(19) Europäisches Patentamt
European Patent Office
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(11) **EP 3 379 645 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**26.09.2018 Bulletin 2018/39**

(51) Int Cl.:
***H01Q 1/24*** *(2006.01)*

(21) Application number: **17162302.8**

(22) Date of filing: **22.03.2017**

(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:
**MA MD**

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Remarks:
Amended claims in accordance with Rule 137(2) EPC.

# (54) SOLAR ANTENNA COMPRISING GRAPHENE, SOLAR UNIT COMPRISING MULTIPLE SOLAR ANTENNAS AND METHOD FOR OPERATING A SOLAR UNIT

(57) The present invention refers to a solar antenna (1) for generating electric energy. Said solar antenna comprises at least a graphene layer (2), an insulation layer (4) and a carrying means (6), wherein the insulation layer (4) is arranged between the graphene layer (2) and the carrying means (6).

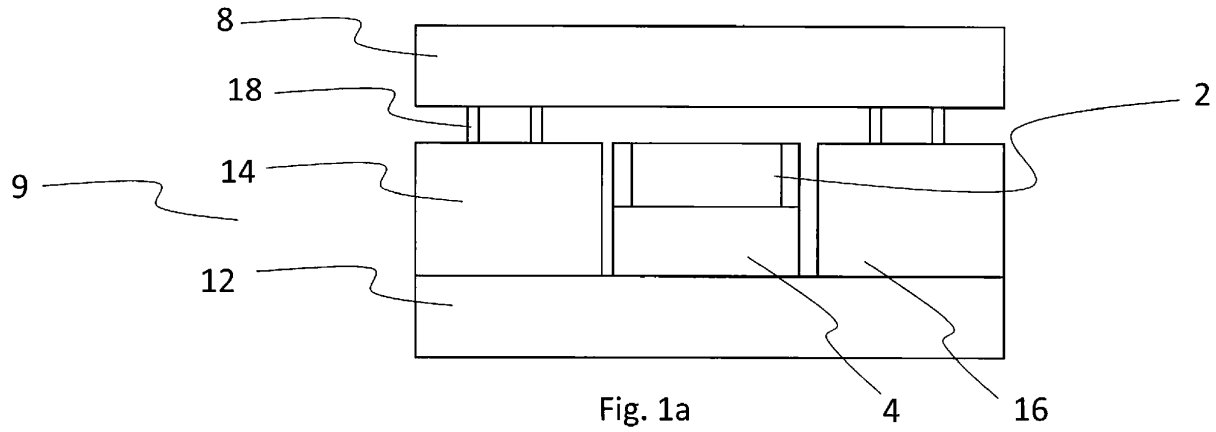


Fig. 1a

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## Description

**[0001]** The present invention refers according to claim 1 to a solar antenna, according to claim 4 to a solar unit and according to claim 12 to a method for operating a solar unit.

## Background of the Invention

**[0002]** Document US20120032847A1 discloses a system for dynamically reconfiguring the radiation pattern of a collection of slot antennas. A collection of slot antennas of various lengths and widths are fabricated. The control system independently drives the feed to one or more slot antennas to produce the desired radiation pattern. The control system activates and deactivates the feed to different slot antennas, thus dynamically reconfiguring the generated radiation pattern.

**[0003]** Document US2015243817A1 discloses a solar antenna array. Said solar antenna array may comprise an array of randomly placed carbon nanotube antennas that may capture and convert sunlight into electrical power. Methods for constructing the solar antenna array may use a mold and self-aligning processing steps to minimize cost. Designs may be optimized for capturing a broad spectrum of non-polarized light. Alternatively, the array may generate light, and when connected in to an array of independently controllable sections may operate as either a reflective or light transmitting display.

**[0004]** Document US20090026579A1 discloses a rectenna capable of power conversion from electromagnetic (EM) waves of high frequencies. In one embodiment, a rectenna element generates currents from two sources-based upon the power of the incident EM wave and from an n-type semiconductor, or another electron source attached to a maximum voltage point of an antenna element. The combined current from both sources increases the power output of the antenna, thereby increasing the detection sensitivity of the antenna of a low power signal. Full wave rectification is achieved using a novel diode connected to a gap in the antenna element of a rectenna element.; The diode is conductive at forward bias voltage or reverse bias voltage, and rectifies the antenna signal generated by the desired EM wave received by antenna raise from the rectenna element of the present invention may be used as a building block to create large rectenna arrays.

## Object of the Invention

**[0005]** It is the object of the present invention to provide solar antennas, solar units and methods for operating such solar units which are more efficient.

## Description of the Invention

**[0006]** The before mentioned object is solved by a solar antenna for generating electric energy according to claim 1. The solar antenna according to the present invention preferably comprises at least a graphene layer, an insulation layer and a carrying means, wherein the insulation layer is arranged between the graphene layer and the substrate respectively carrying means. The term solar antenna preferably defines a rectenna (rectifying antenna). The thickness of the graphene layer is preferably below 1000nm, in particular below 500nm or below 300nm, and/or above 100nm.

**[0007]** This solution is beneficial since due to the graphene layer the antenna can be operated at high frequencies, like in the 35GHz frequency band with 0.86mm wavelength or in a THz band. For efficient radiation mechanism as a conductor, graphene is used since it does not show edge effect down to the size of 100nm. This is one of the key points for a solar energy collector antenna. Solar energy spectrum can even reach as far as frequency of 30THz. General conductor materials, like as copper, silver, etc., show edge effect at these frequencies.

**[0008]** Further preferred embodiments are subject-matter of the dependent claims and/or of the following specification parts.

**[0009]** According to a preferred embodiment of the present invention the graphene layer is covered by a transparent protection means. The transparent protection means is preferably a glass and has preferably a thickness that is thicker than the thickness of the graphene layer. Transparent hereby preferably means said at least visible light and preferably UV and/or infrared light is able to pass the protection means.

**[0010]** The graphene layer has according to a further preferred embodiment of the present invention a surface between $1nm^2$ and $1000nm^2$, in particular between $2nm^2$ and $10nm^2$ or between $10nm^2$ and $500nm^2$ or between $20nm^2$ and $400nm^2$. This embodiment is beneficial since the inventive solar antenna can be used at all photovoltaic systems that have some space between the individual modules, in particular gaps of a few millimeters or centimeters. That means the solar antennas according to the present invention can be arranged in between said gaps. Thus, gaps between photovoltaic cells can be filled with especially nano-scale solar antennas. This kind of systems with nano-scale antennas increases the collected total amount of the energy.

**[0011]** Therefore, this invention can be used in many solar photovoltaic panel systems.

**[0012]** The before mentioned object is also solved by a solar unit, in particularly a solar photovoltaic panel system, according to claim 5. Said solar unit preferably comprises at least multiple photo voltaic modules for generating electric energy, a solar antenna according to any of proceeding claims, wherein electric energy generated by the photo voltaic modules and the solar antenna is feed into a common electric lead.

**[0013]** This solution is beneficial, since current PV systems have not been eliminated, and it is still the main part of the energy collector system. However, to increase the overall performance of the system at least one an-

tenna array respectively multiple solar antennas or rectennas with smart control module are provided to track the sun during the daytime without using any mechanical motion.

**[0014]** According to a further preferred embodiment of the present invention the carrying means is a back sheet connecting the cells of multiple, in particularly at least or exactly two, photovoltaic modules, wherein at least one string, in particularly two or at least two strings, is arranged on one side of the cells of each photovoltaic module, wherein the back sheet is arranged on the opposing side of each of said cells.

**[0015]** This embodiment is beneficial since the present structure of the PV cells has been used in the design and manufacturing of the antennas. Materials that have been used in PV cells also constitute the structure of the antennas. So, manufacturing cost of the system has also been degraded. Thus, in this invention - by using same platform for the PV cells and antennas - area, that is used for energy collecting, has been efficiently utilized. So, two different solar power collector techniques have been merged on the same substance, incorporated without using any additional area, and so solar power collector efficiency (watts per square meter) is raised.

**[0016]** The photo voltaic modules are according to a further preferred embodiment of the present invention spaced apart from each other, wherein an intermediate space between said photovoltaic modules is present, wherein the solar antenna, in particular a plurality of solar antennas, is arranged in said intermediate space.

**[0017]** The string is according to a further preferred embodiment of the present invention covered by a protection means, wherein the protection means is transparent for light, in particularly at least visible and/or UV light and/or infrared light. This embodiment is beneficial since the solar antenna respectively solar antennas are arranged between PV cells and thus no further additional space or protection needs to be provided.

**[0018]** According to a further preferred embodiment of the present invention the carrying means is a string of a photovoltaic module, wherein the string is arranged on one side of cells of said photovoltaic module, wherein a back sheet is arranged on the opposing side of said cells. This embodiment is beneficial since due to a stacked arrangement the necessary area size can be small.

**[0019]** According to a further preferred embodiment of the present invention a first control means for detecting the orientation of incident light is provided and a second control means connected to the solar antenna for detecting the power and/or phase of incident light captured by said solar antenna is provided. The critical problem in this subject is the change of the direction of the sunlight during the day time. Also, current PV cell structures contain empty spaces which are not used for solar power harvesting. So, combining solar power collector antenna structures, together with PV system a more efficient total system results. By modifying the pattern of the antenna according to the angle incidence of sunlight which is related with to the time of the day, total amount of the energy that is collected can be increased, and more efficient accumulation of the energy can be obtained.

**[0020]** Multiple solar antennas respectively rectennas are preferably arranged as array respectively arrays. Preferably, each array respectively array antenna consists of two different control units. Thus, first of them, which is preferably in the input part of the system, is to detect the orientation of the sun regarding to the sky. According to the response of the first part respectively first control means, in the second part respectively second control means the precise amount of distribution of power and phase to each antenna are determined. So, the second module respectively second control means preferably comprises switch modules related with the phase shifters to manage the constitution of the proper beam forming with respect to the direction of sunlight which is detected in first phase respectively by first control means.

**[0021]** It is also possible that one or multiple of the herein described solar antennas are forming a solar antenna unit, wherein such first and second control means are present, wherein each solar antenna or an array of solar antennas is connected to said first and second control means.

**[0022]** The second control means comprises according to a further preferred embodiment of the present invention a phase shifter means for shifting the phase of incident light in dependency of the orientation of the incident light detected by the first module. This embodiment is beneficial since the efficiency of the overall system can be enhanced.

**[0023]** An example of a phase shifter control module is disclosed here: https://www.researchgate.net/publication/257971538_Liquid_crystal_phase_shifters_at_millimeter_wave_frequencies

It is further possible that multiple solar antennas are provided and arranged as array.

**[0024]** The before mentioned object is also solved by a method according to claim 12 for operating a solar unit. The method according to the present invention preferably comprises the steps: Providing a solar unit, wherein the solar unit comprises at least multiple photo voltaic modules for generating electric energy, multiple solar antennas according to any of claims 1 to 4, a first control means for detecting the orientation of incident light and a second control means connected to the solar antenna for detecting the power and/or phase of incident light captured by said solar antenna, wherein the second control means comprises a phase shifter means for shifting the phase of incident light in dependency of the orientation of the incident light detected by the first module, wherein electric energy generated by the photo voltaic modules and the solar antenna is feed into a common electric lead, Modifying the beam shape of incident light captured by said solar antennas in dependency of an orientation of said incident light.

**[0025]** Further benefits, goals and features of the

present invention will be described by the following specification of the attached figures, in which exemplarily components of the invention are illustrated. Components of the systems, devices and methods according to the inventions, which match at least essentially with respect to their function can be marked with the same reference sign, wherein such components do not have to be marked or described multiple times with respect to said figures.

**[0026]** In the following the invention is just exemplarily described with respect to the attached figures.

**Brief Description of the Drawing**

**[0027]**

Fig. 1a shows a schematic side view of a first solar unit according to the present invention;

Fig. 1b shows a schematic top view of the first solar unit according to the present invention;

Fig. 2a shows a schematic side view of a second solar unit according to the present invention; and

Fig. 2b shows a schematic top view of the second solar unit according to the present invention.

**[0028]** Fig. 1 a and 1 b show two illustrations of a first system combining two different energy capturing techniques. As shown in fig. 1 a the solar unit preferably comprises a back sheet 12. Said back sheet 12 serves as substrate respectively carrying layer for holding respectively carrying cells 14, 16 of PV modules and an insolation layer 4 of solar antenna 1. Said insulation layer 4 is arranged between a graphene layer 2 and said back sheet 12. On top of said cells 14, 16 preferably multiple string members 18 are present. Said string members are preferably interconnecting multiple cells. A protection means 8, in particularly a glass layer, is preferably arranged on top of said strings 18.

**[0029]** Fig. 1b shows a top view of the arrangement shown in fig. 1 a. Fig. 1b further shows that multiple, in particular nano-scale solar antennas 1, are arranged between the cells. Preferably more than 12 solar antennas per $cm^2$, in particularly more than 1200 or more than 12000 or up to 1200 or up to 12000 or up to 20000, are arranged between said cells.

**[0030]** Fig. 2a and 2b show two illustrations of a second system combining two different energy capturing techniques.

**[0031]** Fig. 2a shows that cells 14, 16 of PV modules 10 are arranged on top of a back sheet 12 respectively substrate. Above said cell 14, 16 a string member 18 is present. Said string member preferably interconnects multiple cells 14, 16. On top of said sting member 18 an insulation layer 4 is present said insulation layer spaces a graphene layer and the string member 18 away from each other. A protection means 8 is arranged above said graphene layer 2. Thus, light passing said solar antenna 1 can be captured by the underlying cell of said PV module 10.

**[0032]** Fig. 2b shows said besides said solar antennas 1 a surface part of said cells 14, 16 is provided for capturing light.

**[0033]** Thus, two different design structures have been proposed for application of solar smart antennas, which can track sunlight with an electronic control module, incorporated with PV cells on using same area without obstructing each technology the other.

**[0034]** Introduced design structure that make to operate solar antennas and PV cells together at the same time and place.

**[0035]** Thus, the present invention refers to a solar unit at least comprising multiple photo voltaic modules for generating electric energy and at least one solar antenna at least comprising a graphene layer, an insulation layer and a carrying means, wherein the insulation layer is arranged between the graphene layer and the substrate. The electric energy generated by the photo voltaic modules and the solar antenna is feed into a common electric lead.

**[0036]** In this invention, current PV system has not been eliminated, and it is still the main part of the energy collector system. However, to increase the overall performance of the system antenna array with smart control module to track the sun during the daytime without using any mechanical motion.

**[0037]** Also, in this invention, present structure of the PV cells has been used in the design and manufacturing of the antennas. Materials that have been used in PV cells also constitute the structure of the antennas. So, manufacturing cost of the system has also been degraded.

**[0038]** In this invention, by using same platform for the PV cells and antennas, area, that is used for energy collecting, has been efficiently utilized. So, two different solar power collector techniques have been merged on the same substance, incorporated without using any additional area, and so solar power collector efficiency (watts per square meter) is raised.

**[0039]** Thus, the present invention refers to a solar antenna 1 for generating electric energy. Said solar antenna comprises at least a graphene layer 2, an insulation layer 4 and a carrying means 6, wherein the insulation layer 4 is arranged between the graphene layer 2 and the carrying means 6.

**List of reference numbers**

**[0040]**

| | |
|---|---|
| 1 | Solar antenna |
| 2 | graphene layer |
| 4 | insulation layer |
| 6 | carrying means |
| 8 | protection means |

9 solar unit
10 photo voltaic module
12 back sheet
14 first cell
16 second cell
18 string

**Claims**

**1.** Solar antenna (1) for generating electric energy, at least comprising:

a graphene layer (2),
an insulation layer (4) and
a carrying means (6),
wherein the insulation layer (4) is arranged between the graphene layer (2) and the carrying means (6).

**2.** Solar antenna according to claim 1,
**characterized in that**
the thickness of the graphene layer (2) is below 1000nm, in particular below 500nm or below 300nm.

**3.** Solar antenna according to claim 1 or 2,
**characterized in that**
the graphene layer (2) is covered by a transparent protection means (8).

**4.** Solar antenna according to any of the proceeding claims,
**characterized in that**
the graphene layer (2) has a surface between $1nm^2$ and $1000nm^2$, in particular between $10nm^2$ and $500nm^2$ or between $20nm^2$ and $400nm^2$.

**5.** Solar unit (9),
at least comprising
multiple photo voltaic modules (10) for generating electric energy,
a solar antenna (1) according to any of proceeding claims,
wherein electric energy generated by the photo voltaic modules (10) and the solar antenna (1) is feed into a common electric lead.

**6.** Solar unit according to claim 4,
**characterized in that**
the carrying means (6) is a back sheet (12) connecting cells (14, 16) of multiple photovoltaic modules (10),
wherein at least one string (18) is arranged on one side of the cells (14, 16) of each photovoltaic module (10),
wherein the back sheet (12) is arranged on the opposing side of each of said cells (14, 16).

**7.** Solar unit according to claim 5,
**characterized in that**
the photo voltaic modules (10) are spaced apart from each other,
wherein an intermediate space between said photovoltaic modules (10) is present, wherein the solar antenna (1), in particular a plurality of solar antennas (1), is arranged in said intermediate space.

**8.** Solar unit according to claim 5 or 6,
**characterized in that**
the string (18) is covered by a protection means (8), wherein the protection means (8) is transparent for light, in particularly at least visible and UV light.

**9.** Solar unit according to claim 4,
**characterized in that**
the carrying means (6) is a string (18) of a photovoltaic module (10),
wherein the string (18) is arranged on one side of cells (14, 16) of said photovoltaic module (10),
wherein a back sheet (12) is arranged on the opposing side of said cells (14, 18).

**10.** Solar unit according to claims 4 to 8,
**characterized by**
a first control means for detecting the orientation of incident light
and
a second control means connected to the solar antenna for detecting the power and/or phase of incident light captured by said solar antenna (1).

**11.** Solar unit according to claim 9,
**characterized in that**
the second control means comprises a phase shifter means for shifting the phase of incident light in dependency of the orientation of the incident light detected by the first module.

**12.** Solar unit according to claims 4 to 9,
**characterized in that**
multiple solar antennas (1) are provided and arranged as array.

**13.** Method for operating
a solar unit (9)
comprises the steps:

Providing a solar unit (9), wherein the solar unit (9) comprises at least
multiple photo voltaic modules (10) for generating electric energy,
multiple solar antennas (1) according to any of claims 1 to 4,
a first control means for detecting the orientation of incident light
and

a second control means connected to the solar antenna for detecting the power and/or phase of incident light captured by said solar antenna (1),
wherein the second control means comprises a phase shifter means for shifting the phase of incident light in dependency of the orientation of the incident light detected by the first module,
wherein electric energy generated by the photo voltaic modules and the solar antenna (1) is feed into a common electric lead,
Modifying the beam shape of incident light captured by said solar antennas (1) in dependency of an orientation of said incident light.

**Amended claims in accordance with Rule 137(2) EPC.**

**1.** Solar antenna (1) for generating electric energy from sunlight,
at least comprising:

a graphene layer (2) as a conductor,
an insulation layer (4) and
a carrying means (6),
wherein the insulation layer (4) is arranged between the graphene layer (2) and the carrying means (6).

**2.** Solar antenna according to claim 1,
**characterized in that**
the thickness of the graphene layer (2) is below 1000nm, in particular below 500nm or below 300nm.

**3.** Solar antenna according to claim 1 or 2,
**characterized in that**
the graphene layer (2) is covered by a transparent protection means (8).

**4.** Solar antenna according to any of the proceeding claims,
**characterized in that**
the graphene layer (2) has a surface between $1nm^2$ and $1000nm^2$, in particular between $10nm^2$ and $500nm^2$ or between $20nm^2$ and $400nm^2$.

**5.** Solar unit (9),
at least comprising
multiple photo voltaic modules (10) for generating electric energy,
a solar antenna (1) according to any of proceeding claims,
wherein electric energy generated by the photo voltaic modules (10) and the solar antenna (1) is feed into a common electric lead,
the carrying means (6) is a back sheet (12) connecting cells (14, 16) of multiple photovoltaic modules (10),
wherein at least one string (18) is arranged on one side of the cells (14, 16) of each photovoltaic module (10),
wherein the back sheet (12) is arranged on the opposing side of each of said cells (14, 16), wherein the photo voltaic modules (10) are spaced apart from each other,
wherein an intermediate space between said photovoltaic modules (10) is present,
wherein the solar antenna (1), in particular a plurality of solar antennas (1), is arranged in said intermediate space.

**6.** Solar unit according to claim 5,
**characterized in that**
the string (18) is covered by a protection means (8), wherein the protection means (8) is transparent for light, in particularly at least visible and UV light.

**7.** Solar unit according to claim 5,
**characterized in that**
the carrying means (6) is a string (18) of a photovoltaic module (10),
wherein the string (18) is arranged on one side of cells (14, 16) of said photovoltaic module (10),
wherein a back sheet (12) is arranged on the opposing side of said cells (14, 18).

**8.** Solar nit according to claims 5 to 7,
**characterized by**
a first control means for detecting the orientation of incident light
and
a second control means connected to the solar antenna for detecting the power and/or phase of incident light captured by said solar antenna (1).

**9.** Solar unit according to claim 8,
**characterized in that**
the second control means comprises a phase shifter means for shifting the phase of incident light in dependency of the orientation of the incident light detected by the first module.

**10.** Solar unit according to claims 5 to 8,
**characterized in that**
multiple solar antennas (1) are provided and arranged as array.

**11.** Method for operating
a solar unit (9)
comprises the steps:

Providing a solar unit (9), wherein the solar unit (9) comprises at least
multiple photo voltaic modules (10) for generating electric energy,

multiple solar antennas (1) according to any of claims 1 to 4,
a first control means for detecting the orientation of incident light
and
a second control means connected to the solar antenna for detecting the power and/or phase of incident light captured by said solar antenna (1),
wherein the second control means comprises a phase shifter means for shifting the phase of incident light in dependency of the orientation of the incident light detected by the first module,
wherein electric energy generated by the photo voltaic modules and the solar antenna (1) is feed into a common electric lead,
Modifying the beam shape of incident light captured by said solar antennas (1) in dependency of an orientation of said incident light.

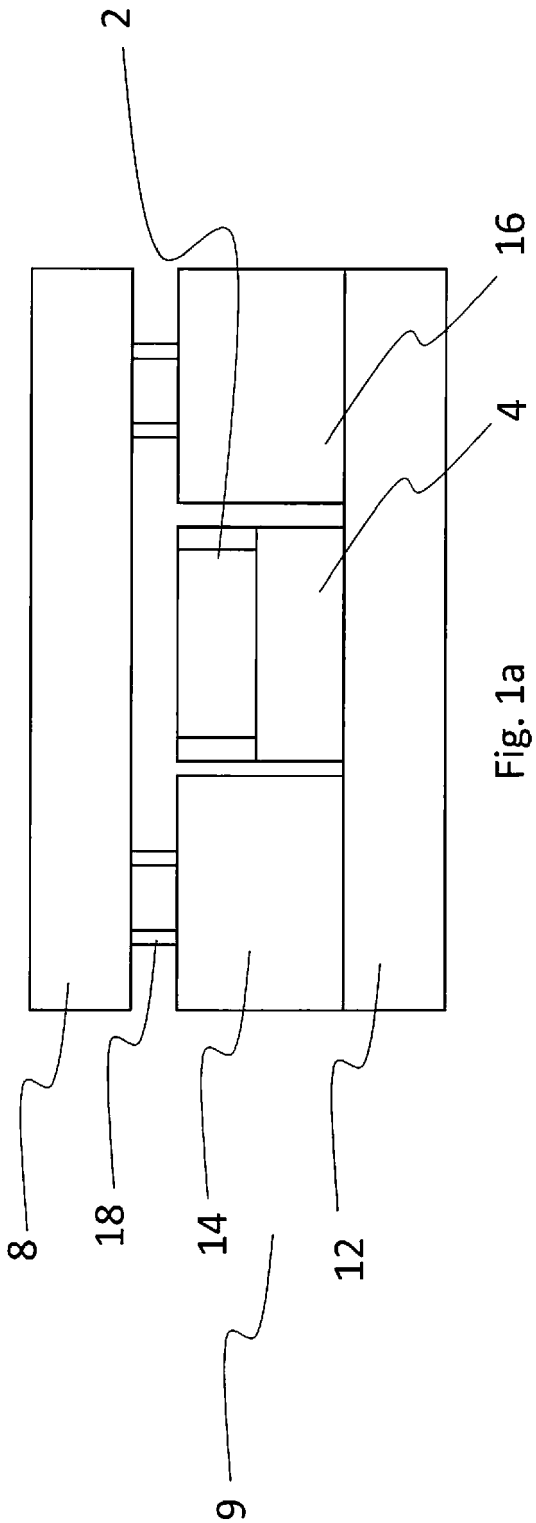


Fig. 1a

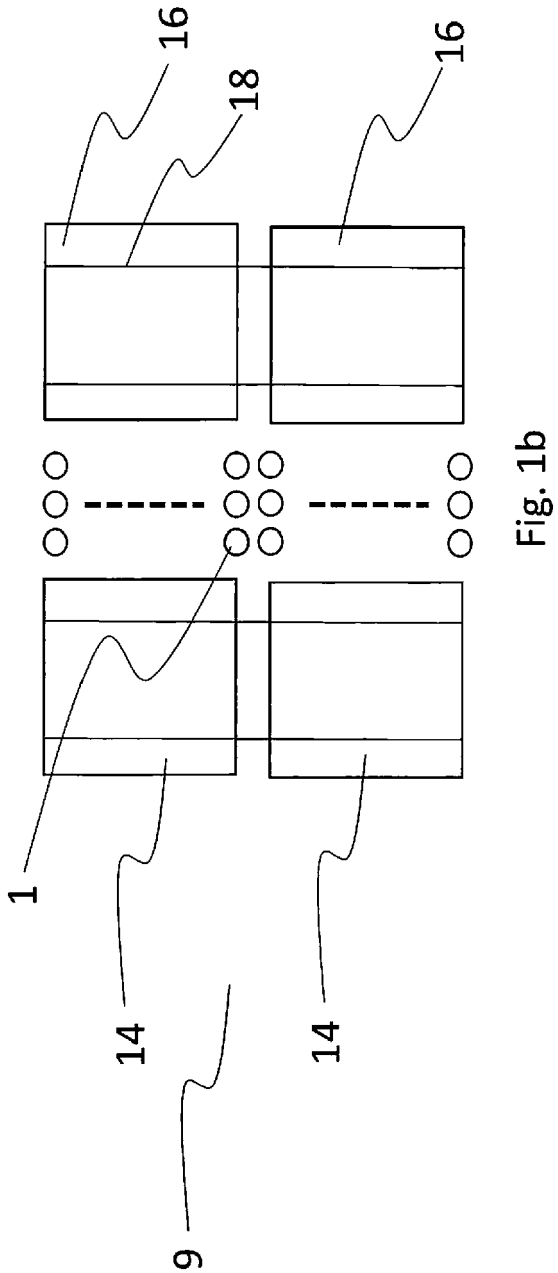


Fig. 1b

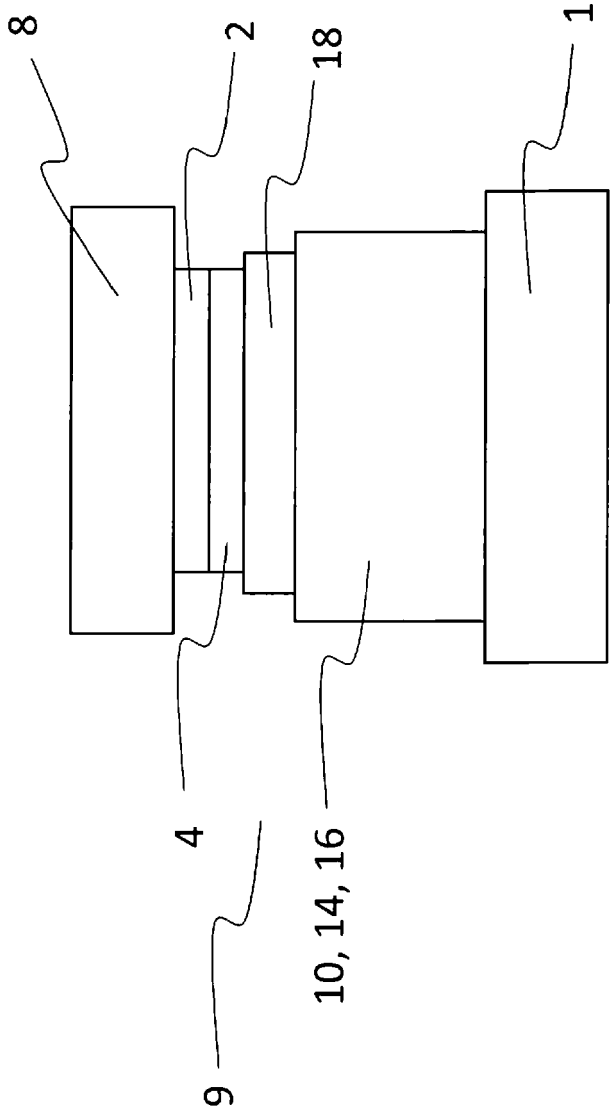


Fig. 2a

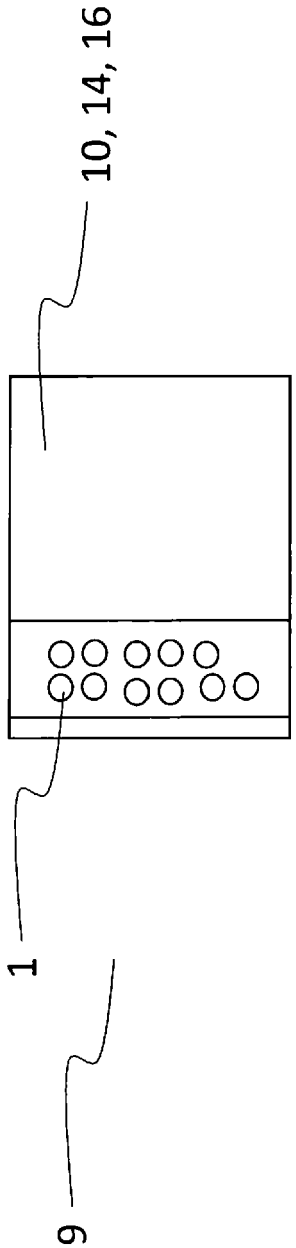


Fig. 2b

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# EUROPEAN SEARCH REPORT

Application Number
EP 17 16 2302

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
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| A | US 2007/240757 A1 (REN ZHIFENG [US] ET AL)<br>18 October 2007 (2007-10-18)<br>* paragraph [0041] - paragraph [0043]; figure 1 * | 5 | TECHNICAL FIELDS SEARCHED (IPC)<br>H01Q |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 15 September 2017 | Degraeve, Alexis |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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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

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EPO FORM 1503 03.82 (P04C01)

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 16 2302

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
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15-09-2017

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

## REFERENCES CITED IN THE DESCRIPTION

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- US 2015243817 A1 **[0003]**
- US 20090026579 A1 **[0004]**