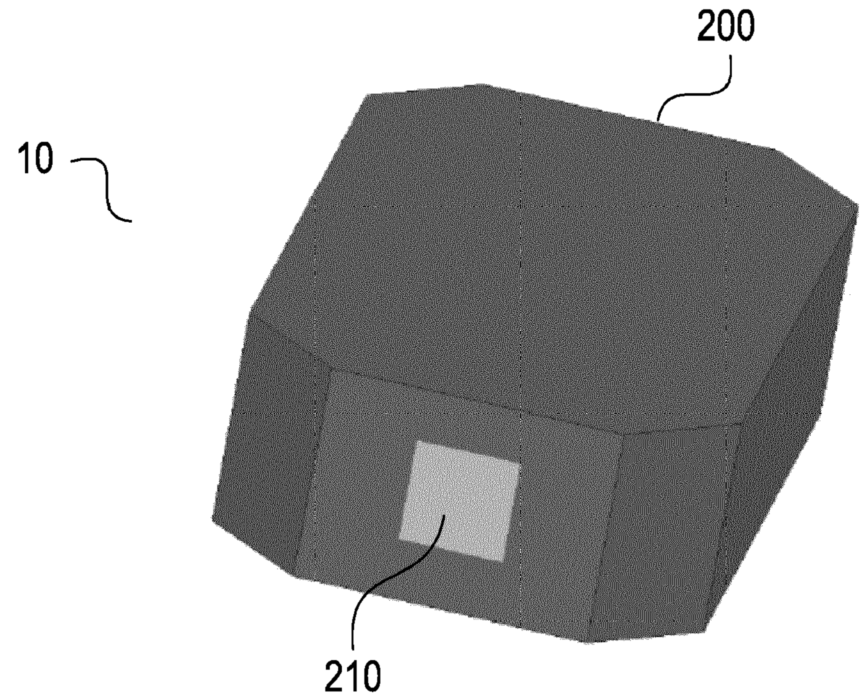
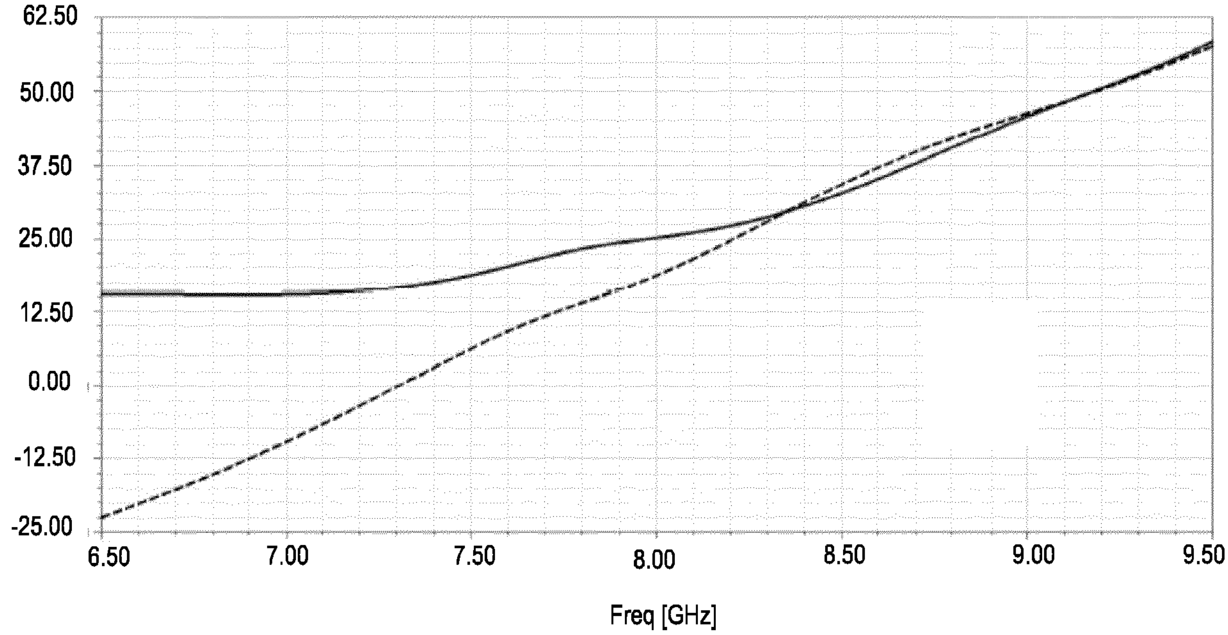

200
10
210

FIG 7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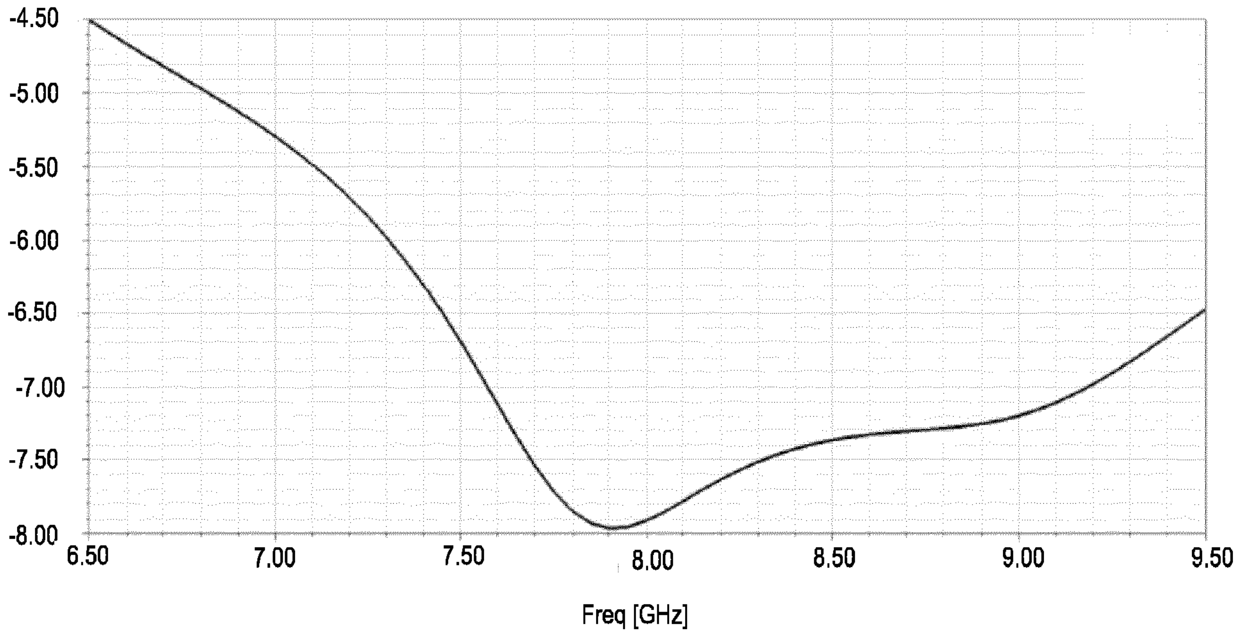
9.50
Freq [GHz]

FIG 8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9.00
9.50
Freq [GHz]

FIG 9

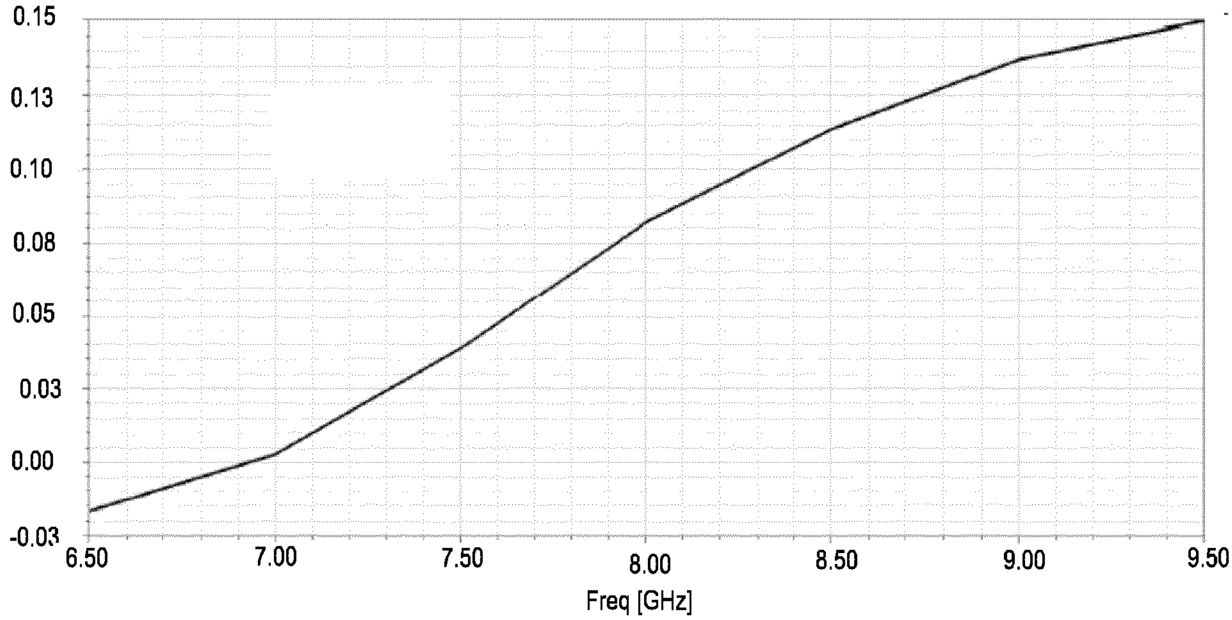
0.15
0.13
0.10
0.08
0.05
0.03
0.00
-0.03
6.50
7.00
7.50
8.00
8.50
9.00
9.50
Freq [GHz]

FIG 10

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# EUROPEAN SEARCH REPORT

Application Number
EP 22 46 5535

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X<br>A | US 2016/301127 A1 (SONODA RYUTA [JP] ET AL) 13 October 2016 (2016-10-13)<br>* paragraphs [0018] - [0019], [0027], [0033] - [0040], [0045] - [0053], [0073] - [0075]; figures 1-7 * | 1,3-9, 13-15<br>2,10-12 | INV.<br>H01Q9/36<br>H01Q1/32<br>H01Q1/22<br>H01Q5/25<br>H01Q5/378<br>H01Q1/40 |
| X<br>A | US 2021/053531 A1 (PANHWAR MUHAMMAD FAWAD [DE]) 25 February 2021 (2021-02-25)<br>* paragraphs [0002], [0008] - [0017]; figure 1 * | 1-8, 13-15<br>9-12 | |
| A | WO 2020/167627 A1 (SONY CORP [JP]; SONY MOBILE COMMUNICATIONS INC [US]) 20 August 2020 (2020-08-20)<br>* paragraphs [0002], [0017] - [0018], [0029] - [0032]; figures 1A, 1B, 2, 3,8,9 * | 1-15 | |
| A | US 2012/068902 A1 (CLOW NATHAN [GB] ET AL) 22 March 2012 (2012-03-22)<br>* paragraphs [0037] - [0042]; figures 1-5 * | 1-15 | TECHNICAL FIELDS SEARCHED (IPC) |
| | | | H01Q |

The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 20 October 2022 | Georgiadis, A |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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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 22 46 5535

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