(19) SUOMI - FINLAND
(FI)

PATENTTI- JA REKISTERIHALLITUS
PATENT- OCH REGISTERSTYRELSEN
FINNISH PATENT AND REGISTRATION OFFICE

(10) **FI 129966 B**
(12) **PATENTTIJULKAISU**
**PATENTSKRIFT**
**PATENT SPECIFICATION**

(45) Patentti myönnetty - Patent beviljats - Patent granted **30.11.2022**

(51) Kansainvälinen patenttiluokitus - Internationell patentklassifikation - International patent classification
***H01Q 15/00*** (2006.01)
***E06B 3/67*** (2006.01)
***E06B 7/28*** (2006.01)
***C03C 17/06*** (2006.01)
***H01Q 13/10*** (2006.01)
***H04B 7/145*** (2006.01)

(21) Patenttihakemus - Patentansökning - Patent application 20195349

(22) Tekemispäivä - Ingivningsdag - Filing date **29.04.2019**

(23) Saapumispäivä - Ankomstdag - Reception date **29.04.2019**

(43) Tullut julkiseksi - Blivit offentlig - Available to the public **30.10.2020**

(73) Haltija - Innehavare - Proprietor
**1 •StealthCase Oy,** PL 74, 33101 TAMPERE, SUOMI - FINLAND, (FI)

(72) Keksijä - Uppfinnare - Inventor
**1 •Lilja, Juha,** TAMPERE, SUOMI - FINLAND, (FI)

(74) Asiamies - Ombud - Agent
**Berggren Oy,** Visiokatu 1, 33720 Tampere

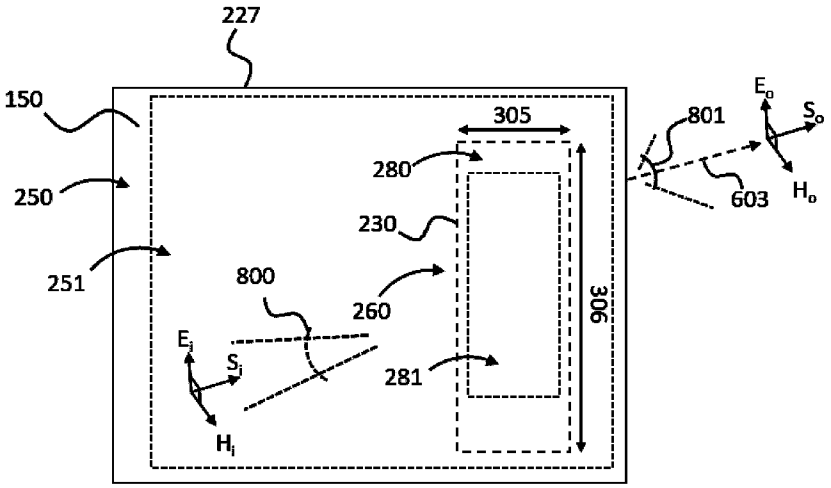
(54) Keksinnön nimitys - Uppfinningens benämning - Title of the invention
**Mikroaaltomuunnin ja järjestelmä sen valmistamiseksi**
**Mikrovågomvandlare och system för dess framställning**
**A microwave transformer and a system for fabricating the same**

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WO 2019073116 A2, US 2017250456 A1, US 2004107641 A1, BURNIER, L. et al. Energy saving glazing with a wide band-pass FSS allowing mobile communication: upscaling and characterization. IET Microwaves, Antennas & Propagation 2017-08-03, Vol. 11, No. 10, pp. 1449-1455, DOI:10.1049/iet-map.2016.0685

(57) Tiivistelmä - Sammandrag - Abstract

Esillä oleva keksintö koskee sähköä johtavaa kerrosta (150), joka käsittää mikroaaltomuuntimen (260) ensimmäisellä taajuudella olevan mikroaaltosignaalin voimakkuuden skaalaamiseksi skaalauskertoimella. Muunnin (260) käsittää ensimmäisen fyysisen alueen (280), jota rajaa sähköä johtavan kerroksen (150) päällä oleva suljettu käyrä (230), mainitun mikroaaltosignaalin vastaanottamiseksi ensimmäisestä avaruuskulmasta (800) ja mainitun mikroaaltosignaalin säteen (603) uudelleenlähettämiseksi toiseen avaruuskulmaan (801). Ensimmäinen fyysinen alue (280) käsittää vyöhykkeen, jossa on sähköä johtavaa materiaalia, ja toisen vyöhykkeen (214), jossa ei ole sähköä johtavaa materiaalia. Ensimmäinen fyysinen alue (280) käsittää ensimmäisen vaikuttavan alueen (281) siten, että mainitun ensimmäisen vaikuttavan alueen (281) ja mainitun ensimmäisen fyysisen alueen (280) suhde on suurempi kuin skaalauskerroin. Sähköä johtava kerros (150) käsittää toisen fyysisen alueen (250), jota rajaa suljettu reunakäyrä (227), ja toisen vaikuttavan alueen (251), siten että mainitun toisen vaikuttavan alueen (251) ja mainitun toisen fyysisen alueen (250) välinen suhde on pienempi kuin kaksi kertaa skaalauskerroin. Lisäksi mainitun ensimmäisen fyysisen alueen (280) ja mainitun toisen fyysisen alueen (250) välinen suhde on pienempi kuin 0,5, ja mainitun ensimmäisen vaikuttavan alueen (281) ja mainitun ensimmäisen fyysisen alueen (280) välinen suhde on vähintään kaksi kertaa yhtä suuri kuin mainitun toisen vaikuttavan alueen (251) ja mainitun toisen fyysisen alueen (250) välinen suhde. Skaalauskerroin on uudelleenlähetetyn säteen (603) maksimivoimakkuuden ja sen säteen voimakkuuden suhde, joka kulkee avoimen aukon kautta, jonka fyysinen alue on yhtä suuri kuin mainittu toinen fyysinen alue (250) samassa suunnassa kuin uudelleenlähetetty säde (603).

The present invention relates to a conductive layer (150) comprising a microwave transformer (260) for scaling the intensity of a microwave signal of a first frequency by a scaling factor. The transformer (260) comprises a first physical area (280) delimited with a closed curve (230) on the conductive layer (150) for receiving said microwave signal from a first space angle (800) and re-emitting a ray (603) of said microwave signal to a second space angle (801). The first physical area (280) has a region with electrically conductive material and another region (214) without electrically conductive material. The first physical area (280) has a first effective area (281) so that the ratio of said first effective area (281) to said first physical area (280) is larger than the scaling factor, The conductive layer (150) has a second physical area (250) delimited with a closed edge curve (227) and a second effective area (251) so that the ratio of said second effective area (251) to said second physical area (250) is smaller than twice the scaling factor. Furthermore, the ratio of said first physical area (280) to said second physical area (250) is smaller than 0.5, and the ratio of said first effective area (281) to said first physical area (280) is at least two times as large as the ratio of said second effective area (251) to said second physical area (250). The scaling factor is the ratio of the maximal intensity of the re-emitted ray (603) and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area (250) in the same direction than the re-emitted ray (603).



# A microwave transformer and a system for fabricating the same

## Technical Field

The present invention relates to a conductive layer comprising a microwave transformer, to a method of manufacturing said conductive layer, and to a system for fabricating said conductive layer.

More specifically, the present invention relates to a conductive layer comprising a microwave transformer for scaling the intensity of a microwave signal of a first frequency by a scaling factor, said transformer comprising a first physical area delimited with a closed curve on the conductive layer for receiving said microwave signal from a first space angle and re-emitting a ray of said microwave signal to a second space angle.

## Background Information

In an aim to provide, e.g. building architects, with means to design building facades with certain measurable level of radio signal permeability, there's a clear lack in the industry to provide architects with such means.

The motivation behind this work has been to raise the state of the art in the industry by providing a conductive layer that may be arranged to reach a level that reaches a measurable performance level that equals an equivalent open aperture in a wall. It will be shown in this specification that the prior art fails to specify products that are equal to a given sized hole in a wall, primarily due to the fact that the measurable signal permeability value according to the prior art is a combination of material loss and geometry of the structure.

Some embodiments of the invention comprise a conductive layer wherein both the geometry of the device and the associated losses are arranged to reach a signal permeability value that is comparable with an equivalent hole in the wall, and at the same time to provide an enhanced coverage efficiency compared to the solutions of the prior art. Moreover, an advantage of the present invention is that it may be arranged to increase the production speed in mass production in accordance with advantageous embodiments.

20195349 PRH 25 -10- 2022

In order to enhance the connectivity through a highly attenuating medium, such as a building element comprising e.g. a coated thermally effective glass pane of a window element or a highly insulated panel comprising metal coatings, both the amount of total power that is delivered through said medium, and the directivity of the building element need to be considered. The connectivity performance through said attenuating medium is a combination of material/reflection losses and the directivity due to the geometry of the permeable structure.

Prior art, e.g. different Frequency Selective Surfaces (FSS) have been concentrating on providing a maximal transmission coefficient in the maximum gain direction, wherein said transmission coefficient is typically determined for a directly penetrated wave, and the effects of field scattering on the horizontal coverage efficiency have been typically ignored. A large glass pane having FSS patterns on its coating becomes highly directive as it will be shown in this specification. The transmission coefficient of a glass pane having FSS structures can be determined in an anechoic chamber using two antennas, one on each side of the pane to be tested, and these antennas are aligned for Line of Sight (LoS) position with respect to each other. The transmission coefficient through a tested pane may then be measured using a Vector Network Analyzer (VNA) to determine the scattering parameters (such as "S21") for said pane. An alternative method for similar characterization is using a signal generator and a spectrum analyser. However, the results provided by this test setup is always a product of both the transmittance (loss) of the pane and the directivity of the pane, and using the above test method the effects of these two factors cannot be distinguished. In other words, the above method measures only the gain of the pane in its expected maximum direction, and doesn't characterize the pane thoroughly.

The above limitation applies for typical computational methods for designing FSS structures by using periodic boundaries in full wave simulation tools, where a plane wave illumination and plane wave transmission is typically forced by said boundary conditions.

Performance coatings in glass panes may come with variety of conductivities. Typical surface resistance values for coated glasses are in the range of few ohms per square. Furthermore, different electrochromic layers may provide

20195349 PRH 25 -10- 2022

conductivity values significantly differing from the above. What is common for said performance coatings is that the amount of conductor loss may become significant, and the behaviour of said coatings may differ from layers of good conductivity such as copper layers. Reduced conductivity may detune antennas when identical antenna geometries being implemented first on layers of good conductivity and then on layers of reduced conductivity. Furthermore, the effect of loss may become significant when aiming to maximize signal penetration through a conductive layer.

It is shown in this specification that a conductive layer having a region, where said region being arranged for diffractive bistatic scattering may provide more microwave energy through the conductive layer than a traditional FSS panel having larger value for the transmission coefficient when determined using methods similar to ones described above. It is shown that if the Total Radiated Power (TRP) through the conductive layer is not determined, e.g. integrating the Poynting vector in the full hemisphere behind the panel, the performance or efficiency of a given structure cannot be unambiguously determined, and the performance enhancement provided by this invention remains unattained.

Therefore, it becomes evident that a person skilled in the art would not consider it obvious of providing a conductive layer with a region where said region being arranged for bistatic scattering that provides a scaled field intensity for a re-emitted ray, wherein said intensity being scaled with a scaling factor, and at the same time the total transmitted power through said layer being remained at high level by forcing the region for diffractive scattering by means of arranging the dimensions of said region and at the same time forcing the re-emitted microwave energy to expand widely with an enlarged horizontal coverage beam, and wherein said layer being adapted to compensate the effects of conductor loss in said conductive layer by providing said aperture with an aperture efficiency of larger than said scaling factor, or providing said aperture with larger efficiency than an equivalent square aperture.

The international patent application WO 2019/073116 relates to a building material comprising at least an electrically conductive low emissivity surface provided with an aperture for transmitting radio signals, for boosting the transmission of electromagnetic signals. An edge of an opening provided on a low emissivity surface, constitutes at least one closed edge curve, and the

20195349 PRH 25 -10- 2022

opening defines a closed envelope curve so that the opening is within the closed envelope curve, and the surface defined by the closed envelope curve has an area substantially larger than the area of the opening within the closed envelope curve, and a length substantially smaller than the length of the closed envelope curve, whereby at least one such low emissivity surface area is formed within the area defined by the closed envelope curve, at which the closed envelope curve is not congruent with the edge curve.

The patent application US 2017/0250456 discloses an electrically conductive coating of an automotive heatable windshield having a frequency selective surface (FSS) area that facilitates the transmission of radio frequency signals. The FSS area may be a high-pass filter such that RF signals at any polarization can pass through the glazing over a wide frequency band. The FSS area is defined by a pattern in the conductive coating such that, when the conductive coating is used to heat the windshield, electrical current flows through the FSS area to mitigate hot and cold spots.

The patent application US 2004/0107641 discloses a sidelobe controlled radio transmission region in a metallic panel. The metallic panel may be included in a window such as the window of a vehicle or building. An aperture is formed in the metallic panel to enable radio frequency signals to be transmitted through the metallic panel. The design of the aperture may be selected to enable the transmission of the desired frequency band. Furthermore, the aperture is designed such that there is a taper in the transmission amplitude and/or the phase to suppress lobing effects on the other side of the aperture.

**On the fabrication speed**

It is an aim of the present invention to provide a conductive layer comprising a microwave transformer in a form where the production speed of said conductive layer comprising said transformer can be raised to a level that reduces bottlenecks from a mass production line.

Traditionally, Frequency Selective Surfaces have been fabricated on glass panes by using a laser that is attached on a Computerized Numerical Control (CNC) table, where the pane is stationary, and the large glass surface is processed by providing a two-way movement for a laser scanning unit. The

20195349 PRH 25 -10- 2022

laser scanning unit is an arrangement to deflect the laser beam, provided by a laser source, and to provide a focal region. A typical scanning area for a laser scanning unit depends heavily on the laser configuration and processing parameters.

Given a first example, a glass pane having dimensions of 150 x 150 cm would be over 200 times a given scanning area of 10 x 10 cm, and over 900 times a given scanning area of 5 x 5 cm. It becomes clear that such processing approach is inefficient in mass production, and would make large bottlenecks in the mass production of, e.g. insulation glass units, where the insulation glass units may travel tens of meters per minute in the factory line along conveyors or the like. When a glass pane is required to remain stationary for processing needs of the order of a minute or even several minutes, production turnaround is significantly deteriorated, leading to large waiting times, reduced production efficiency, and increased unit costs. Moreover, manual placement of such glass units on the processing table further increase unit costs.

In a second example, if an exemplary scribing pattern of a well-known crosshatch FSS would be manufactured on a glass pane, and each scanning area would be processed one after another, said exemplary scanning areas could easily require tens of thousands of laser beam switch on / switch off – instants for the exemplary glass pane. It is obvious that given a time of tens of milliseconds for the laser beam to switch on and off, such processing approach would increase the waiting time of the order of minutes for a large glass pane.

In addition, when small tolerances are required, i.e. for a precise alignment of the start and endpoints of an ablated trace on a glass coating, the bottleneck for processing speed is pronounced. This is especially in the case if there is a requirement to deviate the position of the scanner with respect to the position of the glass pane.

Furthermore, another bottleneck for the position deviation speed of the scanner with respect to the position of the glass pane arises if the ablated structure on the coating of a glass pane is required to make multiple return loops, or considerable movement in the direction that opposes the processing direction, i.e. the direction where the position of the scanner with respect to the glass pane is increasing. In such cases the targeted coordinate point for

20195349 PRH 25 -10- 2022

ablation on the glass coating would drop off from the laser scanning area if the scanner would be re-positioned too fast. In practice, the ablated pattern on the coating may become heavily distorted if the mutual position between the scanner and the glass pane is deviated too fast, and the scanner is not able to remain synch with the glass pane coordinates. Both of the above-mentioned issues may arise when producing, for example, a plurality of nested and closed loops with high process speeds.

In addition to creating bottlenecks for high-speed mass production, another drawback of well-known FSS structures is that the efficiency of these is optimized by maximizing the ablated surface area on the glass pane. Said well-known crosshatch FSS is a traditional example, where the entire coating area is broken into thousands of isolated conductive segments, all being separated from each other galvanically. Said example sheet of 1.5x1.5m may easily require 50 thousand isolated segments in order to provide high permeability for a wireless signal. Large ablated regions on conductive coatings create problems for both visual quality and production speed.

Brief summary of the invention

It is an aim to provide means to design facades with a measurable level of radio signal permeability with a device according to the present invention.

The invention raises the state of the art in the industry by providing a conductive layer that may be arranged to reach a level that reaches a measurable performance level that equals an equivalent open aperture in a wall or facade.

It will be shown in this specification how the prior art fails to specify products that are equal to a given sized hole in a wall, primarily due to the fact that the measurable signal permeability value according to the prior art is a combination of material loss and geometry of the structure.

In accordance witn an embodiment, there is provided a conductive layer wherein both the geometry of the device and the associated losses are arranged to reach a signal permeability value that is comparable with an

20195349 PRH 25 -10- 2022

equivalent hole in the wall, and at the same time to provide an enhanced coverage efficiency.

It is an aim of the present invention to provide a conductive layer comprising a microwave transformer for scaling the intensity of a microwave signal of a first frequency by a scaling factor, wherein the transformer comprises a first physical area on the conductive layer for receiving said microwave signal from a first space angle and re-emitting a ray of said microwave signal to a second space angle, and the conductive layer having a second physical area, wherein the scaling factor is the ratio of the maximal intensity of the re-emitted ray and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area in the same direction than the re-emitted ray.

It is an aim of the present invention to provide a conductive layer comprising a microwave transformer in a form where the production speed of said conductive layer comprising said transformer can be raised to a level that reduces bottlenecks from a mass production line. There are provided embodiments wherein the required equipment for fast mass production of the conductive layer of the present invention can be simplified by firstly, providing an improved method for the fabrication and secondly, providing an arrangement wherein the transformer may be fabricated without shutting down the laser beam with beam shutters or the like. The apparent benefits of the invention can be exploited to remove production bottlenecks and hence reach lower manufacturing costs, provide visually more aesthetic products, and to provide technically enhanced products with enhanced efficiency and coverage efficiency.

According to the present invention there is provided a conductive layer as defined by claim 1.

Description of the drawings

In the following, the present invention will be described in more detail with reference to the appended drawings, in which

20195349 PRH 25 -10- 2022

Fig. 1 shows an example of a conductive layer comprising a microwave transformer for scaling the intensity of a microwave signal;

Fig. 2a shows examples of three different structures having equal outer perimeters;

Figs. 2b shows Finite Element Method simulation results for the radar cross section, total radiated power, and beam width of three example structures;

Figs. 2c shows the determination of the equivalent square aperture for the example structures using the total radiated power through an aperture;

Fig. 3a shows an example of a system for fabricating a conductive layer comprising a microwave transformer;

Fig. 3b shows an example of coupled microwave resonators on a repeating sequence along a primary processing direction;

Fig. 4 shows an arrangement of the conductive layer adjacent to a secondary conductive layer;

Fig. 5 shows an example of a method of fabricating the conductive layer 150 comprising said microwave transformer 260;

Figs. 6a and 6b
show examples of the first and second set of resonators;

Fig. 7 shows a process flow for producing insulation glass units 106 out of jumbo glasses in a repeating process;

Figs. 8a and 8b
show examples of a system for fabricating the conductive layer comprising the microwave transformer;

20195349 PRH 25 -10- 2022

Figs. 9a to 9h
show numerous examples of the projection paths.

Detailed description of the invention

Electromagnetic scattering is a process where an object receives electromagnetic energy from an incident electromagnetic signal and re-radiates at least a part of this received electromagnetic energy to a solid angle or a plurality of directions having separate solid angles. The incident electromagnetic signal comprises an oscillating electromagnetic wave, which may be characterized by its polarization and oscillation frequency. Polarization is defined by the electric field orientation of said signal in a given state, and it is well known how an electromagnetic signal may be linearly, elliptically, or circularly polarized.

Electromagnetic energy carried by a propagating electromagnetic signal may be characterized by the Poynting vector, i.e. the intensity vector, of the wave front, which describes the energy flux through a unit area per time unit. Energy flux may be denoted by watts per square meter ($W/m^2$). In other words, it describes the power density over a given surface, or the intensity of the electromagnetic signal, thus giving the amount of energy that is flowing through a given surface area in a time unit.

Figure 1 shows an abstraction of a conductive layer 150 according to the present invention, in accordance with an embodiment. In the example, there is provided a microwave signal of a first frequency, said signal arriving from a first space angle 800, and comprising an oscillating electric field vector ($E_i$) and a corresponding magnetic field vector ($H_i$), and a Poynting vector defining the propagation direction of the incident electromagnetic field intensity ($S_i$). There is also presented a re-emitted ray 603 in a second space angle 801, said ray comprising an oscillating electric field vector ($E_o$) and a corresponding magnetic field vector ($H_o$), and a Poynting vector defining the propagation direction of the re-emitted electromagnetic field intensity ($S_o$).

Radar cross section (RCS) is used to describe how much a scattering object captures and re-radiates electromagnetic energy from an incident electromagnetic wave which is illuminating said scattering object. Radar cross

20195349 PRH 25 -10- 2022

section may also be denoted as scattering cross section, and the concept of RCS is well known by anyone skilled in the art. RCS is a function of the polarizations of both the incident and the scattered field, as well as the directions of both the incident and scattered waves. A commonly used concept of RCS is the monostatic case, in which the source of the incident wave and the observation of the scattered or reflected wave occur in the same direction. However, when the behavior of the device according to the present invention is of interest, the bistatic radar cross section is mainly of interest. Bistatic radar cross section refers to a concept where the direction of the incident wave deviates from the direction of the scattered wave.

It may be advantageous to use the intensity of the incident and scattered electromagnetic waves to describe the conductive layer 150 comprising the microwave transformer 260 of the present invention due to the fact that an aim of the present invention is to provide an enhanced conductive layer 150 for controlling the farfield characteristics of re-emitted ray 603.

The total power received by an aperture from a given incident signal direction may be defined as the product of the effective receiving aperture and the incident field intensity. Effective aperture of a radiator, sometimes referred to as receiving aperture or an antenna aperture, may not be equal to a physical dimensions of the same. An uncoated glass, or a glass with aperture in the coating can be thought of as an aperture antenna, for which an aperture efficiency may be determined.

It is well known that the aperture of an antenna may be characterized by the gain, directivity and efficiency of the antenna, and said aperture may be used to calculate how much an antenna receives power from a certain direction from a certain incident power density of an electromagnetic wave. Hence, it is well known that an aperture is a function of direction as well as polarization similarly to the gain of an antenna. For an antenna that has clearly detectable feeding terminal, said received power can be detected in this terminal. However, in case of a clearly detectable terminal is lacking, the received power may be stored in the electric and magnetic fields of the antenna, or in a plurality of mutually coupled resonators acting as antennas. In such cases the power received by said device may be characterized by the surface of an imaginary volume enclosing said device. The volume defines a surface through which

20195349 PRH 25-10-2022

both the incident and scattered waves flow. The power flow through the surface in an arbitrary solid angle may be characterized by the receiving aperture and intensity of the propagating electromagnetic wave related to the solid angle.

If the radiation pattern of a transmitting antenna (or in this case the bistatic scattering pattern through an aperture in a conductive layer or a signal permeable construction supply) is not known, the aperture efficiency in a transmitted space angle is not a measure of the transmitted total energy. This is a major source of misunderstandings in solutions of the prior art when different solutions are being compared based on the transmission coefficient value that only considers the transmission values in with the directly incident waves through a signal permeable construction supply.

For the sake of clarity, it is defined that in the scope of this specification, a physical aperture comprises physical dimensions and physical surface area of a conductive layer. Antenna area/aperture, receiving area/aperture, or effective area/aperture define an imaginary area or an aperture, which characterizes the radiation properties of an object, including receiving and emitting an electromagnetic wave. The effective aperture is related to a gain or directivity of an object, which may be characterized by the RCS, and is dependent on polarization, frequency and angles of observation of any of the related waves.

The peak effective area of an ideal uniformly illuminated lossless aperture equals its geometric area, independent of wavelength. With any other imperfection, the effective area is smaller than the geometric area. The aperture efficiency of a physical aperture (with a geometric area) is defined as the ratio of the effective area to geometric area.

In the example of Figure 1, there is provided an example of a conductive layer 150 comprising the microwave transformer 260 for scaling the intensity of a microwave signal of a first frequency by a scaling factor, wherein the scaling factor is the ratio of the maximal intensity of the re-emitted ray 603 and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area 250 in the same direction than the re-emitted ray 603.

20195349 PRH 25-10-2022

By forming a polarization independent and uniformly illuminated aperture in a conductive panel, said aperture having an area, it can be shown that the electromagnetic power that is captured by said area is almost independent of the shape of said area. When the aperture scatters said captured electromagnetic power to the other side of said panel (or conductive layer 150), the power scattered to the other side of the panel is almost independent of the shape of said area. The total amount of electromagnetic energy that is delivered through said aperture may be calculated by performing a three-dimensional integration of the Poynting vector in the hemisphere on the other side of the plane. For a given plane wave illumination having a respective Poynting vector, the Total Radiated Power (TRP) may be calculated through said aperture. The directivity of the scattering pattern, on the other hand, may be adequately characterized by the bistatic radar cross section (RCS) in said hemisphere.

When the smallest dimension of the aperture becomes smaller than a wavelength at a first frequency, the scattering of a signal of a first polarization to the other side of the panel becomes more sensitive to small changes of said smallest dimension when compared to a case when the smallest dimension is a multiple of the wavelength of the first frequency. When the smallest dimension becomes smaller than half of a wavelength at the first frequency, this effect becomes more severe.

Resonant behavior of the aperture shape and perimeter may be used in advance to control the TRP and RCS through said aperture at the first frequency when the smallest dimension of the aperture becomes smaller than the wavelength at the first frequency.

The total amount of power captured by said area from a plane wave arriving from a given direction may be characterized by the effective receiving area of said aperture. The effective receiving area is a function of the angle of arrival.

The bistatic radar cross section through said aperture may be characterized by the effective receiving area of the aperture. Similarly to the effective receiving area, also bistatic RCS is a function of the angle of arrival. Furthermore, it is also a function of the observed scattering angle on the other side of the plane. The peak bistatic RCS on the other side of the plane is

20195349 PRH 25 -10- 2022

typically observed in a direction of direct path of the incident wave, as expected from physical optics.

The peak bistatic RCS through the aperture at the first frequency is almost independent of the aperture shape, when the area defined by the aperture perimeter remains constant. Resonant behavior or non-uniform aperture illumination and aperture field taper may cause small deviations. The maximal bistatic RCS through the aperture may be adequately characterized by the known RCS of an equivalent square having the same surface area than said aperture.

For a fixed surface area of the aperture, the total amount of scattered electromagnetic energy, or TRP through said aperture is almost independent of the aperture shape or the frequency of observation, when the smallest dimension of the aperture is larger than a wavelength at a first frequency.

The total amount of electromagnetic power delivered through the aperture, i.e. the 3D integral of the Poynting vector over the second hemisphere, may be adequately characterized by referencing the total amount of the scattered power to the equivalent power delivered by said equivalent square aperture having the same surface area than said aperture.

When the aperture causes loss for the transmitted energy, i.e. reflection loss, aperture tapering loss, aperture illumination loss, or material loss, the effective area of said aperture becomes smaller than the physical area of said aperture.

When said aperture is fully or partially filled with a conductive material, the effective aperture size of said aperture becomes smaller than the physical size of said aperture. This may be characterized by the aperture efficiency of said aperture. Aperture efficiency is affected by both the filling factor of the conductive material within the aperture, and the material properties such as surface resistance of the filling material. Said filling material may also comprise multiple heterogeneous or homogeneous layers, or only the surface impedance or transmittance at microwave frequencies may be appropriate to characterize said filling material.

When the aperture is fully or partially filled with a conductive material and said filling material is provided with coupled microwave resonators formed by

20195349 PRH 25-10-2022

openings in said filling material, the effective area of said aperture may be recovered. With unideal conductivity of the filling material, the factor of material loss may become significant, and it is not obvious that any resonator formed in the filling material could provide effective aperture sizes that are of the same order than the unfilled aperture. This is especially the case with coating materials used in thermally efficient window glasses. Furthermore, similar resonator geometries with good conductors, such as aluminum panels, may be significantly detuned when implemented in glass coatings, and also the effective aperture size of the aperture may be heavily degraded. We have also investigated that very narrow openings, e.g. less than 0.2 mm in width, become poor antenna radiators when arranged in a lossy conductor surface when compared to identical openings in good metals. An example of a lossy conductor is, e.g. a coating having a surface resistance of the order of 5 ohms per square, and an example of a good conductor is, e.g. copper or aluminum.

When an array of coupled microwave resonators are formed within said aperture, wherein said resonators being made sensitive to the signal of the first polarization, recovery in effective aperture size may be provided. When the smallest dimension of the aperture is smaller than the wavelength at the first frequency, and when the orientation of said smallest dimension at least partially crosses the orientation of the first polarization and said resonators being made sensitive to the signal of the first frequency, the formation of said resonators may increase the effective aperture size being larger than the physical aperture size.

In an aperture where the edges of the aperture become close to each other, i.e. when the smallest dimension of the aperture is comparable with the wavelength, the diffraction phenomenon becomes more effective. This can be exploited in building elements to provide wide coverage both outdoors towards the horizon and indoors where the location of the wireless device is unknown.

**First and second effective area**

Figure 2a shows three different structures having equal outer perimeters, and Figure 2b shows Finite Element Method (FEM) simulation results for these three example structures.

20195349 PRH 25 -10- 2022

Figure 2c shows a FEM simulation result for the bistatic radar cross section through a square aperture, i.e. an equivalent aperture, with respect to the aperture area, and a FEM simulation result for the total radiated power (TRP) through the same square aperture. The RCS and TRP values of the structures presented in Figure 2a and 2b are illustrated in Figure 2c with respect to the equivalent aperture.

The first example structure in Figure 2a shows an open aperture in a perfectly conducting wall. This structure is referred to as "CURVE_227_OPEN", and it shows an open aperture that is delimited by the curve 227, and having a physical area equivalent to the second physical area 250. For the open aperture, the first and second physical areas are equal and indistinguishable.

The simulations for the three structures are performed at the frequency of 900 MHz, and the physical area delimited by the curve 227 is $4\lambda^2$, where $\lambda$ is the wavelength at 900 MHz. This same aperture area is used for the three other example structures. The region that is outside of curve 227 is fully covered with the perfectly conducting wall.

The second structure is referred to as "REF1", and it represents a frequency selective structure according to the prior art. It is a FSS with dual concentric rings in each unit cell. The area of this FSS structure is delimited with curve 227 that is identical to the first example on the left. This curve 227 delimits the second physical area 250 of the conductive layer 150, and the first physical area 280 is arranged equal to the second physical area.

The third example structure from the left in Figure 2a shows an example of a conductive layer 150 comprising a microwave transformer 260 in accordance with an embodiment of the present invention. This is referred to as "TRANSFORMER" in Figure 2a and Figure 2b.

Figure 2b shows the simulation results for the three compared structures. There is presented the scattering patterns in the XY-plane in terms of bistatic RCS, and a table showing the maximal values of RCS in the direction of the positive X axis. This is the direction of $\theta=90°$ and $\varphi = 0°$. All of the structures are illuminated with a plane wave having an electric field strength of 1 V/m, and the plane wave is arriving from the direction of the normal of the conductive

20195349 PRH 25 -10- 2022

layer 150 from the negative X-axis. The total power that is transmitted through the apertures comprised by curves 227 are integrated in the hemisphere comprised by the positive X axis. The 3 dB beamwidhts for the simulated RCS patterns in the XY-plane are also provided.

Firstly, it may be observed that the RCS of the "CURVE_227_OPEN" is 13.54 dBsm, and the beamwidth is 25.9°. This acts as a reference for the maximal power that may be transmitted through the aperture.

Secondly, it may be seen that "REF1" shows RCS of 6.14 dBsm, which can be translated into penetration loss of -7.4 dB (or transmission loss) when characterized according to a direct beam measurement method that is commonly used in the prior art. It is emphasized that this value is what is commonly being characterized in the prior art when the transmission through a FSS structure is measured with using VNA measurements with two antennas measuring the direct ray path in a face-to-face setup.

However, it is next shown how this result is a measure for the combined effect of both the aperture transmittance and the geometry of the entire aperture. This is also a reason why prior art fails to present the conductive layer 150 of the present invention.

The total power that is transmitted through the second physical area 250 of "REF1", when integrated over the entire hemisphere comprised by the positive X-axis, is -40.15 dBm, which is 7.86 dB less than through the same physical area of "CURVE_227_OPEN". In other words, "REF1" attenuates the total energy by an amount of 7.86 dB. The scaling factor for "REF1" is 0.182, which may be determined from the reduction of the RCS with respect to the RCS of the "CURVE_227_OPEN".

The third structure that presents an example of the present invention in accordance with an embodiment ("TRANSFORMER"), has a RCS value of 2.52 dBsm. In other words, the measurement that would be performed using the methods used traditionally to characterize the structures of the prior art, would imply that "TRANSFORMER", which is the structure according to the present invention, would have 3.62 dB lower performance than "REF1". However, as it can be seen, "TRANSFORMER" delivers -38.38 dBm power

20195349 PRH 25-10-2022

through the aperture (through curve 227), which is 1.77 dB larger total power than what is achieved with structure "REF1". The scaling factor for "TRANSFORMER" is 0.08, which may be determined from the reduction of the RCS with respect to the RCS of the "CURVE_227_OPEN" by an amount of 11.02 dB.

According to a preferred embodiment, there is provided a conductive layer 150 comprising a microwave transformer 260 for scaling the intensity of a microwave signal of a first frequency by a scaling factor, wherein the scaling factor is the ratio of the maximal intensity of the re-emitted ray 603 and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area 250 in the same direction than the re-emitted ray 603, wherein said transformer 260 being arranged to provide at least 6 dB lower radar cross section for the re-emitted ray 603 than said open aperture having the physical area equivalent to said second physical area 250, and to increase the 3dB RCS beamwidth at least by a factor of two with respect to the RCS beamwidth of said open aperture having the physical area equivalent to said second physical area 250.

It may be seen from Figure 2b that the conductive layer 150 according to the present invention increases the 3 dB radar cross section beamwidth when compared to either of "REF1" or "CURVE_227_OPEN".

According to another preferred embodiment, there is provided a conductive layer 150 comprising a microwave transformer 260 for scaling the intensity of a microwave signal of a first frequency by a scaling factor, wherein the scaling factor is the ratio of the maximal intensity of the re-emitted ray 603 and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area 250 in the same direction than the re-emitted ray 603, wherein said scaling factor being less than 0.25.

The functionality of the present invention can be reached by arranging a first physical area 280, a first effective area 281, a second physical area 250, and a second effective area 251 in accordance with the scaling factor.

In an embodiment of the invention, said transformer 260 comprising the first physical area 280 delimited with a closed curve 230 on the conductive layer

20195349 PRH 25 -10- 2022

150 for receiving said microwave signal from the first space angle 800 and re-emitting the ray 603 of said microwave signal to the second space angle 801, said first physical area 280 having at least one region with electrically conductive material and at least one region 214 without electrically conductive material.

In an embodiment, said first physical area 280 having a first effective area 281 for said re-emitted ray 603, wherein the ratio of said first effective area 281 to said first physical area 280 being larger than the scaling factor.

In an embodiment, the conductive layer 150 having a second physical area 250 delimited with a closed edge curve 227 and a second effective area 251 for said re-emitted ray 603, wherein the ratio of said second effective area 251 to said second physical area 250 being smaller than twice the scaling factor.

In an embodiment, the ratio of said first effective area 281 to said first physical area 280 being at least two times as large as the ratio of said second effective area 251 to said second physical area 250.

In an embodiment, the ratio of said first physical area 280 to said second physical area 250 being smaller than 0.5.

In an embodiment, said scaling factor being less than 0.25.

In an embodiment, said first physical area 280 and said second physical area 250 are overlapping.

For a practical aperture in the conductive layer 150, the effective area may be less than one due to field taper and metal edge effects. When material loss is present, the effective area and aperture efficiency are reduced.

When the aperture antenna is diffractive and/or provides a broad beam, the effective area is reduced in any direction due to the effects of the structure geometry. This, however, is not a guarantee that the total amount of transmitted energy, or TRP is reduced. By forcing the re-emitted field to expand spatially, as with the conductive layer 150 of the present invention, one may reach better spatial coverage, and at the same time deliver as much or more microwave energy to the other side of the conductive layer. This is

20195349 PRH 25 -10- 2022

particularly true when comparing a traditional large FSS pane with a device according to the present invention and using the VNA measurement setup described above and using a measurement for the direct line of sight (LoS) ray to make a comparison between the two different solutions. Therefore, it becomes evident that the prior art does not account for the discrepancy between total transmitted power and a product of transmitted power and device directivity.

**Equivalent area**

An equivalent area is an area of an open square aperture in the conductive layer that delivers the same amount of total electromagnetic energy through the conductive layer than a device or aperture being considered. The total radiated power through the open square aperture may be accurately determined using, e.g. modern full wave electromagnetic simulation tools.

The effective area is defined for a re-radiated ray, whereas the equivalent area is defined for a 3D integral of the transmitted power to a hemisphere. The equivalent area relates to the total amount of transmitted power, whereas the effective area is determined from the bistatic RCS. For example, for a directive aperture, the effective area is at its maximum for a line of sight ray, and it's significantly smaller when it is observed from an angle that deviates from the LoS path. The equivalent area for such example aperture, however, would be independent of the observation angle of the re-emitted ray, when the direction of the incident signal would remain constant.

In an advantageous embodiment of the invention, the conductive layer 150 is characterized in having the first physical area 280 with the first effective area 281 for said re-emitted ray 603, and the second physical area 250 with the second effective area 251 for said re-emitted ray 603, and the first effective area 281 being less than 10% smaller than the second effective area 251.

The equivalent area is independent of the azimuth or elevation angle of the transmitted ray, because it is the integral of the Poynting vector in the hemisphere behind the conductive layer. It is, however, a function of the incident angle and polarization of the incident ray, because each illumination

20195349 PRH 25-10-2022

direction provides a unique scattering pattern to the other side of the conductive panel.

The equivalent area depends on the angle of the illumination signal, but is independent of the angle of the transmitted signal. The effective area depends on both the illumination angle and the angle of the transmitted signal.

When the equivalent area of an aperture or a device, e.g. a coated glass pane on a metal wall is known for a given illumination signal, it can be uniquely determined how much that aperture or device is able to deliver microwave energy through the conductive layer.

Figure 2c shows the FEM simulation result for the bistatic radar cross section through the square aperture, i.e. an equivalent aperture, with respect to the aperture area, and the FEM simulation result for the total radiated power (TRP) through the same square aperture. The RCS and TRP values of the structures presented in Figure 2a and 2b are illustrated in Figure 2c with respect to the equivalent aperture.

First, it is emphasized how the geometry changes of the aperture in the conductive panel affect both the total transmitted power and the maximal RCS value, which is the one that is primarily characterized in the prior art. It is seen from Figure 2c how doubling of the aperture area without lossy layers doubles the total amount of transmitted total power. The total power is integrated over the transmitted hemisphere. However, it is also seen that doubling the aperture area quadruples the maximal value of the RCS. An expert in the field would appreciate the fact that the value of the maximal RCS and TRP are relatively immune to the shape of the aperture, when resonance behavior is not significant.

The physical area of the aperture, that is, the area delimited with the curve 227, is $4\lambda^2$, where $\lambda$ is the wavelength of the first frequency. In this illustrative example, the first frequency is 900 MHz. The physical area of the aperture is therefore 0.444 $m^2$.

The RCS of 13.54 dBsm and the TRP of -32.29 dBm of the "CURVE_227_OPEN" aperture are presented with solid black dots. It can be

20195349 PRH 25-10-2022

verified that the physical area equals the area of the equivalent square area of 0.444 $m^2$.

The RCS of 6.14 dBsm and the TRP of -40.15 dBm of the "REF1" aperture are presented with crosshatched dots. It can be verified that the physical area of 0.444 $m^2$ delivers a total power that is equal to an equivalent square area of 0.0674 $m^2$.

The RCS of 2.52 dBsm and the TRP of -38.38 dBm of the "TRANSFORMER" are presented with white dots. It can be verified that the physical area of 0.444 $m^2$ delivers a total power that is equal to an equivalent square area of 0.1099 $m^2$. In other words, "TRANSFORMER" corresponds to 63% larger equivalent aperture area than "REF1" of the prior art.

For the open aperture ("CURVE_227_OPEN"), the first 280 and second 250 physical areas are equal to 0.444 $m^2$.

For the structure "REF1", the first physical area 280 equals 0.444 $m^2$, the second physical area 250 equals 0.444 $m^2$, and the scaling factor is 0.182.

For the structure "TRANSFORMER", the first physical area 280 equals 0.1040 $m^2$ and the second physical area 250 equals 0.444 $m^2$, and the scaling factor is 0.0791.

In an embodiment of the invention, the conductive layer 150 is arranged on a substrate 151, and said first physical area 280 having a first dimension 305 and a second dimension 306, wherein said first effective area 281 being arranged to be at least twice as large as an equivalent square area of the substrate 151 wherein the conductive layer 150 on the equivalent square area is absent, and wherein both the width and height of the equivalent square area being equal to the first dimension 305. In said arrangement, the first effective area 281 is forced to expand the coverage area with the re-emitted ray 603 in order to scale the intensity of the microwave signal of the first frequency by the scaling factor, wherein said arrangement being forced to deliver an amount of electromagnetic energy through the first physical area 280.

From Figure 2b it can be seen that the transformer 260 is arranged to expand the coverage area where the bistatic radar cross section (RCS) is less than 3

20195349 PRH 25-10-2022

dB smaller than the peak RCS of the re-emitted ray 603 by a factor of at least two, when compared to the open aperture or the FSS structure of the prior art.

In an embodiment of the invention, the transformer 260 comprises the first physical area 280, wherein said first physical area 280 having the first dimension 305 and the second dimension 306, wherein said microwave transformer 260 being arranged to expand the coverage area where the bistatic radar cross section (RCS) is less than 3 dB smaller than the peak RCS of the re-emitted ray 603, wherein said coverage area being expanded by a factor of at least two with respect to the 3 dB RCS coverage area of an equivalent physical area that is equal to the physical area of said conductive layer 250 but wherein said conductive layer 250 is absent, wherein said coverage expansion being provided with an arrangement where the ratio of the first dimension 305 to the second dimension 306 being smaller than twice the scaling factor.

**On the system for fabricating a conductive layer and a transformer**

Figure 3a shows an example of a system 900 for fabricating a conductive layer 150 comprising a microwave transformer 260.

In the illustrative example, there is provided a glass pane 100, wherein said conductive layer 150 being a coating layer on said glass pane 100. In the exemplary arrangement, the glass pane 100 is acting as the substrate material 151 for the conductive layer 150, wherein said glass pane has a thickness 109, and a first dimension 102 defining at least a length exceeding three wavelengths at the first frequency between at least two edge sections 103.

In the example of Figure 3a, there is also provided a laser apparatus 200, wherein said laser apparatus 200 being arranged to produce at least part of the transformer 260. Said laser apparatus 200 is primarily characterized in having a laser beam 201, wherein said laser beam 201 being arranged to aim energy to the beam projection 203 on the conductive layer 150.

In an embodiment, said laser apparatus 200 is arranged to deviate the position of the beam projection 203 along the surface of the conductive layer 150, and following a projection path 205 to provide said coupled microwave resonators 400 within a scanning region 202 (or scanfield) of the laser apparatus 200.

20195349 PRH 25-10-2022

In an embodiment of the invention, said system 900 comprises means for forming said transformer 260 comprising a first physical area 280 delimited with a closed curve 230 on the conductive layer 150 for receiving said microwave signal from a first space angle 800 and re-emitting a ray 603 of said microwave signal to a second space angle 801.

In another embodiment of the invention, said system 900 comprises means for forming said first physical area 280 with at least one region with electrically conductive material and at least one region 214 without electrically conductive material.

In an embodiment of the invention, said means for forming said first physical area 280 with at least one region with electrically conductive material and at least one region 214 without electrically conductive material comprising at least a laser apparatus 200.

In another embodiment of the invention, said system 900 comprises means for forming said first physical area 280 with a first effective area 281 for said re-emitted ray 603, wherein the ratio of said first effective area 281 to said first physical area 280 being larger than the scaling factor, and means for arranging the conductive layer 150 with a second physical area 250 delimited with a closed edge curve 227 and a second effective area 251 for said re-emitted ray 603, wherein the ratio of said second effective area 251 to said second physical area 250 being smaller than twice the scaling factor.

In another embodiment of the invention, said system 900 comprises means for arranging the ratio of said first physical area 280 to said second physical area 250 being smaller than twice the scaling factor, and means for arranging the ratio of said first effective area 281 to said first physical area 280 being at least two times as large as the ratio of said second effective area 251 to said second physical area 250.

In another embodiment of the invention, the system 900 comprises means for providing said conductive layer 150 or a substrate 150 comprising said conductive layer 150 with any of added metal pads, laminated circuit boards, printed electronics components, printed conductors, printed insulation layers,

20195349 PRH 25 -10- 2022

printed diodes, printed transistors, or printed solar cells to be connected with said microwave transformer 260.

In the example of Figure 3a, there is provided the transformer 260 comprising the first physical area 280, wherein said first physical area 280 having at least one region with electrically conductive material and at least one region 214 without electrically conductive material, wherein said at least one region 214 without electrically conductive material comprises coupled microwave resonators 400 on a repeating sequence along a primary processing direction 701.

Figure 3b shows an illustrative example of coupled microwave resonators 400 on a repeating sequence along a primary processing direction 701. The coordinate system 700 is shown in Figure 3a and 3b, wherein the coordinate system 700 is aligned on the conductive layer 150.

In an embodiment, said at least one region 214 without electrically conductive material comprises coupled microwave resonators 400 on a repeating sequence 212, wherein said repeating sequence 212 being provided with multiple replicas of a unit image 180 along a primary processing direction 701, wherein said coupled microwave resonators 400 being sensitive at least to a first polarization, and said coupled microwave resonators 400 being connected to at least one region 214 without electrically conductive material in said conductive layer 150, wherein said at least one region 214 without electrically conductive material comprise at least two sets 215 of substantially parallel and uninterrupted paths 216 within regions without electrically conductive material, wherein said uninterrupted paths 216 being separated by a first distance 217, and said uninterrupted paths 216 having an uninterrupted length of at least 20 times said first distance 217, and wherein said coupled microwave resonators 400 being coupled by means of coherent segments of surface currents 403 in said conductive layer 150, and said first distance 217 being arranged in the direction of said coherent segments of surface currents 403.

In an embodiment, said at least one region 214 without electrically conductive material comprises uninterrupted paths 216 within regions without electrically conductive material on a repeating sequence 212, wherein said uninterrupted

20195349 PRH 25-10-2022

paths 216 being separated at least by a first distance 217, and said uninterrupted paths 216 having an uninterrupted length of at least 20 times said first distance 217 and a width 219 of at least 10 times smaller than said first distance 217, and said uninterrupted paths 216 being arranged to form at least a first row of parallel radiating electric field sources at said first frequency range for scaling the intensity of said microwave signal by said scaling factor.

In an advantageous embodiment, said first distance 217 being arranged between 1 mm and 5 mm, said uninterrupted length being arranged at least 100 mm in length, and said width 219 of the uninterrupted path 216 being arranged between 1 um and 100 um.

In another advantageous embodiment, said first distance 217 being arranged between 1 mm and 3 mm, said uninterrupted length being arranged at least 60 mm in length, and said width 219 of the uninterrupted path 216 being arranged between 1 um and 100 um.

In Figure 3b, there is provided an example of a symmetry reference, wherein the repeating sequence 212 comprises multiple mirrored copies of the uninterrupted paths 216.

In an embodiment, said uninterrupted paths 216 comprising regions of mirrored symmetry with respect to a symmetry reference of a symmetry axis, or regions of rotational symmetry with respect to a symmetry reference of a rotation point, wherein the symmetry reference being arranged to separate the symmetrical regions of said uninterrupted paths 216 by a distance smaller than half of a wavelength at the first frequency.

**A plurality of conductive layers**

Figure 4 shows an arrangement of the conductive layer, in accordance with an embodiment. In Figure 4, there is provided a primary conductive layer 150' comprising a microwave transformer 260 of the present invention adjacent to a secondary conductive layer 150'' comprising another microwave transformer 260 of the present invention. The conductive layers 150 are arranged on substrates 151. In the example of Figure 4, the substrate material is glass. There is provided a separation 101 between the primary and the secondary conductive layer. Both the primary 150' and the secondary 150'' conductive

20195349 PRH 25 -10- 2022

layers comprise at least one region 214 without electrically conductive material comprising uninterrupted paths 216 according to an embodiment. The transformers of the two adjacent conductive layers may comprise the same repeating pattern, or they may be different.

In an embodiment, the conductive layer 150 comprising a microwave transformer 260 is arranged adjacent to another conductive layer 150 comprising another microwave transformer 260 according to the present invention, wherein said conductive layers 150 being arranged as an insulation glass unit 106, and said conductive layers 150 being provided with a separation 101 between the said conductive layers.

There is provided the repeating sequence 212 in both the primary 150' and the secondary 150'' conductive panel, wherein said uninterrupted paths 216 being separated at least by a first distance 217 in each conductive panel. In both conductive panels, said uninterrupted paths 216 are arranged to form at least a first row of parallel radiating electric field sources at said first frequency range for scaling the intensity of said microwave signal by said scaling factor.

The FEM simulation results for the bistatic radar cross section pattern in the XZ-plane is presented in Figure 4, wherein the RCS is simulated for a microwave signal through a stack of conductive layers according to an embodiment.

In a first example structure ("STRUCTURE 1") the first distance 217 is dimensioned to a value that is smaller than the separation 101 between the primary 150' and the secondary 150'' conductive layer. Furthermore, in said arrangement, the repeating sequence 212 is dimensioned to a value being smaller than the separation 101.

In a second example structure ("STRUCTURE 2") the first distance 217 is dimensioned to a value that is larger than the separation 101 between the primary 150' and the secondary 150'' conductive layer. Furthermore, in said arrangement, the repeating sequence 212 is dimensioned to a value being smaller than twice the separation 101. The first dimension 305 for both the first and second example structure was the same.

20195349 PRH 25 -10- 2022

In the FEM simulations, both structures are simulated in a first arrangement where the primary and secondary conductive layers are aligned in the same position with respect to the patterns in each panel. In these simulations the patterns are similar in both panels. In the second arrangement, there is provided a delta between the repeating sequence 212 of the primary 150' and the secondary 150'' conductive layer, wherein the delta is provided in the direction of the Y-axis. The delta in each simulation equals half of the length of the repeating sequence 212.

The simulation results show that by limiting the repeating sequence 212 to a value that is smaller than twice of the separation 101 between the primary 150' and the secondary 150'' conductive layer, the structure becomes more robust to manufacturing tolerances. In other words, with proper dimensioning of the transformer 260, there is no need to align the transformers 260 of the stacked conductive layers in two dimensions. The alignment of the transformer 260 is required only in one coordinate axis. The benefit of this arrangement is that the production speed may be improved and the production line may simplified. The processing of the microwave transformer 260 on the conductive layer 150 may therefore be run on the fly.

In an embodiment, said conductive layer 150 is arranged as a primary conductive layer 150' adjacent to a secondary conductive layer 150'', wherein the repeating sequence 212 of the primary conductive layer 150' is smaller than twice the separation 101 between the primary conductive layer 150' and the secondary conductive layer 150''.

In a preferred embodiment, said conductive layer 150 is arranged as a primary conductive layer 150' adjacent to a secondary conductive layer 150'', wherein the repeating sequence 212 of the primary conductive layer 150' is smaller than the separation 101 between the primary conductive layer 150' and the secondary conductive layer 150''.

In another embodiment, said conductive layer 150 is arranged as a primary conductive layer 150' adjacent to a secondary conductive layer 150'', wherein the first distance 217 of the primary conductive layer 150' is smaller than the separation 101 between the primary conductive layer 150' and the secondary conductive layer 150''.

20195349 PRH 25-10-2022

In accordance with a preferred embodiment, there is provided a method for fabricating said conductive layer 150 comprising said microwave transformer 260, wherein said method being characterized in providing said substrate 151 with said conductive layer 150 in form of a glass pane 100, wherein said conductive layer 150 being a coating layer on said glass pane 100, and wherein said method comprises at least process steps of cutting glass panes 100 out of jumbo glasses 108, wherein at least one of said glass panes 100 being provided with said conductive layer 150, and assembling said glass panes 100 into insulation glass units 106.

In accordance with the presented embodiments, there may be a plurality of conductive layers 150 on a stack, wherein said stack comprises at least two conductive layers. In a single coating layer, there may be multiple conductive layers. In a laminated glass pane 100 there may be a plurality of conductive layers. In an insulation glass unit, there may be a plurality of conductive layers 150, and in a window unit there may be a plurality of conductive layers 150 on a stack.

In an embodiment, there the primary 150' and the secondary 150'' conductive layer are laminated on an insulation material, wherein the thickness of the insulation material being arranged to provide the separation 101.

**On the method of manufacturing a conductive layer**

In accordance with an embodiment, there is provided a method for fabricating a conductive layer 150 comprising a microwave transformer 260 for scaling the intensity of a microwave signal of a first frequency by a scaling factor, wherein the scaling factor is the ratio of the maximal intensity of the re-emitted ray 603 and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area 250 in the same direction than the re-emitted ray 603.

In accordance with an embodiment, said method for fabricating a conductive layer 150 comprising said microwave transformer 260 being characterized by providing a substrate 151 with said conductive layer 150 and forming said transformer 260 by forming a first physical area 280 delimited with a closed curve 230 on the conductive layer 150 for receiving said microwave signal from

20195349 PRH 25-10-2022

a first space angle 800 and re-emitting a ray 603 of said microwave signal to a second space angle 801, and forming said first physical area 280 to have at least one region with electrically conductive material and at least one region 214 without electrically conductive material, and forming said first physical area 280 to have a first effective area 281 for said re-emitted ray 603, by arranging the ratio of said first effective area 281 to said first physical area 280 being larger than the scaling factor.

In accordance with an embodiment, said method for fabricating a conductive layer 150 comprising said microwave transformer 260 being characterized by arranging the conductive layer 150 to have a second physical area 250 delimited with a closed edge curve 227 and a second effective area 251 for said re-emitted ray 603, by arranging the ratio of said second effective area 251 to said second physical area 250 being smaller than twice the scaling factor, and arranging the ratio of said first physical area 280 to said second physical area 250 to be smaller than twice the scaling factor, and arranging the ratio of said first effective area 281 to said first physical area 280 to be at least two times as large as the ratio of said second effective area 251 to said second physical area 250.

In accordance with an advantageous embodiment, said method for fabricating a conductive layer 150 comprising said microwave transformer 260 being characterized by arranging the conductive layer 150 to have a second physical area 250 delimited with a closed edge curve 227 and a second effective area 251 for said re-emitted ray 603, by arranging the ratio of said second effective area 251 to said second physical area 250 being smaller than twice the scaling factor, and arranging the ratio of said first physical area 280 to said second physical area 250 to be smaller than 0.5 and larger than the scaling factor, and arranging the ratio of said first effective area 281 to said first physical area 280 to be at least two times as large as the ratio of said second effective area 251 to said second physical area 250.

In accordance with another embodiment, said method for fabricating a conductive layer 150 comprising said microwave transformer 260 being characterized in arranging said scaling factor to less than 0.25, and arranging said first effective area 281 to be less than 10% smaller than said second effective area 251.

20195349 PRH 25-10-2022

In accordance with another embodiment, said method for fabricating a conductive layer 150 comprising said microwave transformer 260 being characterized in arranging said first physical area 280 to have a first dimension 305 and a second dimension 306, and arranging said first effective area 281 to be at least twice as large as an equivalent square area of the substrate 151 wherein the conductive layer 150 on the equivalent square area is absent.

In accordance with another embodiment, said method for fabricating a conductive layer 150 comprising said microwave transformer 260 being characterized in arranging said transformer 260 for scaling the intensity of the microwave signal of the first frequency by means of bistatic scattering of the microwave signal through said first physical area 280 by increasing the maximal bistatic radar cross section of the microwave signal through said conductive layer 150 by arranging said at least one region with electrically conductive material and said at least one region 214 without electrically conductive material as microwave resonators 400, and delimiting the maximal bistatic RCS of said ray 603 through said conductive layer 150 at the first frequency to a value that is at least 6 dB below an equivalent peak bistatic radar cross section through an equivalent area of said substrate 151 that corresponds to the second physical area 250, and wherein the conductive layer 150 of the equivalent area is absent.

In a preferred embodiment, there is provided a method for fabricating said conductive layer 150 comprising said microwave transformer 260, wherein said method being characterized in forming said at least one region 214 without electrically conductive material of said first physical area 280 by applying coupled microwave resonators 400 on the conductive layer 150 along a primary processing direction 701 by using a laser apparatus 200, and applying said microwave resonators 400 using a repeating sequence 212 to apply multiple replicas of a unit image 180 along said primary processing direction 701, and arranging said coupled microwave resonators 400 being sensitive at least to a first polarization, and arranging said coupled microwave resonators 400 to be connected to at least one region 214 without electrically conductive material, wherein said at least one region 214 comprise at least two sets 215 of substantially parallel and uninterrupted paths 216 within regions without electrically conductive material, wherein said uninterrupted

20195349 PRH 25-10-2022

paths 216 being separated by a first distance 217, and said uninterrupted paths 216 having an uninterrupted length of at least 20 times said first distance 217, and wherein said coupled microwave resonators 400 being coupled by means of coherent segments of surface currents 403 in said conductive layer 150, and said first distance 217 being arranged in the direction of said coherent segments of surface currents 403.

There is also provided an alternative method for further enhancing the production speed of the first physical area 280 by using a fixed unit image 180.

In accordance with an embodiment, forming said transformer 260 being characterized by forming the first physical area 280 delimited with a closed curve 230 on the conductive layer 150 for receiving said microwave signal from a first space angle 800 and re-emitting a ray 603 of said microwave signal to a second space angle 801, and forming said first physical area 280 to have at least one region with electrically conductive material and at least one region 214 without electrically conductive material, and forming said first physical area 280 to have a first effective area 281 for said re-emitted ray 603, by arranging the ratio of said first effective area 281 to said first physical area 280 being larger than the scaling factor, and forming said at least one region 214 without electrically conductive material using a fixed unit image 180 by repeatedly stamping said unit image along a primary processing direction 701 to produce multiple replicas of resonators 400 defined by said unit image.

In an embodiment, said fixed unit image being a mechanical tool.

In another embodiment, said fixed unit image being a laser projection mask 210 comprising predefined exposure sections 206.

In Figure 5, there is provided an example of a method of fabricating the conductive layer 150 comprising said microwave transformer 260, in accordance with an embodiment. In said example, there is presented the primary processing direction 701, a pre-defined trace 204, the projection path 205, the scanning region 202, and the beam projection 203. Furthermore, there is shown the closed curve 230 delimiting the first physical area 280, exposure sections 206 of the laser ablated areas, transition sections 207 between exposure sections 206 along the pre-defined trace 204, and transition

20195349 PRH 25-10-2022

points 208. Furthermore, there is shown a first set 401 of coupled microwave resonators and a second set 402 of coupled microwave resonators.

In an embodiment, applying said coupled microwave resonators 400 on the conductive layer 150 along the primary processing direction 701 by using the laser apparatus 200 is primarily characterized in: providing a laser beam 201 within the scanning region 202 of the laser apparatus 200, and a beam projection 203 to be positioned on the conductive layer 150 by intersecting said laser beam 201 with said conductive layer 150, and arranging said primary processing direction 701 along an axis on the surface of said conductive layer 150, deviating the position of said scanning region 202 along the surface of said conductive layer 150 at least partly on the direction of said primary processing direction 701 by moving the conductive layer 150 to a direction 702 that opposes said primary processing direction 701 and/or by moving said scanning region 202 of the laser apparatus 200 along said primary processing direction 701, and providing a pre-defined trace 204 for controlling the movement of said beam projection 203 along a projection path 205. And further in said method, using said pre-defined trace 204 to define N exposure sections 206 along said projection path 205 by using said exposure sections 206 to define segments of said projection path 205 where laser energy exceeding a threshold value is being concentrated on said beam projection 203, and using integer 1 or larger for N, and further using said projection path 205 to produce a first set 401 of mutually coupled microwave resonators by forming said at least two sets 215 of substantially parallel and uninterrupted paths 216 within regions without electrically conductive material, and forming said exposure sections 206 by repeatedly deflecting said beam projection 203 along said projection path 205 in a direction that is crossing said primary processing direction 701 by a distance of less than a pre-determined deflection, and arranging said first distance 217 to less than lambda/20 from each other to provide mutual electromagnetic coupling between said at least two sets 215 of substantially parallel and uninterrupted paths 216, wherein lambda equals the free space wavelength of the corresponding resonance frequency of a coupled microwave resonator of said first set 401 of mutually coupled microwave resonators.

20195349 PRH 25-10-2022

In an embodiment, said pre-determined deflection being smaller than the first dimension 305 of the first physical area 280.

In an embodiment, said method being characterized in arranging the resonance frequency of said first set 401 of mutually coupled microwave resonators to the first frequency.

In accordance with an embodiment, said threshold value for the laser energy being arranged to sublimate a region of the conductive layer 150 from the location of the beam projection 203.

In an embodiment, applying said coupled microwave resonators 400 on the conductive layer 150 along the primary processing direction 701 by using the laser apparatus 200 is characterized in providing a displacement step for said beam projection 203 in the direction of said primary processing direction 701 while moving said beam projection 203 along said projection path 205, and providing an average position rate of change dy/dt exceeding 10 cm/s for said displacement step.

In an embodiment, applying said coupled microwave resonators 400 on the conductive layer 150 along the primary processing direction 701 by using the laser apparatus 200 is characterized in providing a cumulative length exceeding 5 cm for said exposure sections 206 that are crossing the direction of said primary processing direction 701 within a displacement step of 1 cm in the direction of said primary processing direction 701, or providing a cumulative length exceeding 50 cm for said exposure sections 206 that are crossing the direction of said primary processing direction 701 within a displacement step of 10 cm in the direction of said primary processing direction 701.

In an embodiment, applying said coupled microwave resonators 400 on the conductive layer 150 along the primary processing direction 701 by using the laser apparatus 200 is characterized in that the method comprises a step of connecting said at least two sets 215 of substantially parallel and uninterrupted paths 216 within regions without electrically conductive material along said projection path 205 by said transition sections 207 that connect two transition points 208 along said projection path 205, or using bends of said exposure

20195349 PRH 25 -10- 2022

sections, where said bends exceeding 45° angles or said bends having bending radiuses less than 5mm.

In an embodiment, applying said coupled microwave resonators 400 on the conductive layer 150 along the primary processing direction 701 by using the laser apparatus 200 is characterized in that the method comprises a step of using said exposure sections 206 to produce a second set 402 of mutually coupled microwave resonators at a second microwave frequency range of a first polarization or at said first microwave frequency range of a second polarization by forming at least two sets 215 of substantially parallel and uninterrupted paths 216 within regions without electrically conductive material, and connecting said uninterrupted paths 216 along said projection path 205 by said transition sections 207 that connect two transition points 208 along said projection path 205, or using bends of said exposure sections, said bends exceeding 45° angles or said bends having bending radiuses less than 5mm.

In an alternative embodiment, there is provided a method for fabricating said conductive layer 150 comprising said microwave transformer 260, wherein said method being characterized in forming said at least one region 214 without electrically conductive material of said first physical area 280 by applying coupled microwave resonators 400 on the conductive layer 150 along a primary processing direction 701 by using a laser apparatus 200, wherein said method comprises at least steps of: First, providing a plurality of scanning regions 202 on said conductive layer 150 by using at least two scanners, and providing a laser beam 201 for each of said plurality of scanning regions 202, and intersecting each of said laser beams 201 with the surface of said conductive layer 150; Second, deflecting at least one of said laser beams 201 in a direction that is crossing the direction of said primary processing direction 701; and third, synchronizing the deflection of said laser beams 201 within said plurality of scanning regions 202 with respect to a configurable coordinate axis on the surface of said conductive layer 150 by using a timer, motion sensor, image detection, or speed sensor.

In an alternative embodiment, there is provided a method for fabricating said conductive layer 150 comprising said microwave transformer 260, wherein the step of providing a substrate 151 with a conductive layer 150 comprises at least: Arranging a jumbo glass 108 to a glass cutting device 501, where said

20195349 PRH 25 -10- 2022

jumbo glass 108 having a conductive layer 150 formed therein; and providing a cutting layout and a cutting sequence for cutting said jumbo glass 108 into a plurality of unequally sized glass panes using a manual or an automated process of cutting layout optimization; and providing said substrate 151 as a glass pane 100 by cutting it out of said jumbo glass 108, said glass pane 100 having a thickness 109, and at least a first dimension 102 separating two edge sections 103 of said glass pane 100, said first dimension 102 being at least 50 centimeters in length, and at least one surface of said glass pane 100 having a surface area of at least 0.5 square meters; and detecting said glass pane 100 out of the plurality of unequally sized glass panes; and arranging said glass pane 100 to be processed with said laser apparatus 200 by positioning said glass pane 100 under the scanning region 202 of said laser apparatus 200 either by transferring said glass pane 100 to a laser working station or using an actuator 502 to transfer said scanning region 202 of said laser apparatus 200 over said glass pane 100.

In an embodiment, providing said substrate 151 as a glass pane 100 further comprises removal of the conductive layer from the edges of said glass pane 100 using appropriate edge deletion apparatus, and washing and/or tempering said glass pane 100 before assembling said glass pane 100 into an insulation glass unit 106.

In the example shown in Figure 3b, there is presented a first resonant node 405 of the electric field, wherein said first resonant node 405 being arranged within said at least one region 214 without electrically conductive material.

There is also presented a second resonant node 406 of the electric field, wherein said second resonant node 406 being arranged within said at least one region 214 without electrically conductive material, and wherein said second resonant node 406 being arranged to offset the first resonant node 405 in the direction of the first dimension 305.

In an advantageous embodiment, the first physical area 280 comprises at least one region 214 without electrically conductive material, wherein the first effective area 281 being arranged with a first set 401 of resonators forming an array of the first resonant nodes 405, wherein said first resonant nodes 405 having a standing wave node, and wherein said at least one region 214 without

20195349 PRH 25-10-2022

electrically conductive material further comprises a second set 402 of resonators forming an array of the second resonant nodes 406, wherein said second resonant nodes 406 being arranged to offset the first resonant nodes 405 in the direction of the first dimension 305, and wherein said first 405 and second 406 resonant nodes being comprised by the same unit image 180.

In the example of Figure 3b, there is also presented a third resonant node 407 of the electric field, wherein said third resonant node 407 being arranged within said at least one region 214 without electrically conductive material, and wherein said third resonant node 407 being arranged to offset either the first resonant node 405 or the second resonant node 406 in the direction of the first dimension 305, and wherein said first 405, second 406, and third 407 resonant nodes being comprised by the same unit image 180.

In an embodiment, said at least one region 214 without electrically conductive material is arranged with a plurality of exposure sections 206, wherein said at least one region 214 without electrically conductive material comprise uninterrupted paths 216 within said regions 214 without electrically conductive material, wherein said uninterrupted paths 216 comprise self-intersecting paths.

The advantage of offsetting the resonant nodes may improve the effectiveness of each resonator. This is due to the fact that the coherent current segments 403 corresponding to each of the coupled resonators, may couple more effectively to another resonator of the same kind. In other word, coupled resonators at the first frequency become more effective when the currents of said resonators are arranged to couple mutually without disruptions. Another resonator that is targeted to operate at another frequency or polarization, may be advantageously arranged in such configuration that the coherent current segments 403 forming the mutual coupling of the resonators 400 of the first frequency are not disturbed.

In an embodiment, said at least one region 214 without electrically conductive material is arranged with a plurality of exposure sections 206, wherein said at least one region 214 without electrically conductive material comprise uninterrupted paths 216 within said regions 214 without electrically conductive

20195349 PRH 25 -10- 2022

material on a repeating sequence 212, wherein said uninterrupted paths 216 comprise self-intersecting paths.

In another embodiment, said at least one region 214 without electrically conductive material is arranged with a single continuous exposure section 206.

In another embodiment, said at least one region 214 without electrically conductive material is arranged with a single exposure section 206, wherein said exposure section comprises an uninterrupted path 216 within said region 214 without electrically conductive material, wherein said uninterrupted path 216 comprise a self-intersecting path.

In an alternative embodiment, there is provided a method for forming said first physical area 280 to have at least one region with electrically conductive material and at least one region 214 without electrically conductive material, said method being characterized by modifying the properties of the conductive layer 150 without removing said layer 150. Said method comprises at least providing said substrate 151 with said conductive layer 150 in form of a glass pane 100, and using a laser apparatus 200 for surface treatment or sintering of said conductive layer 150. Said method of modifying the properties of the conductive layer 150 may be advantageously used to increase the quality value of the microwave resonators 400, or to reduce transmission line loss, or the maintain a coating layer on glass without visually observable openings.

In an embodiment, the method being characterized in providing said substrate 151 with said conductive layer 150 in form of a glass pane 100, and forming said at least one region 214 without electrically conductive material by decaying the electrical conductivity of the conductive layer 150 inside said region 214 by increasing the sheet resistance of the conductive layer 150 at least by a factor of 100 using a laser apparatus 200.

In an embodiment, the method being characterized in increasing the electrical conductivity of the conductive layer 150 around said at least one region 214 without electrically conductive material using a laser apparatus 200.

20195349 PRH 25 -10- 2022

**Isolation of a first and second set of resonators**

Figure 6a and 6b present examples of advantageous embodiments with a symmetry axis or a rotation point. Figure 6a shows a first set of resonators 401, and Figure 6b shows a second set of resonators within the first physical area 280, wherein the first 401 and second 402 set of resonators being isolated in the frequency domain.

In the example of Figure 6a the first physical area 280 comprises at least one region 214 without electrically conductive material, wherein the first effective area 281 being arranged with said first set 401 of resonators forming an array of the first resonant nodes 405, wherein said first resonant nodes 405 having a standing wave node, and wherein said at least one region 214 without electrically conductive material further comprises said second set 402 of resonators forming an array of the second resonant nodes 406, wherein said second resonant nodes 406 being arranged to offset the first resonant nodes 405 in the direction of the first dimension 305, and wherein said first 405.

In an embodiment, the second set 402 of resonators being arranged to isolate an array of the second resonant nodes 406 from the array of the first resonant nodes 405 in spatial domain, frequency domain, or in polarization domain.

In an embodiment, said first 405 and second 406 resonant nodes are arranged within the same region 214 without electrically conductive material and within the first physical area 280.

In another embodiment, said first 405 and second 406 resonant nodes are arranged within separated regions 214 without electrically conductive material and within the first physical area 280.

**A process for mass production**

In accordance with an embodiment, there is provided a system 900 for fabricating a conductive layer 150 comprising a microwave transformer 260.

In an embodiment of the invention, said system 900 comprises means for forming said transformer 260 comprising a first physical area 280 delimited with a closed curve 230 on the conductive layer 150 for receiving said

20195349 PRH 25 -10- 2022

microwave signal from a first space angle 800 and re-emitting a ray 603 of said microwave signal to a second space angle 801. Said system 900 further comprising means for forming said first physical area 280 with at least one region with electrically conductive material and at least one region 214 without electrically conductive material. Said system 900 further comprising means for forming said first physical area 280 with at least one region with electrically conductive material and at least one region 214 without electrically conductive material comprising at least a laser apparatus 200. Said system 900 further comprising means for forming said first physical area 280 with a first effective area 281 for said re-emitted ray 603, wherein the ratio of said first effective area 281 to said first physical area 280 being larger than the scaling factor, and means for arranging the conductive layer 150 with a second physical area 250 delimited with a closed edge curve 227 and a second effective area 251 for said re-emitted ray 603, wherein the ratio of said second effective area 251 to said second physical area 250 being smaller than twice the scaling factor.

In another embodiment of the invention, said system 900 comprises means for arranging the ratio of said first physical area 280 to said second physical area 250 being smaller than twice the scaling factor, and means for arranging the ratio of said first effective area 281 to said first physical area 280 being at least two times as large as the ratio of said second effective area 251 to said second physical area 250.

In another embodiment of the invention, the system 900 comprises means for providing said conductive layer 150 or a substrate 150 comprising said conductive layer 150 with any of added metal pads, laminated circuit boards, printed electronics components, printed conductors, printed insulation layers, printed diodes, printed transistors, or printed solar cells to be connected with said microwave transformer 260.

In a preferred embodiment, said system 900 is arranged as a part of an insulation glass unit 106 factory.

In a preferred embodiment, said system 900 is arranged for mass production of insulation glass units 106.

20195349 PRH 25 -10- 2022

In Figure 7, there is provided a process flow 901 for producing insulation glass units 106 out of jumbo glasses 108 in a repeating process, and using the method for fabricating the conductive layers 150 according to the present invention.

Figures 8a and 8b present examples of a system 900 for fabricating the conductive layer 150 comprising the microwave transformer 260.

In the example of Figure 8a, the resonators 400 are applied while cutting the glass panes 100 out of jumbo glass 108. There is provided a glass cutting device 501, and a plurality of unequally sized glass panes 100, from which identified glass panes 100 are arranged as insulation glass units 106. The example of Figure 8 presents glass panes 100 of a first product, referred to as 'A1' and 'A2', glass panes 100 of a second product, referred to as 'B1' and 'B2', and glass panes 100 of a third product, referred to as 'C1' and 'C2'. In accordance with an embodiment, the system 900 comprises means for identifying said glass panes 100 of separated products. Said products being insulation glass units 106.

In an embodiment, said means for identifying said glass panes 100 comprises automated identification system.

In another embodiment, said means for identifying said glass panes 100 comprises visual means.

In another embodiment, said means for identifying said glass panes 100 comprises a timing sequence and/or scheduling production of individual glass panes 100.

In a preferred embodiment, said system 900 comprises: means for producing insulation glass units 106 with an arrangement for cutting glass panes 100 out of jumbo glasses 108, where said glass panes 100 being arranged to be assembled into said insulation glass units 106, and means for identifying the glass panes 100 for forming transformers 260, and a dedicated process flow 901 for translating said identified glass panes 100 into said insulation glass units 106 with applied microwave resonators 400 in a repeating process, and means for forming said transformers 260 on said identified glass panes 100

20195349 PRH 25 -10- 2022

during the execution of said dedicated process flow 901 with an application of microwave resonators 400.

In the example of Figure 8b, there is provided an example of the system 900, in accordance with an embodiment. In said example, the system 900 comprises a processing station 504, a conveyor 503, and means means for forming the transformer 260 on the conductive layer 150, wherein said conductive layer 150 being comprised by a glass pane 100, and said means means for forming the transformer 260 comprise at least a laser apparatus 200.

In an embodiment, said laser apparatus 200 is connected to an actuator 502.

In an embodiment, said system 900 comprises: means for cutting said glass panes 100 from at least one jumbo glass 108, where said means for cutting said glass panes 100 comprises means for at least partly automated cutting layout generation and a cutting sequence generation, and a plurality of conveyors 503 to connect a plurality of processing stations 504, said plurality of processing stations comprising at least two of a glass cutting device 501, a tempering furnace 505, a glass washing unit 506, a gas filling station 507, an edge spacer assembler 508, or a lamination station 508.

In an embodiment, said system 900 comprises means for quality testing of the applied resonators 400.

**Examples of the projection paths**

Figures 9a-9h, present numerous examples of the projection paths 205.

In Figure 9a, there is provided an example of the resonators, in accordance with an embodiment. In said example, there is presented the primary processing direction 701, the projection path 205, and a sample of an exposure section 206 of the laser ablated area.

The example presents at least one region 214 without electrically conductive material, wherein said at least one region 214 comprises coupled microwave resonators 400 on a repeating sequence 212, wherein said repeating sequence 212 being provided with multiple replicas of a unit image along the

20195349 PRH 25-10-2022

primary processing direction 701, wherein said coupled microwave resonators 400 being sensitive at least to a first polarization, and said coupled microwave resonators 400 being connected to said at least one region 214 without electrically conductive material, wherein said at least one region 214 comprise at least two sets of substantially parallel and uninterrupted paths 216, wherein said at least two sets being formed by coiled segments of said parallel and uninterrupted paths 216, wherein said uninterrupted paths 216 being separated by a first distance 217, and said uninterrupted paths 216 having an uninterrupted length of at least 20 times said first distance 217, and wherein said coupled microwave resonators 400 being coupled by means of coherent segments of surface currents 403 in said conductive layer 150, and said first distance 217 being arranged in the direction of said coherent segments of surface currents 403.

The example also illustrates how substantially parallel and uninterrupted paths 216 may be coiled to arrange coupled microwave resonators 400.

Furthermore, Figure 9b shows how the substantially parallel and uninterrupted paths 216 may be formed using the projection path 205. In said example, the substantially parallel and uninterrupted paths 216, or coiled segments of said parallel and uninterrupted paths 216 may be used to form substantially parallel sets of said paths 216.

The substantially parallel and uninterrupted path 216 is a mathematical curve that may be fitted inside a region 214 without electrically conductive material to illustrate the trace that is formed on the conductive layer 150. It may therefore be described as a section of the projection path 205, on which laser energy over a threshold has been focused on said paths 205, and where an exposure section 206 has created a region 214 without electrically conductive material.

In the example shown in Figure 9b, there is presented a first resonant node 405 of the electric field, wherein said first resonant node 405 being arranged within said at least one region 214 without electrically conductive material. There is also presented a second resonant node 406 of the electric field, wherein said second resonant node 406 being arranged within said at least one region 214 without electrically conductive material, and wherein said

20195349 PRH 25-10-2022

second resonant node 406 being arranged to offset the first resonant node 405 in the direction of the first dimension 305.

In an advantageous embodiment, the first physical area 280 comprises at least one region 214 without electrically conductive material, wherein the first effective area 281 being arranged with a first set 401 of resonators forming an array of the first resonant nodes 405, wherein said first resonant nodes 405 having a standing wave node, and wherein said at least one region 214 without electrically conductive material further comprises a second set 402 of resonators forming an array of the second resonant nodes 406, wherein said second resonant nodes 406 being arranged to offset the first resonant nodes 405 in the direction of the first dimension 305, and wherein said first 405 and second 406 resonant nodes being comprised by the same unit image 180.

In the example of Figure 9b, there is also presented a third resonant node 407 of the electric field, wherein said third resonant node 407 being arranged within said at least one region 214 without electrically conductive material, and wherein said third resonant node 407 being arranged to offset both the first resonant node 405 and the second resonant node 406 in the direction of the first dimension 305, and wherein said first 405, second 406, and third 407 resonant nodes being comprised by the same unit image 180.

In the examples shown in Figure 9c and Figure 9d, there are presented a first resonant node 405 of the electric field, wherein said first resonant node 405 being arranged within said at least one region 214 without electrically conductive material. There is also presented a second resonant node 406 of the electric field, wherein said second resonant node 406 being arranged within said at least one region 214 without electrically conductive material, and wherein said second resonant node 406 being arranged to offset the first resonant node 405 in the direction of the first dimension 305.

In the example of Figure 9e, there is also presented a third resonant node 407 of the electric field, wherein said third resonant node 407 being arranged within said at least one region 214 without electrically conductive material, and wherein said third resonant node 407 being arranged to offset both the first resonant node 405 and the second resonant node 406 in the direction of the first dimension 305.

20195349 PRH 25-10-2022

Furthermore, in the figure 9e, there is presented line 209 of reduced impedance. The line 209 of reduced impedance may be advantageously arranged to connect with the resonators 400 using a characteristic impedance that is arranged to lower the transmission line loss in a thermally efficient coating. A conventional transmission line that is arranged to 50 Ω characteristic impedance can be shown to provide excessive transmission line losses. This results due to the fact that the ohmic square resistance (or sheet impedance) sums quickly in a long transmission line to deteriorate the signal strength.

In an embodiment, the conductive layer 150 comprises a line 209, wherein said line 209 comprises at least a positive line and a negative line, wherein said positive line and said negative line being formed on the conductive layer 150, and separated by an exposure section 206, and said positive or negative line having a line width, and said separating exposure section 206 having a gap width, wherein said line width being at least 30 times said gap width, and said gap width being less than 0.25 mm.

In an advantageous embodiment, said gap width being less than 0.1 mm, and said line width being larger than 5 mm.

In an advantageous embodiment, said line 209 being a coplanar line.

In another advantageous embodiment, said line 209 being a slot line.

In an advantageous embodiment, said line 209 being a connected to an external device, wherein said external device comprising means to interact with a resonator 400 on which said line 209 being connected to, wherein said interaction comprising at least electromagnetic interaction.

In another advantageous embodiment of the invention, the conductive layer 150 comprises any of added metal pads, laminated circuit boards, printed electronics components, printed conductors, printed insulation layers, printed diodes, printed transistors, or printed solar cells to be connected with said microwave transformer 260, wherein said connection being arranged at least partly with a line 209, wherein said line 209 comprises at least a positive line, a negative line, wherein said positive line and a negative line being formed on the conductive layer 150, and separated by an exposure section 206, and said positive or negative line having a line width, and said separating exposure

20195349 PRH 25 -10- 2022

section 206 having a gap width, wherein said line width being at least 30 times said gap width, and said line width being at least 5 mm, and said line 209 being connected to at least one resonator 400 with electromagnetic means.

In another advantageous embodiment, there is provided the conductive layer 150 with the transformer 260 according to the present invention, wherein said conductive layer 150 or said transformer 260 further comprises means to couple an external antenna, a cable, a rigid or flexible printed circuit board (PCB) or a capacitive or inductive loading element to be coupled and/or connected with any of the resonators 400 comprised by the transformer 260.

In another embodiment, there is provided a method, wherein the method being characterized in forming a line 209 of reduced impedance on the conductive layer 150 and arranging said line 209 to be connected with at least one of said microwave resonators 400, wherein forming said line 209 of reduced impedance comprises at least forming a positive line having a line width and forming a gap to separate a negative line from the positive line, and arranging said line 209 of reduced impedance to have a characteristic impedance less than 50 Ω.

In an advantageous embodiment, the characteristic impedance of the line 209 of reduced impedance is between 5 Ω and 35 Ω.

In another advantageous embodiment, the is provided means for matching the line 209 of reduced impedance to a range from 40 Ω to 55 Ω.

The examples of Figure 9f-9h show examples of the projection path 205, in accordance with an embodiment. The example of Figure 9g shows how the projection path 205 may be arranged to isolate the coherent segments of surface currents 403 of the first frequency from the isolated current segments of the second frequency 403' of a first polarization, and from the isolated current segments of the second frequency 403'' of a second polarization. In said example, the corresponding nodes 405, 406, and 407 are isolated in spatial domain, frequency domain, and polarization domain.

The examples of Figure 9d, 9g and 9h show examples of the projection path 205, wherein said projection path 205 is arranged to form self-intersecting paths of the uninterrupted paths 216.

20195349 PRH 25 -10- 2022

**Retrofittable transformer**

In accordance with an embodiment, there is provided a method for fabricating said conductive layer 150 comprising said microwave transformer 260, wherein said conductive layer 150 being on a glass substrate 151, wherein said method is characterized in providing said substrate 151 with said conductive layer 150 as a part of an insulation glass unit 106, and forming said transformer 260 on the conductive layer 150 using retrofitting means.

In accordance with another embodiment, there is provided a method for fabricating said conductive layer 150 comprising said microwave transformer 260, wherein said conductive layer 150 being on a glass substrate 151, wherein said method is characterized in providing said substrate 151 with said conductive layer 150 as a part of an insulation glass unit 106, and forming said transformer 260 on the conductive layer 150 using the system 900 for fabricating said conductive layer 150 comprising a microwave transformer 260, wherein said system 900 is a portable system that is adapted for retrofitting.

In accordance with another embodiment, there is provided a method for fabricating said conductive layer 150 comprising said microwave transformer 260, wherein said conductive layer 150 being on a glass substrate 151, wherein said method is characterized in providing said substrate 151 with said conductive layer 150 as a part of an insulation glass unit 106, and forming said transformer 260 on the conductive layer 150 using the system 900 for fabricating said microwave transformer 260, wherein said system 900 is a portable system that is adapted for retrofitting.

Some of the advantageous embodiments of the present invention are presented below.

In an advantageous embodiment, there is provided a conductive layer 150 comprising a microwave transformer 260 for scaling the intensity of a microwave signal of a first frequency by a scaling factor, said transformer 260 comprising a first physical area 280 delimited with a closed curve 230 on the conductive layer 150 for receiving said microwave signal from a first space angle 800 and re-emitting a ray 603 of said microwave signal to a second space angle 801, said first physical area 280 having at least one region with

20195349 PRH 25-10-2022

electrically conductive material and at least one region 214 without electrically conductive material, and said first physical area 280 having a first effective area 281 for said re-emitted ray 603, wherein the ratio of said first effective area 281 to said first physical area 280 being larger than the scaling factor, and further wherein the conductive layer 150 having a second physical area 250 delimited with a closed edge curve 227 and a second effective area 251 for said re-emitted ray 603, wherein the ratio of said second effective area 251 to said second physical area 250 being smaller than twice the scaling factor, and the ratio of said first physical area 280 to said second physical area 250 being smaller than 0.5, wherein the scaling factor is the ratio of the maximal intensity of the re-emitted ray 603 and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area 250 in the same direction than the re-emitted ray 603.

In an embodiment, the ratio of said first effective area 281 to said first physical area 280 being at least two times as large as the ratio of said second effective area 251 to said second physical area 250.

In an embodiment, said scaling factor being less than 0.25.

In an embodiment, said first effective area 281 being less than 10% smaller than said second effective area 251.

In an embodiment, said first physical area 280 having a first dimension 305 and a second dimension 306, wherein said microwave transformer 260 being arranged to expand the coverage area where the bistatic radar cross section (RCS) is less than 3 dB smaller than the peak RCS of the re-emitted ray 603, wherein said coverage area being expanded by a factor of at least two with respect to the 3 dB RCS coverage area of an equivalent physical area that is equal to the physical area of said conductive layer 250 but wherein said conductive layer 250 is absent, wherein said coverage expansion being provided with an arrangement where the ratio of the first dimension 305 to the second dimension 306 being smaller than twice the scaling factor.

In an embodiment, said conductive layer 150 being arranged on a substrate 151, and said first physical area 280 having a first dimension 305 and a second dimension 306, wherein said first effective area 281 being arranged to be at

20195349 PRH 25-10-2022

least twice as large as an equivalent square area of the substrate 151 wherein the conductive layer 150 on the equivalent square area is absent, and wherein both the width and height of the equivalent square area being equal to the first dimension 305.

In an embodiment, said at least one region 214 without electrically conductive material comprises coupled microwave resonators 400 on a repeating sequence 212, wherein said repeating sequence 212 being provided with multiple replicas of a unit image 180 along a primary processing direction 701, wherein said coupled microwave resonators 400 being sensitive at least to a first polarization, and said coupled microwave resonators 400 being connected to said at least one region 214 without electrically conductive material, wherein said at least one region 214 comprise at least two sets 215 of substantially parallel and uninterrupted paths 216 within regions without electrically conductive material, wherein said uninterrupted paths 216 being separated by a first distance 217, and said uninterrupted paths 216 having an uninterrupted length of at least 20 times said first distance 217, and wherein said coupled microwave resonators 400 being coupled by means of coherent segments of surface currents 403 in said conductive layer 150, and said first distance 217 being arranged in the direction of said coherent segments of surface currents 403.

In an embodiment, said at least one region 214 without electrically conductive material comprises uninterrupted paths 216 within regions without electrically conductive material on a repeating sequence 212, wherein said uninterrupted paths 216 being separated at least by a first distance 217, and said uninterrupted paths 216 having an uninterrupted length of at least 20 times said first distance 217 and a width 219 of at least 10 times smaller than said first distance 217, and said uninterrupted paths 216 being arranged to form at least a first row of parallel radiating electric field sources at said first frequency range for scaling the intensity of said microwave signal by said scaling factor.

In an embodiment, said uninterrupted paths 216 comprising regions of mirrored symmetry with respect to a symmetry reference of a symmetry axis, or regions of rotational symmetry with respect to a symmetry reference of a rotation point, wherein the symmetry reference being arranged to separate the

20195349 PRH 25-10-2022

symmetrical regions of said uninterrupted paths 216 by a distance smaller than half of a wavelength at the first frequency.

In an embodiment, said conductive layer 150 being arranged as a primary conductive layer 150' adjacent to a secondary conductive layer 150'', wherein the repeating sequence 212 of the primary conductive layer 150' is smaller than the separation 101 between the primary conductive layer 150' and the secondary conductive layer 150''.

In an embodiment, said conductive layer 150 being arranged as a primary conductive layer 150' adjacent to a secondary conductive layer 150'', wherein the first distance 217 of the primary conductive layer 150' is smaller than the separation 101 between the primary conductive layer 150' and the secondary conductive layer 150''.

In an embodiment, said conductive layer 150 being part of a wall, a door, a window, a housing container, a train, a ship, a vehicle, an elevator shaft, a shipping container, an electrical cabinet, or a safety locker.

In an embodiment, the ratio of said first effective area 281 to said first physical area 280 being at least 0.5.

In accordance with an embodiment, there is provided a method for fabricating a conductive layer 150 comprising a microwave transformer 260 for scaling the intensity of a microwave signal of a first frequency by a scaling factor, wherein the method comprises: providing a substrate 151 with a conductive layer 150; forming said transformer 260 by forming a first physical area 280 delimited with a closed curve 230 on the conductive layer 150 for receiving said microwave signal from a first space angle 800 and re-emitting a ray 603 of said microwave signal to a second space angle 801, and forming said first physical area 280 to have at least one region with electrically conductive material and at least one region 214 without electrically conductive material, and forming said first physical area 280 to have a first effective area 281 for said re-emitted ray 603, by arranging the ratio of said first effective area 281 to said first physical area 280 being larger than the scaling factor, and arranging the conductive layer 150 to have a second physical area 250 delimited with a closed edge curve 227 and a second effective area 251 for

20195349 PRH 25-10-2022

said re-emitted ray 603, by arranging the ratio of said second effective area 251 to said second physical area 250 being smaller than twice the scaling factor, wherein the scaling factor is the ratio of the maximal intensity of the re-emitted ray 603 and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area 250 in the same direction than the re-emitted ray 603.

In another advantageous embodiment, the method being characterized in arranging the ratio of said first physical area 280 to said second physical area 250 to be smaller than 0.5, and arranging the ratio of said first effective area 281 to said first physical area 280 to be at least two times as large as the ratio of said second effective area 251 to said second physical area 250.

In an embodiment, the method being characterized in arranging said scaling factor to less than 0.25, and arranging said first effective area 281 to be less than 10% smaller than said second effective area 251.

In an embodiment, the method being characterized in arranging said first physical area 280 to have a first dimension 305 and a second dimension 306, and arranging said first effective area 281 to be at least twice as large as an equivalent square area of the substrate 151 wherein the conductive layer 150 on the equivalent square area is absent.

In an embodiment, the method being characterized in arranging said transformer 260 for scaling the intensity of the microwave signal of the first frequency by means of bistatic scattering of the microwave signal through said first physical area 280 by increasing the maximal bistatic radar cross section of the microwave signal through said conductive layer 150 by arranging said at least one region with electrically conductive material and said at least one region 214 without electrically conductive material as microwave resonators 400, and delimiting the maximal bistatic RCS of said ray 603 through said conductive layer 150 at the first frequency to a value that is at least 6 dB below an equivalent peak bistatic radar cross section through an equivalent area of said substrate 151 that corresponds to the second physical area 250, and wherein the conductive layer 150 of the equivalent area is absent.

20195349 PRH 25-10-2022

In an embodiment, the method being characterized in forming said at least one region 214 without electrically conductive material of said first physical area 280 by applying coupled microwave resonators 400 on the conductive layer 150 along a primary processing direction 701 by using a laser apparatus 200, and applying said microwave resonators 400 using a repeating sequence 212 to apply multiple replicas of a unit image 180 along said primary processing direction 701, and arranging said coupled microwave resonators 400 being sensitive at least to a first polarization, and arranging said coupled microwave resonators 400 to be connected to at least one region 214 without electrically conductive material, wherein said at least one region 214 comprise at least two sets 215 of substantially parallel and uninterrupted paths 216 within regions without electrically conductive material, wherein said uninterrupted paths 216 being separated by a first distance 217, and said uninterrupted paths 216 having an uninterrupted length of at least 20 times said first distance 217, and wherein said coupled microwave resonators 400 being coupled by means of coherent segments of surface currents 403 in said conductive layer 150, and said first distance 217 being arranged in the direction of said coherent segments of surface currents 403.

In an embodiment, the method being characterized in providing said substrate 151 with said conductive layer 150 as a part of an insulation glass unit 106, and forming said transformer 260 on the conductive layer 150 using retrofitting means.

In an embodiment, the method being characterized in providing said substrate 151 with said conductive layer 150 in form of a glass pane 100, wherein said conductive layer 150 being a coating layer on said glass pane 100, and wherein said method comprises at least process steps of cutting glass panes 100 out of jumbo glasses 108, wherein at least one of said glass panes 100 being provided with said conductive layer 150, and assembling said glass panes 100 into insulation glass units 106.

In an embodiment, the method being characterized in providing said substrate 151 with said conductive layer 150 in form of a glass pane 100, and forming said at least one region 214 without electrically conductive material by decaying the electrical conductivity of the conductive layer 150 inside said

20195349 PRH 25 -10- 2022

region 214 by increasing the sheet resistance of the conductive layer 150 at least by a factor of 100 using a laser apparatus 200.

In an embodiment, the method being characterized in increasing the electrical conductivity of the conductive layer 150 around said at least one region 214 without electrically conductive material using a laser apparatus 200.

In an embodiment, the method being characterized in forming a line 209 of reduced impedance on the conductive layer 150 and arranging said line 209 to be connected with at least one of said microwave resonators 400, wherein forming said line 209 of reduced impedance comprises at least forming a positive line having a line width and forming a gap to separate a negative line from the positive line, and arranging said line 209 of reduced impedance to have a characteristic impedance less than 50 Ω.

In an embodiment, the method being characterized in increasing the electrical conductivity of the line 209 using a laser apparatus 200.

In accordance with an embodiment, there is provided a system 900 for fabricating a conductive layer 150 comprising a microwave transformer 260 for scaling the intensity of a microwave signal of a first frequency by a scaling factor, wherein the system comprises means for forming said transformer 260 comprising a first physical area 280 delimited with a closed curve 230 on the conductive layer 150 for receiving said microwave signal from a first space angle 800 and re-emitting a ray 603) of said microwave signal to a second space angle 801, and means for forming said first physical area 280 with at least one region with electrically conductive material and at least one region 214 without electrically conductive material, and means for forming said first physical area 280 with a first effective area 281 for said re-emitted ray 603, wherein the ratio of said first effective area 281 to said first physical area 280 being larger than the scaling factor, and means for arranging the conductive layer 150 with a second physical area 250 delimited with a closed edge curve 227 and a second effective area 251 for said re-emitted ray 603, wherein the ratio of said second effective area 251 to said second physical area 250 being smaller than twice the scaling factor, and means for arranging the ratio of said first physical area 280 to said second physical area 250 being smaller than twice the scaling factor, and means for arranging the ratio of said first effective

20195349 PRH 25-10-2022

area 281 to said first physical area 280 being at least two times as large as the ratio of said second effective area 251 to said second physical area 250; wherein the scaling factor is the ratio of the maximal intensity of the re-emitted ray 603 and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area 250 in the same direction than the re-emitted ray 603.

In an embodiment, the system 900 comprises means for providing said conductive layer 150 or a substrate 150 comprising said conductive layer 150 with any of added metal pads, laminated circuit boards, printed electronics components, printed conductors, printed insulation layers, printed diodes, printed transistors, or printed solar cells to be connected with said microwave transformer 260.

In an embodiment, said first physical area 280 having a first effective area 281 for said re-emitted ray 603, wherein the ratio of said first effective area 281 to said first physical area 280 being larger than the scaling factor.

In an embodiment, said first physical area 280 having a first effective area 281 for said re-emitted ray 603, wherein the ratio of said first effective area 281 to said first physical area 280 being larger than twice the scaling factor.

20195349 PRH 25 -10- 2022

Claims:

1. A conductive layer (150) comprising a microwave transformer (260) for scaling the intensity of a microwave signal of a first frequency by a scaling factor:

- said transformer (260) comprising a first physical area (280) delimited with a closed curve (230) on the conductive layer (150) for receiving said microwave signal from a first space angle (800) and re-emitting a ray (603) of said microwave signal to a second space angle (801), and
- said first physical area (280) having at least one region with electrically conductive material and at least one region (214) without electrically conductive material, and
- said first physical area (280) having a first effective area (281) for said re-emitted ray (603), wherein the ratio of said first effective area (281) to said first physical area (280) being larger than the scaling factor, and
- the conductive layer (150) having a second physical area (250) delimited with a closed edge curve (227) and a second effective area (251) for said re-emitted ray (603), wherein the ratio of said second effective area (251) to said second physical area (250) being smaller than twice the scaling factor, and
- the ratio of said first physical area (280) to said second physical area (250) being smaller than 0.5, and
- the ratio of said first effective area (281) to said first physical area (280) being at least two times as large as the ratio of said second effective area (251) to said second physical area (250);
- wherein the scaling factor is the ratio of the maximal intensity of the re-emitted ray (603) and the intensity of a ray through an open aperture having a physical area equivalent to said second physical area (250) in the same direction than the re-emitted ray (603), and

**characterized** in that

- said scaling factor is less than 0.25, and
- said at least one region (214) without electrically conductive material comprises coupled microwave resonators (400) on a repeating sequence (212), wherein said repeating sequence (212) being provided with multiple replicas of a unit image (180) along a primary processing direction (701), wherein said coupled microwave resonators (400) being

20195349 PRH 25-10-2022

sensitive at least to a first polarization, and said coupled microwave resonators (400) being connected to said at least one region (214) without electrically conductive material, wherein said at least one region (214) comprise at least two sets (215) of substantially parallel and uninterrupted paths (216) within regions without electrically conductive material, wherein said uninterrupted paths (216) being separated by a first distance (217), and said uninterrupted paths (216) having an uninterrupted length of at least 20 times said first distance (217), and wherein said coupled microwave resonators (400) being coupled by means of coherent segments of surface currents (403) in said conductive layer (150), and said first distance (217) being arranged in the direction of said coherent segments of surface currents (403), and

- said conductive layer (150) being arranged on a substrate (151), and said first physical area (280) having a first dimension (305) and a second dimension (306), and
- the first physical area (280) comprises at least one region (214) without electrically conductive material, wherein the first effective area (281) being arranged with a first set (401) of resonators forming an array of the first resonant nodes (405), wherein said first resonant nodes (405) having a standing wave node, and wherein said at least one region (214) without electrically conductive material further comprises a second set (402) of resonators forming an array of the second resonant nodes (406), wherein said second resonant nodes (406) being arranged to offset the first resonant nodes (405) in the direction of the first dimension (305).

2. The conductive layer (150) according to claim 1, **characterized** in that said first (405) and second (406) resonant nodes being comprised by the same unit image (180), and the second set (402) of resonators being arranged to isolate an array of the second resonant nodes (406) from the array of the first resonant nodes (405) in spatial domain, frequency domain, or in polarization domain.

3. The conductive layer (150) according to claim 1 or 2, **characterized** in that said first effective area (281) being less than 10% smaller than said second effective area (251).

20195349 PRH 25-10-2022

4. The conductive layer (150) according to any of the claims 1, 2, or 3, **characterized** in that said first physical area (280) having a first dimension (305) and a second dimension (306), wherein said microwave transformer (260) being arranged to expand the coverage area where the bistatic radar cross section (RCS) is less than 3 dB smaller than the peak RCS of the re-emitted ray (603), wherein said coverage area being expanded by a factor of at least two with respect to the 3 dB RCS coverage area of an equivalent physical area that is equal to the physical area of said conductive layer (250) but wherein said conductive layer (250) is absent, wherein said coverage expansion being provided with an arrangement where the ratio of the first dimension (305) to the second dimension (306) being smaller than twice the scaling factor.

5. The conductive layer (150) according to any of the claims 1-4, **characterized** in that said conductive layer (150) being arranged on a substrate (151), and said first physical area (280) having a first dimension (305) and a second dimension (306), wherein said first effective area (281) being arranged to be at least twice as large as an equivalent square area of the substrate (151) wherein the conductive layer (150) on the equivalent square area is absent, and wherein both the width and height of the equivalent square area being equal to the first dimension (305).

6. The conductive layer (150) according to any of the claims 1-5, **characterized** in that a third resonant node (407) being arranged within said at least one region (214) without electrically conductive material, and wherein said third resonant node (407) being arranged to offset either the first resonant node (405) or the second resonant node (406) in the direction of the first dimension (305), and wherein said first (405), second (406), and third (407) resonant nodes being comprised by the same unit image (180)..

7. The conductive layer (150) according to any of the claims 1-6, **characterized** in that said at least one region (214) without electrically conductive material comprises uninterrupted paths (216) within regions without electrically conductive material on a repeating sequence (212), wherein said uninterrupted paths (216) being separated at least by a first distance (217),

20195349 PRH 25 -10- 2022

and said uninterrupted paths (216) having an uninterrupted length of at least 20 times said first distance (217) and a width (219) of at least 10 times smaller than said first distance (217), and said uninterrupted paths (216) being arranged to form at least a first row of parallel radiating electric field sources at said first frequency range for scaling the intensity of said microwave signal by said scaling factor.

8. The conductive layer (150) according to claims 6 or 7, **characterized** in that said uninterrupted paths (216) comprising regions of mirrored symmetry with respect to a symmetry reference of a symmetry axis, or regions of rotational symmetry with respect to a symmetry reference of a rotation point, wherein the symmetry reference being arranged to separate the symmetrical regions of said uninterrupted paths (216) by a distance smaller than half of a wavelength at the first frequency.

9. The conductive layer (150) according to any of the claims 6-8, **characterized** in that said conductive layer (150) being arranged as a primary conductive layer (150') adjacent to a secondary conductive layer (150'') according to any of the claims 1-8, wherein the repeating sequence (212) of the primary conductive layer (150') is smaller than the separation (101) between the primary conductive layer (150') and the secondary conductive layer (150'').

10. The conductive layer (150) according to any of the claims 6-8, **characterized** in that said conductive layer (150) being arranged as a primary conductive layer (150') adjacent to a secondary conductive layer (150'') according to any of the claims 1-8, wherein the first distance (217) of the primary conductive layer (150') is smaller than the separation (101) between the primary conductive layer (150') and the secondary conductive layer (150'').

11. The conductive layer (150) according to any of the claims 1-10, **characterized** in that said conductive layer being part of a wall, a door, a window, a housing container, a train, a ship, a vehicle, an elevator shaft, a shipping container, an electrical cabinet, or a safety locker.

20195349 PRH 25-10-2022

12. The conductive layer (150) according to any of the claims 1-11, **characterized** in that the ratio of said first effective area (281) to said first physical area (280) being at least 0.5.

20195349 PRH 25 -10- 2022

Patenttivaatimukset:

1. Sähköä johtava kerros (150), joka käsittää mikroaaltomuuntimen (260) ensimmäisellä taajuudella olevan mikroaaltosignaalin voimakkuuden skaalaamiseksi skaalauskertoimella:

- mainittu muunnin (260) käsittää ensimmäisen fyysisen alueen (280), jota rajaa sähköä johtavan kerroksen (150) päällä oleva suljettu käyrä (230) mainitun mikroaaltosignaalin vastaanottamiseksi ensimmäisestä avaruuskulmasta (800) ja mainitun mikroaaltosignaalin säteen (603) uudelleenlähettämiseksi toiseen avaruuskulmaan (801), ja
- mainittu ensimmäinen fyysinen alue (280) käsittää ainakin yhden vyöhykkeen, jossa on sähköä johtavaa materiaalia, ja ainakin yhden vyöhykkeen (214), jossa ei ole sähköä johtavaa materiaalia, ja
- mainittu ensimmäinen fyysinen alue (280) käsittää ensimmäisen vaikuttavan alueen (281) mainittua uudelleenlähetettyä sädettä (603) varten, jolloin mainitun ensimmäisen vaikuttavan alueen (281) ja mainitun ensimmäisen fyysisen alueen (280) suhde on suurempi kuin skaalauskerroin, ja
- sähköä johtava kerros (150) käsittää toisen fyysisen alueen (250), jota rajaa suljettu reunakäyrä (227), ja toisen vaikuttavan alueen (251) mainittua uudelleenlähetettyä sädettä (603) varten, jolloin mainitun toisen vaikuttavan alueen (251) ja mainitun toisen fyysisen alueen (250) välinen suhde on pienempi kuin kaksi kertaa skaalauskerroin, ja
- mainitun ensimmäisen fyysisen alueen (280) ja mainitun toisen fyysisen alueen (250) välinen suhde on pienempi kuin 0,5, ja
- mainitun ensimmäisen vaikuttavan alueen (281) ja mainitun ensimmäisen fyysisen alueen (280) välinen suhde on vähintään kaksi kertaa yhtä suuri kuin mainitun toisen vaikuttavan alueen (251) ja mainitun toisen fyysisen alueen (250) välinen suhde;
- siten että skaalauskerroin on uudelleenlähetetyn säteen (603) maksimivoimakkuuden ja sen säteen voimakkuuden suhde, joka kulkee avoimen aukon kautta, jonka fyysinen alue on yhtä suuri kuin mainittu toinen fyysinen alue (250) samassa suunnassa kuin uudelleenlähetetty säde (603), ja

20195349 PRH 25 -10- 2022

**tunnettu** siitä, että

- mainittu skaalauskerroin on pienempi kuin 0,25, ja
- mainittu ainakin yksi vyöhyke (214), jossa ei ole sähköä johtavaa materiaalia, käsittää toistuvaksi jaksoksi (212) kytkettyjä mikroaaltoresonaattoreita (400), jolloin mainittuun toistuvaan jaksoon (212) on järjestetty useita kopioita yksikkökuvasta (180) primaarista käsittelysuuntaa (701) pitkin, jolloin mainitut kytketyt mikroaaltoresonaattorit (400) ovat herkkiä ainakin ensimmäiselle polarisaatiolle, ja mainitut kytketyt mikroaaltoresonaattorit (400) on liitetty mainittuun ainakin yhteen vyöhykkeeseen (214), jossa ei ole sähköä johtavaa materiaalia, joka mainittu ainakin yksi vyöhyke (214) käsittää ainakin kaksi sarjaa (215) oleellisesti yhdensuuntaisia ja yhtenäisiä polkuja (216) vyöhykkeiden sisällä, joissa ei ole sähköä johtavaa materiaalia, joita mainittuja yhtenäisiä polkuja (216) erottaa toisistaan ensimmäinen etäisyys (217), ja mainittujen yhtenäisten polkujen (216) yhtenäinen pituus on vähintään 20 kertaa mainittu ensimmäinen etäisyys (217), ja mainitut kytketyt mikroaaltoresonaattorit (400) on kytketty mainitussa sähköä johtavassa kerroksessa (150) olevien pintavirtojen (403) koherenttien lohkojen avulla, ja mainittu ensimmäinen etäisyys (217) on järjestetty pintavirtojen (403) mainittujen koherenttien lohkojen suunnassa, ja
- mainittu sähköä johtava kerros (150) on järjestetty alustamateriaalin (151) päälle, ja mainitulla ensimmäisellä fyysisellä alueella (280) on ensimmäinen ulottuvuus (305) ja toinen ulottuvuus (306), ja
- ensimmäinen fyysinen alue (280) käsittää ainakin yhden vyöhykkeen (214), jossa ei ole sähköä johtavaa materiaalia, jolloin ensimmäiseen vaikuttavaan alueeseen (281) on järjestetty ensimmäinen sarja (401) resonaattoreita, jotka muodostavat joukon ensimmäisiä resonoivia solmuja (405) siten, että mainitut ensimmäiset resonoivat solmut (405) käsittävät seisovan aallon solmun, ja mainittu ainakin yksi vyöhyke (214), jossa ei ole sähköä johtavaa materiaalia, käsittää lisäksi toisen sarjan (402) resonaattoreita, jotka muodostavat joukon toisia resonoivia solmuja (406) siten, että mainitut toiset resonoivat solmut (406) on järjestetty sivuun ensimmäisiin resonoiviin solmuihin (405) näiden ensimmäisen ulottuvuuden (305) suunnassa.

20195349 PRH 25 -10- 2022

2. Patenttivaatimuksen 1 mukainen sähköä johtava kerros (150), **tunnettu** siitä, että mainitut ensimmäiset (405) ja toiset (406) resonoivat solmut muodostuvat samasta yksikkökuvasta (180), ja toinen sarja (402) resonaattoreita on järjestetty eristämään toisten resonoivien solmujen (406) joukko ensimmäisten resonoivien solmujen (405) joukosta spatiaalisesti, taajuudellisestia tai polarisoidusti.

3. Patenttivaatimuksen 1 tai 2 mukainen sähköä johtava kerros (150), **tunnettu** siitä, että mainittu ensimmäinen vaikuttava alue (281) on alle 10 % pienempi kuin mainittu toinen vaikuttava alue (251).

4. Jonkin patenttivaatimuksen 1, 2 tai 3 mukainen sähköä johtava kerros (150), **tunnettu** siitä, että mainitulla ensimmäisellä fyysisellä alueella (280) on ensimmäinen ulottuvuus (305) ja toinen ulottuvuus (306), ja että mainittu mikroaaltomuunnin (260) on järjestetty laajentamaan peittoaluetta, jossa bistaattinen tutkakaikupinta (RCS) on alle 3 dB pienempi kuin uudelleenlähetetyn säteen (603) huippu-RCS siten, että mainittu peittoalue laajenee kertoimella, joka on vähintään kaksi, verrattuna yhtä suuren fyysisen alueen 3 dB RCS-peittoalaan, joka on yhtä suuri kuin mainitun sähköä johtavan kerroksen (250) fyysinen alue mutta jossa ei ole mainittua sähköä johtavaa kerrosta (250), siten että mainittu peittoalueen laajennus saadaan aikaan järjestelyllä, jossa ensimmäisen ulottuvuuden (305) ja toisen ulottuvuuden (306) suhde on pienempi kuin kaksi kertaa skaalauskerroin.

5. Jonkin patenttivaatimuksen 1–4 mukainen sähköä johtava kerros (150), **tunnettu** siitä, että mainittu sähköä johtava kerros (150) on järjestetty alustamateriaalin (151) päälle, ja mainitulla ensimmäisellä fyysisellä alueella (280) on ensimmäinen ulottuvuus (305) ja toinen ulottuvuus (306), jolloin mainittu ensimmäinen vaikuttava alue (281) on järjestetty ainakin kaksi kertaa niin suureksi kuin alustamateriaalin (151)ekvivalentti pinta-ala, josta ekvivalentista pinta-alasta puuttuu sähköä johtava kerros (150) ja jonka ekvivalentin pinta-alan sekä leveys että korkeus ovat yhtä suuret kuin ensimmäinen ulottuvuus (305).

6. Jonkin patenttivaatimuksen 1–5 mukainen sähköä johtava kerros (150), **tunnettu** siitä, että mainittuun ainakin yhteen vyöhykkeeseen (214), jossa ei

20195349 PRH 25 -10- 2022

ole sähköä johtavaa materiaalia, on järjestetty kolmas resonoiva solmu (407), joka kolmas resonoiva solmu (407) on järjestetty sivuun joko ensimmäisestä resonoivasta solmusta (405) tai toisesta resonoivasta solmusta (406) ensimmäisen ulottuvuuden (305) suunnassa, ja jotka ensimmäinen (405), toinen (406) ja kolmas (407) resonoiva solmu koostuvat samasta yksikkökuvasta (180).

7. Jonkin patenttivaatimuksen 1–6 mukainen sähköä johtava kerros (150), **tunnettu** siitä, että mainittu ainakin yksi vyöhyke (214), jossa ei ole sähköä johtavaa materiaalia, käsittää yhtenäisiä polkuja (216) vyöhykkeillä, joissa ei ole sähköä johtavaa materiaalia, toistuvana jaksona (212) siten, että mainittuja yhtenäisiä polkuja (216) erottaa toisistaan ainakin ensimmäinen etäisyys (217), ja mainittujen yhtenäisten polkujen (216) yhtenäinen pituus on vähintään 20 kertaa mainittu ensimmäinen etäisyys (217), ja leveys (219) on vähintään 10 kertaa pienempi kuin mainittu ensimmäinen etäisyys (217), ja mainitut yhtenäiset polut (216) on järjestetty muodostamaan ainakin ensimmäinen jono yhdensuuntaisia, mainitulla ensimmäisellä taajuusalueella säteileviä sähkökenttälähteitä mainitun mikroaaltosignaalin voimakkuuden skaalaamiseksi mainitulla skaalauskertoimella.

8. Patenttivaatimuksen 6 tai 7 mukainen sähköä johtava kerros (150), **tunnettu** siitä, että mainitut yhtenäiset polut (216) käsittävät vyöhykkeitä, jotka ovat peilisymmetrisiä symmetria-akselin symmetriavertailukohtaan nähden, tai vyöhykkeitä, jotka ovat pyörähdyssymmetrisiä pyörähdyspisteen symmetriavertailukohtaan nähden, jolloin symmetriavertailukohta on järjestetty erottamaan mainittujen yhtenäisten polkujen (216) symmetriset vyöhykkeet toisistaan etäisyydellä, joka on pienempi kuin puolet aallonpituudesta ensimmäisellä taajuudella.

9. Jonkin patenttivaatimuksen 6–8 mukainen sähköä johtava kerros (150), **tunnettu** siitä, että mainittu sähköä johtava kerros (150) on järjestetty jonkin patenttivaatimuksen 1–8 mukaiseksi primaariksi sähköä johtavaksi kerrokseksi (150') sekundaarisen sähköä johtavan kerroksen (150'') viereen, jolloin primaarin sähköä johtavan kerroksen (150') toistosekvenssi (212) on pienempi kuin primaarin sähköä johtavan kerroksen (150') ja sekundaarisen sähköä johtavan kerroksen (150'') välinen ero (101).

20195349 PRH 25 -10- 2022

10. Jonkin patenttivaatimuksen 6–8 mukainen sähköä johtava kerros (150), **tunnettu** siitä, että mainittu sähköä johtava kerros (150) on järjestetty jonkin patenttivaatimuksen 1–8 mukaiseksi primaariksi sähköä johtavaksi kerrokseksi (150') sekundaarisen sähköä johtavan kerroksen (150'') viereen, jolloin primaarin sähköä johtavan kerroksen (150') ensimmäinen etäisyys (217) on pienempi kuin primaarin sähköä johtavan kerroksen (150') ja sekundaarisen sähköä johtavan kerroksen (150'') välinen ero (101).

11. Jonkin patenttivaatimuksen 1–10 mukainen sähköä johtava kerros, **tunnettu** siitä, että mainittu sähköä johtava kerros on osa seinää, ovea, ikkunaa, asuntokonttia, junaa, laivaa, kulkuneuvoa, hissikuilua, kuljetuskonttia, sähkökaappia tai turvalokeroa.

12. Jonkin patenttivaatimuksen 1–11 mukainen sähköä johtava kerros, **tunnettu** siitä, että mainitun ensimmäisen vaikuttavan alueen (281) ja mainitun ensimmäisen fyysisen alueen (280) välinen suhde on vähintään 0,5.

20195349 PRH 25 -10- 2022

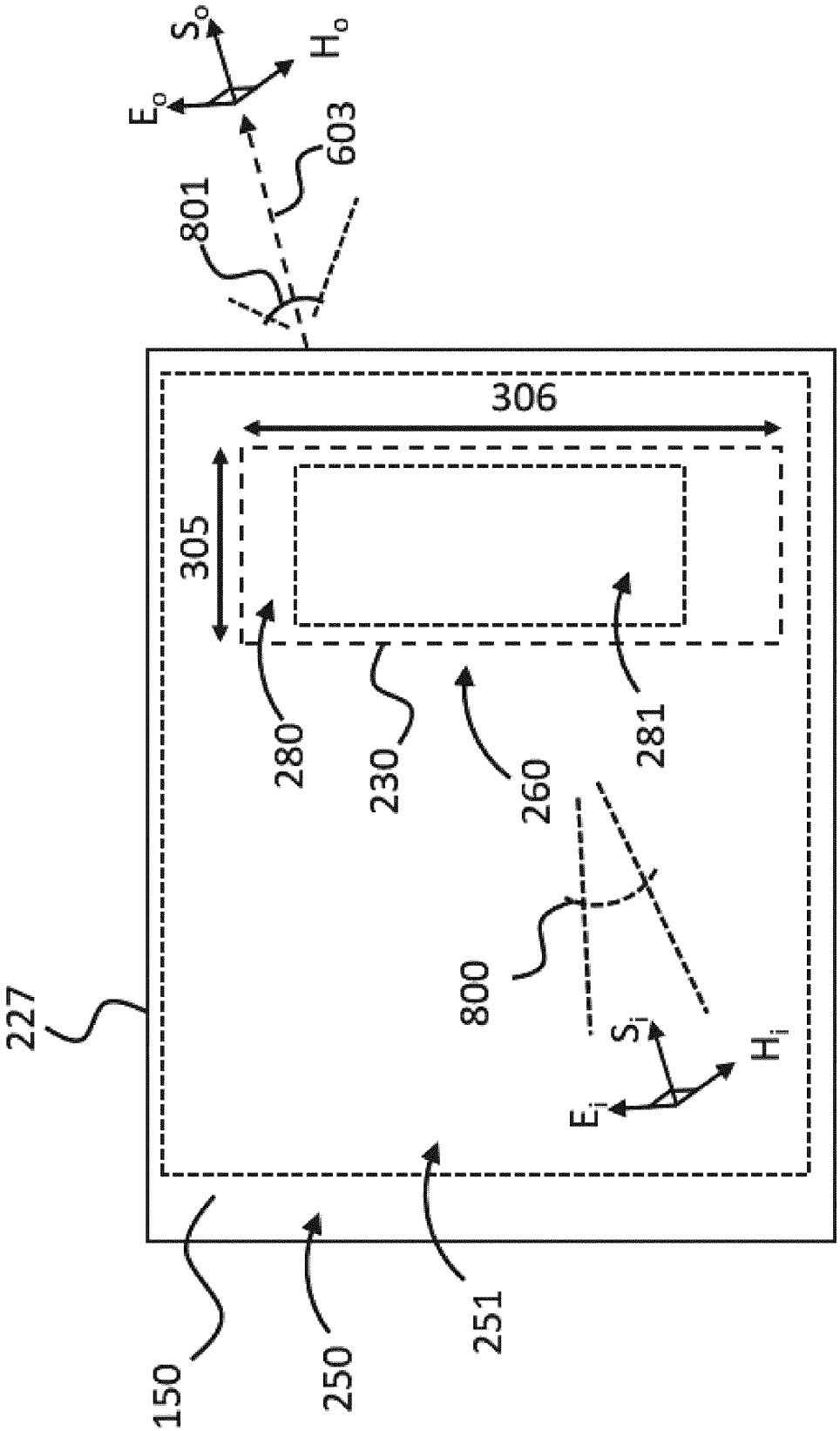

$S_o$
$H_o$
$E_o$
603
801
306
305
280
230
260
281
227
800
$S_i$
$H_i$
$E_i$
150
250
251

Fig. 1

20195349 PRH 29 -04- 2019



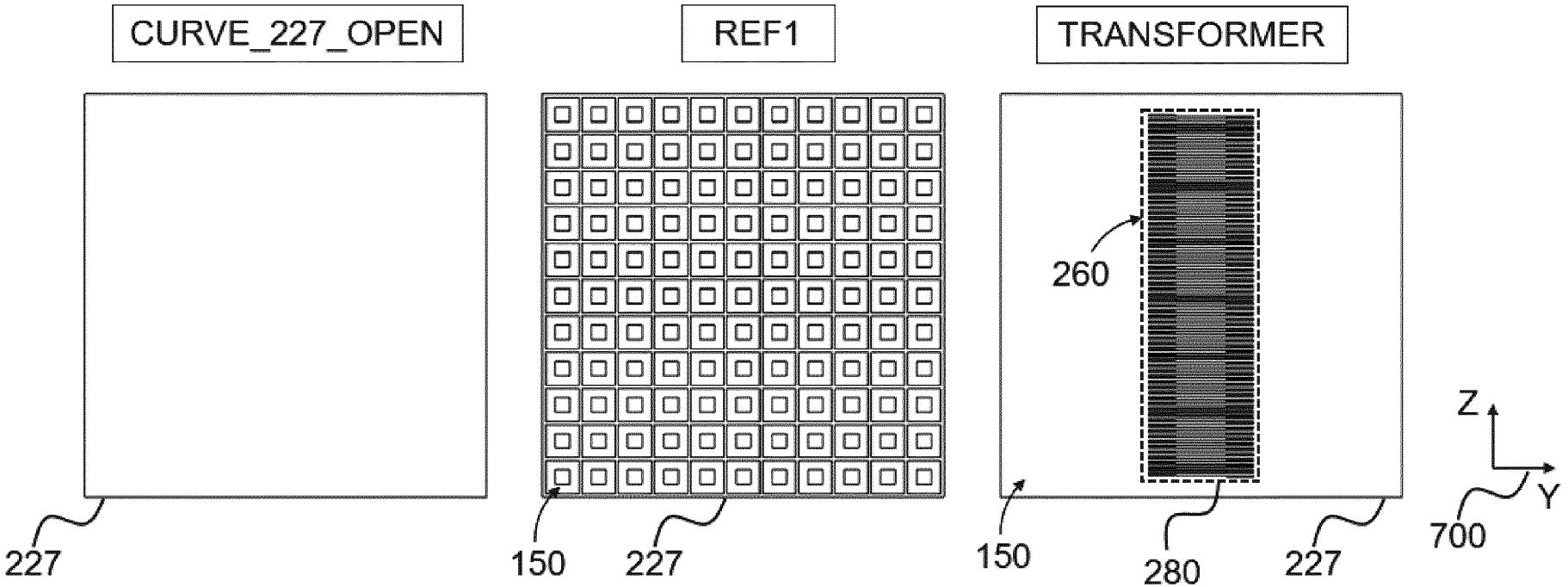
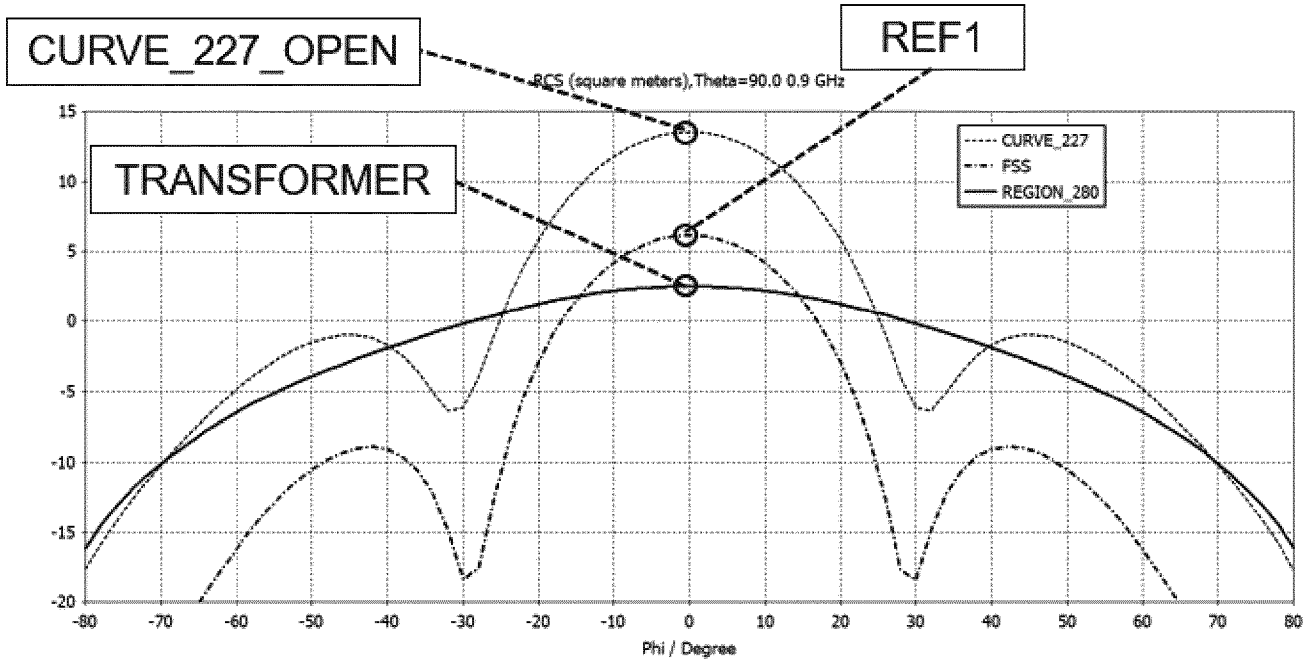



Fig. 2a




| $E_i$ = 1 V/m | RCS max (dBsm) | TRP (dBm) | RCS beamwidth (3 dB) |
|---|---|---|---|
| CURVE_227_OPEN | 13.54 | -32.29 | 25.9° |
| REF1 | 6.14 | -40.15 | 24.6° |
| TRANSFORMER | 2.52 | -38.38 | 64.2° |

Fig. 2b

20195349 PRH 29 -04- 2019

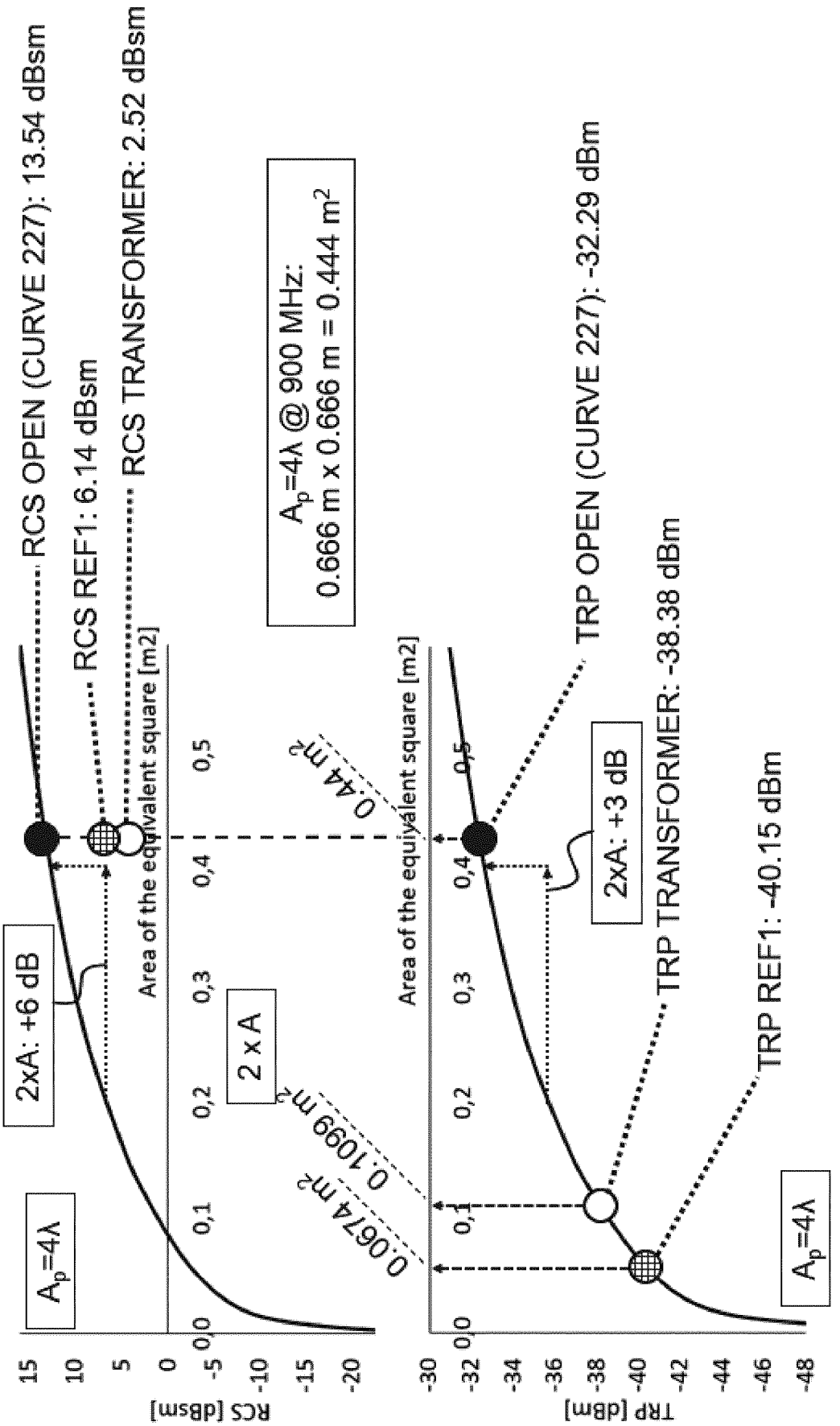

RCS OPEN (CURVE 227): 13.54 dBsm
RCS REF1: 6.14 dBsm
RCS TRANSFORMER: 2.52 dBsm
2xA: +6 dB
$A_p$=4λ
2 x A
0.0674 m²
0.1099 m²
0.444 m²
Area of the equivalent square [m2]
RCS [dBsm]
$A_p$=4λ @ 900 MHz:
0.666 m x 0.666 m = 0.444 m²
TRP OPEN (CURVE 227): -32.29 dBm
TRP TRANSFORMER: -38.38 dBm
TRP REF1: -40.15 dBm
2xA: +3 dB
TRP [dBm]
—900 MHz

Fig. 2c

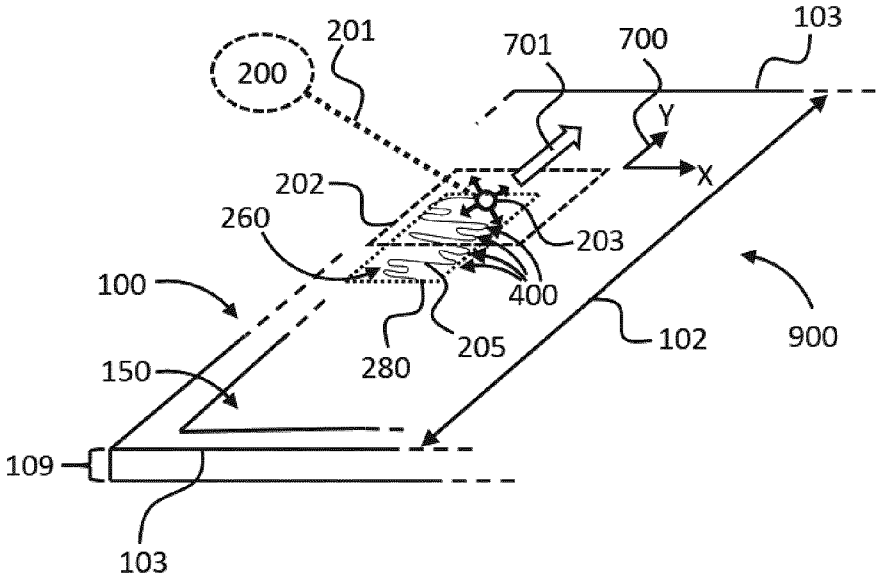



Fig. 3a

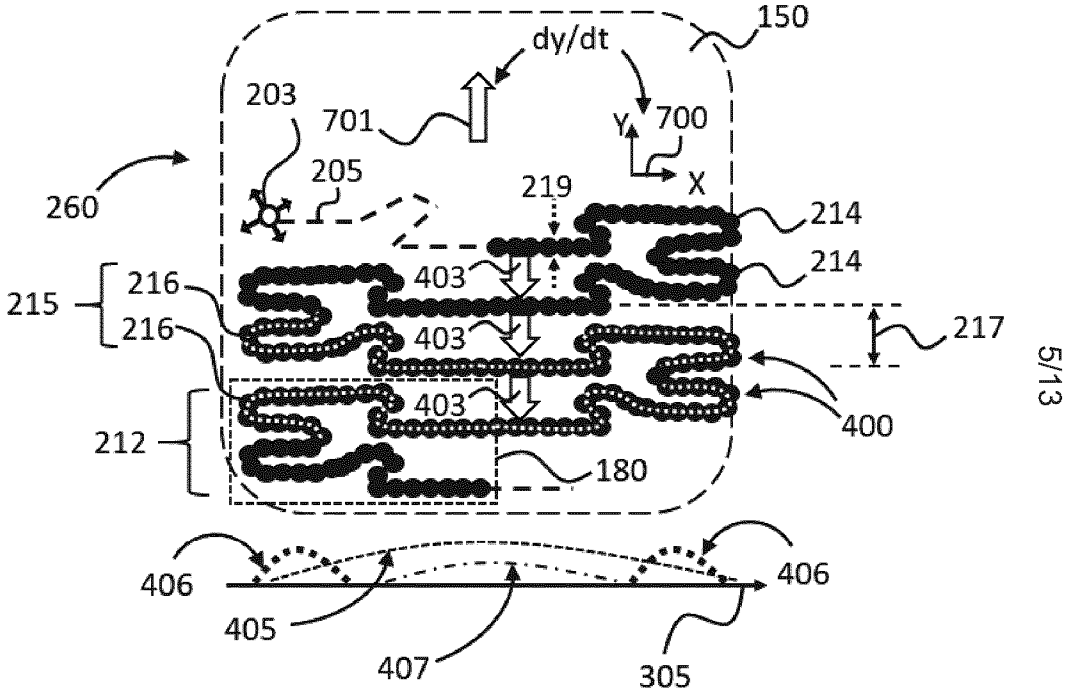



Fig. 3b

20195349 PRH 29 -04- 2019

20195349 PRH 29 -04- 2019

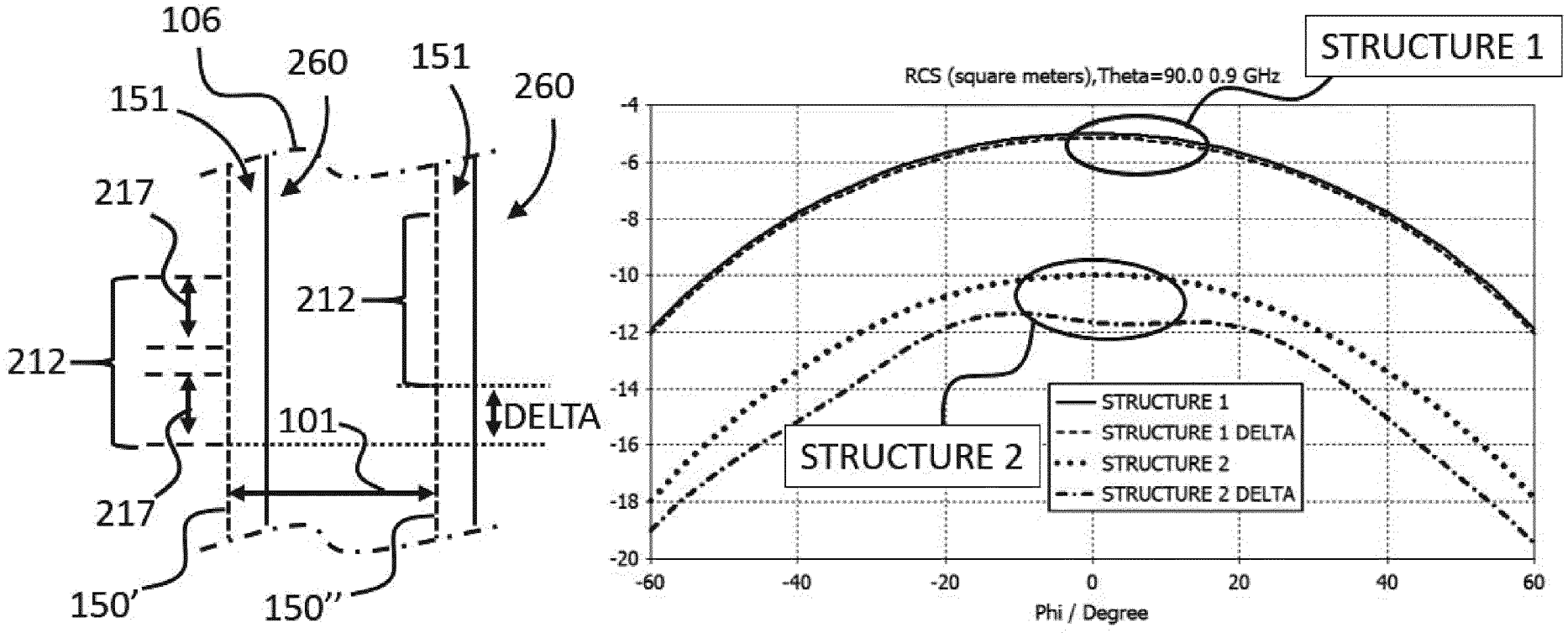



Fig. 4

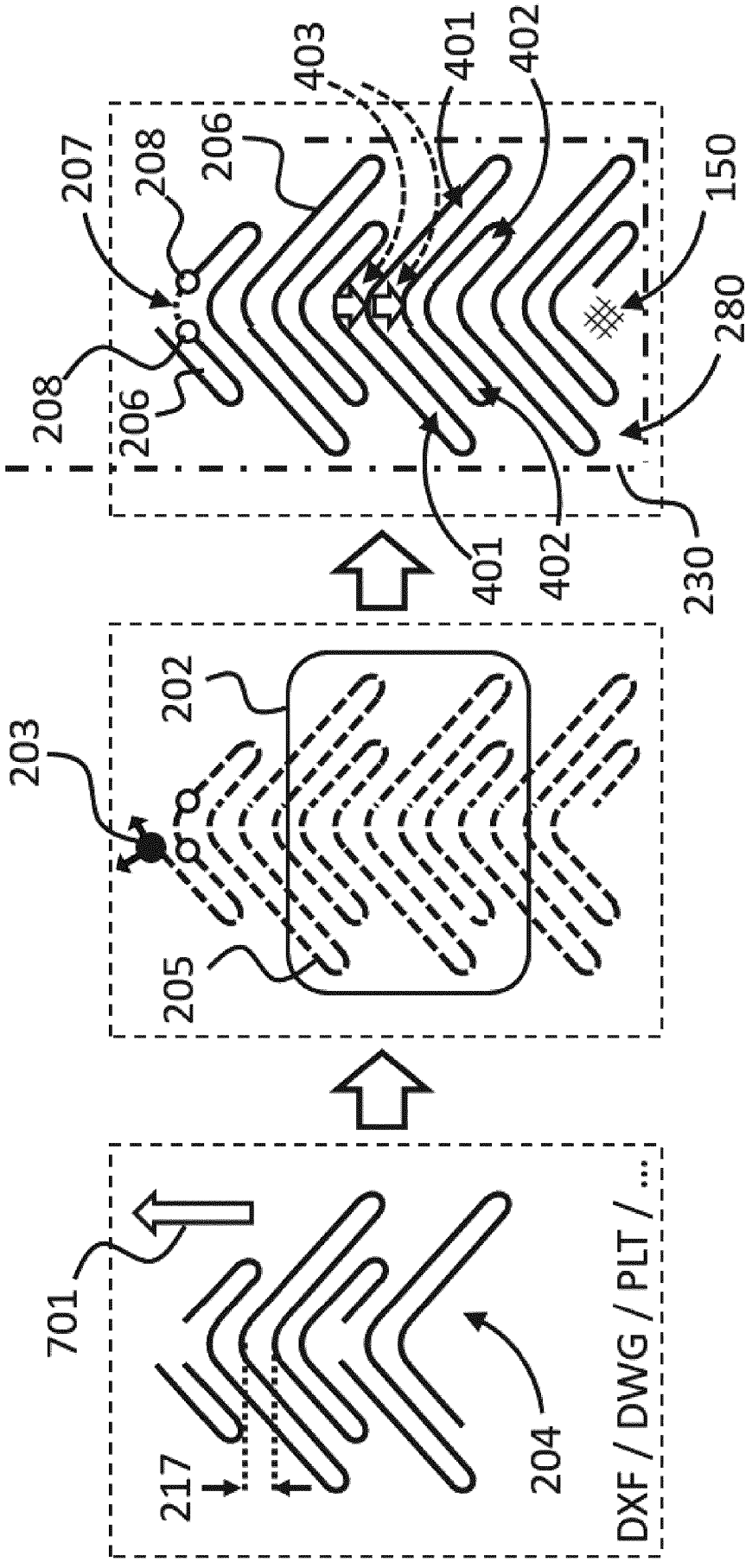

701
DXF / DWG / PLT / ...
217
204
203
202
205
403
401
402
207
208
206
208
206
150
280
401
402
230

Fig. 5

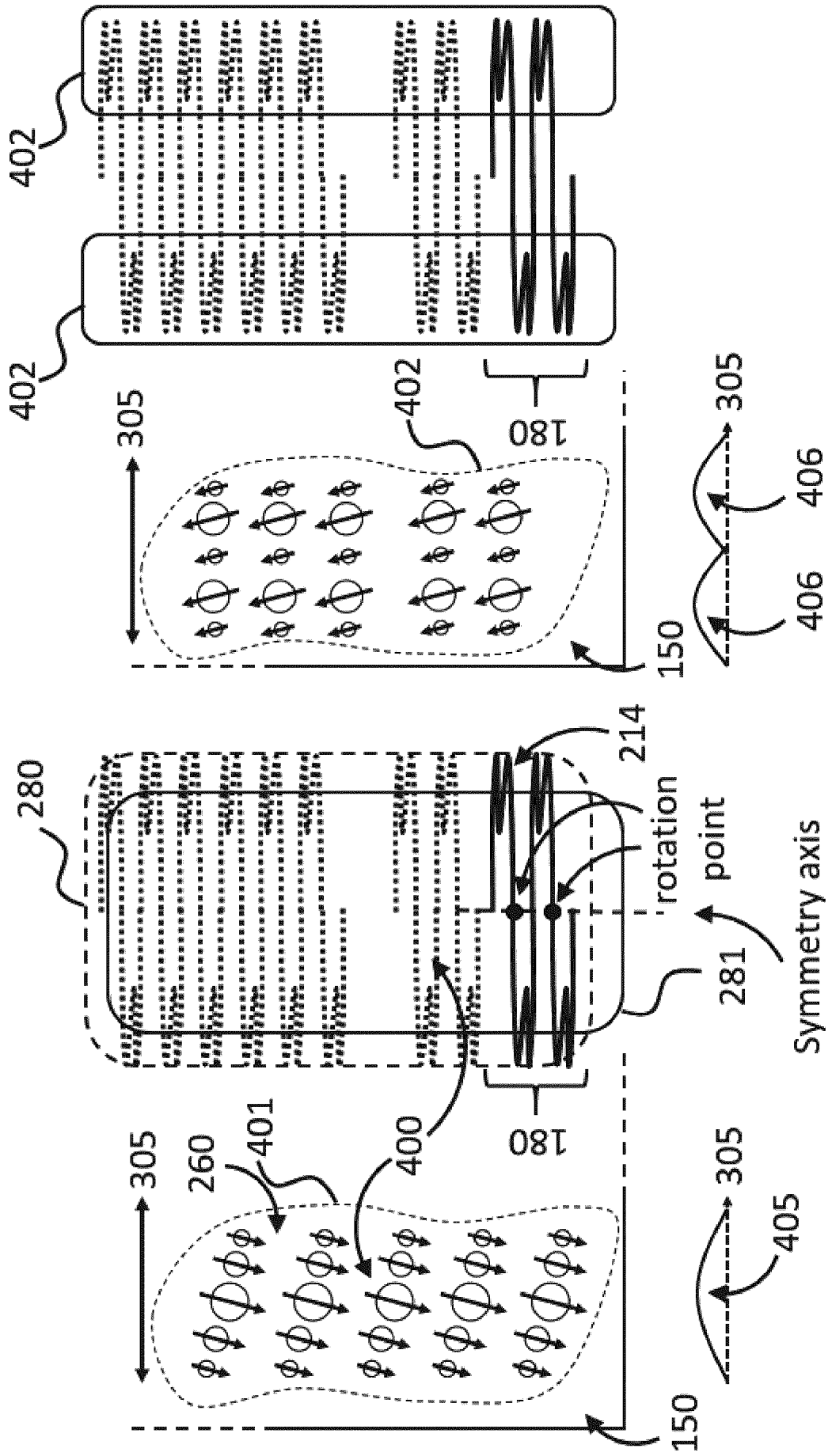

402
402
305
402
180
150
305
406
406
280
214
rotation point
281
Symmetry axis
305
260
401
400
180
305
405
150

Fig. 6b

Fig. 6a

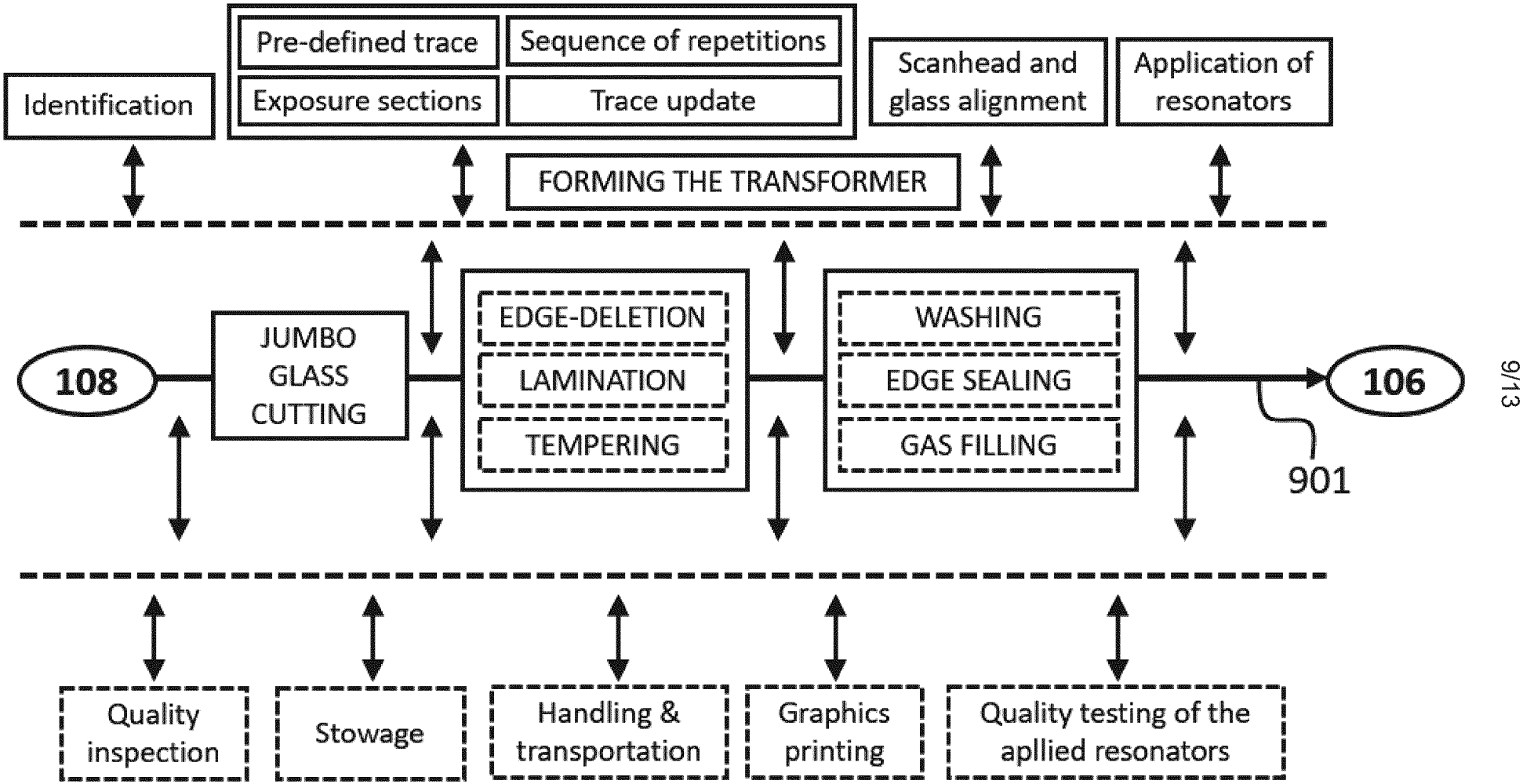



Fig. 7

20195349 PRH 29 -04- 2019

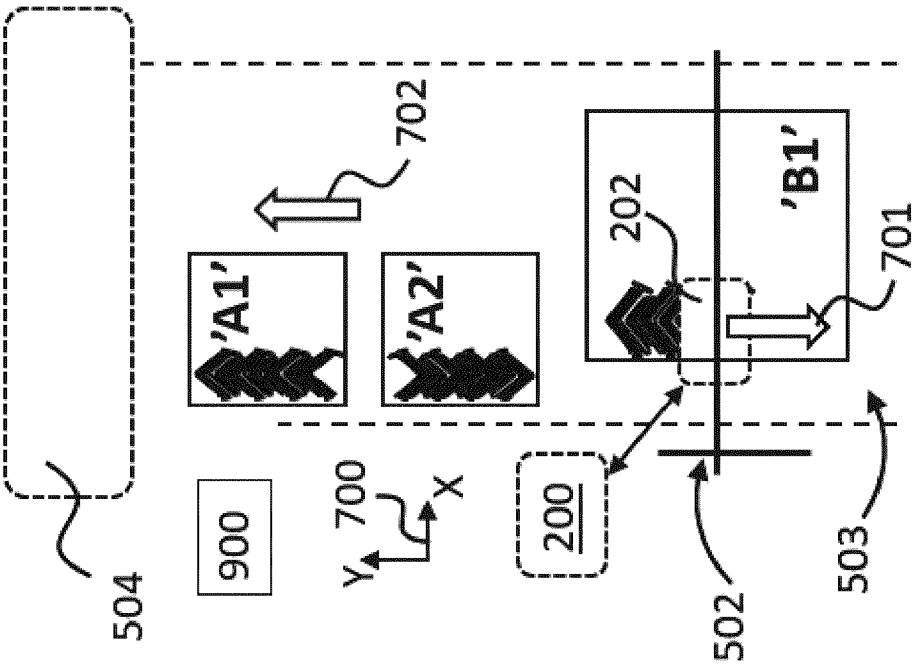

504
900
700
Y
X
200
502
503
'A1'
'A2'
702
202
'B1'
701

Fig. 8b

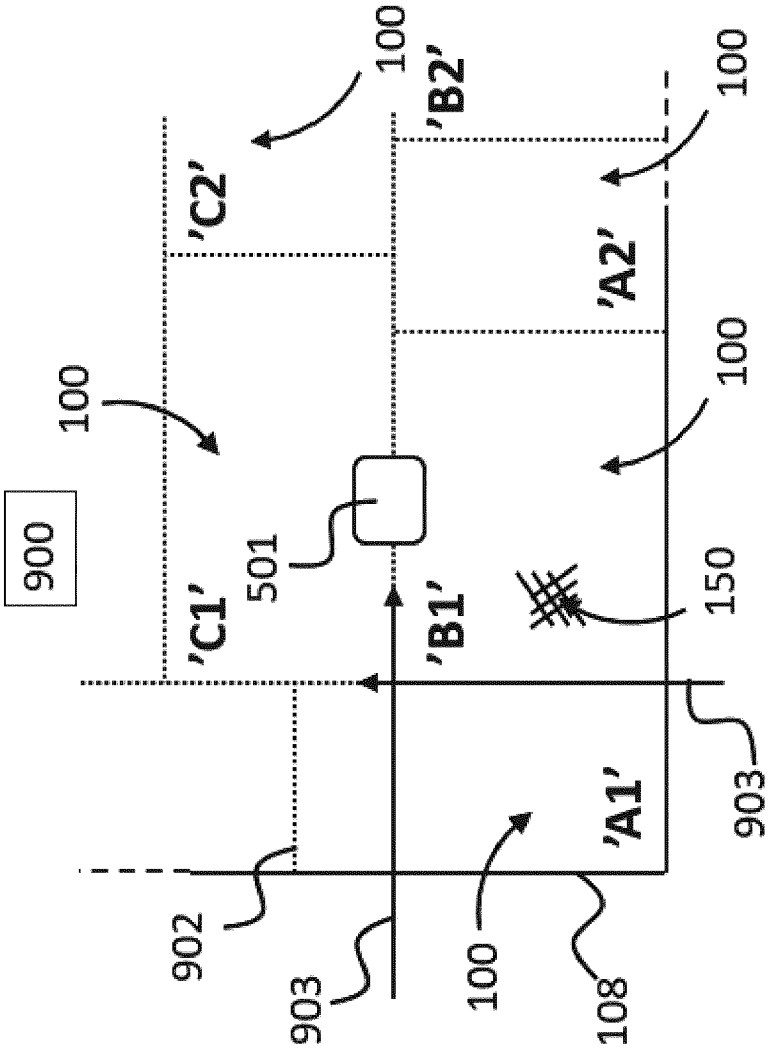

900
100
'C1'
'C2'
100
'B2'
501
'B1'
'A2'
100
100
150
'A1'
903
902
903
100
108

Fig. 8a

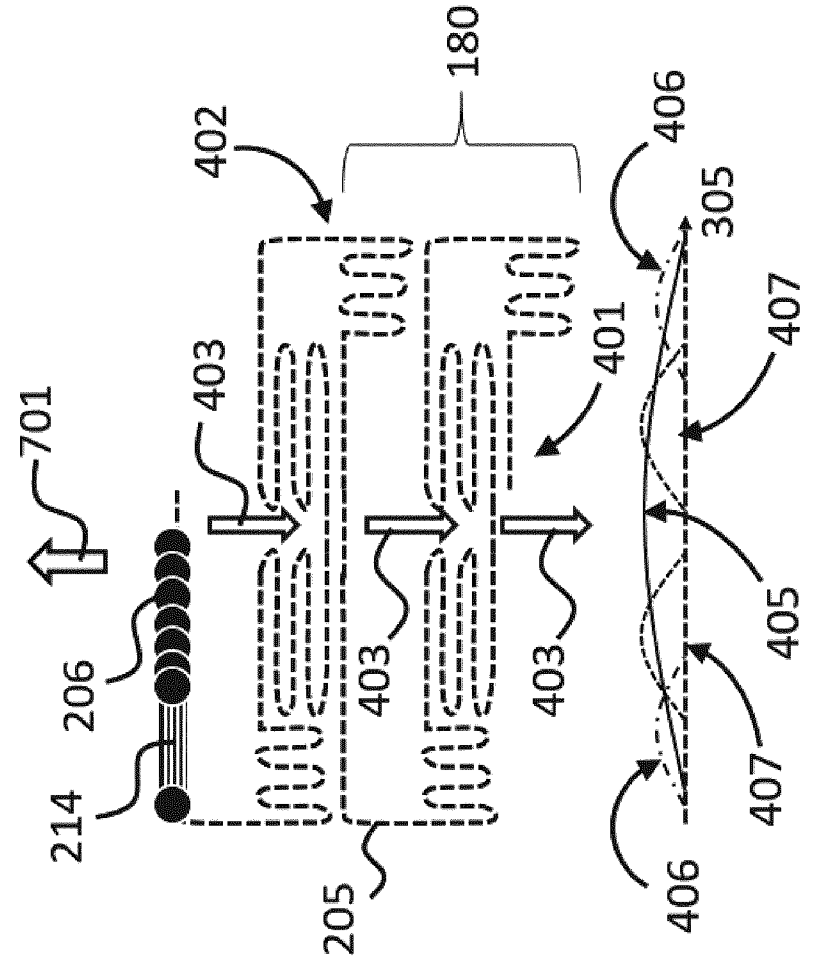

701
206
214
403
402
180
205
401
406
305
407
405

Fig. 9b

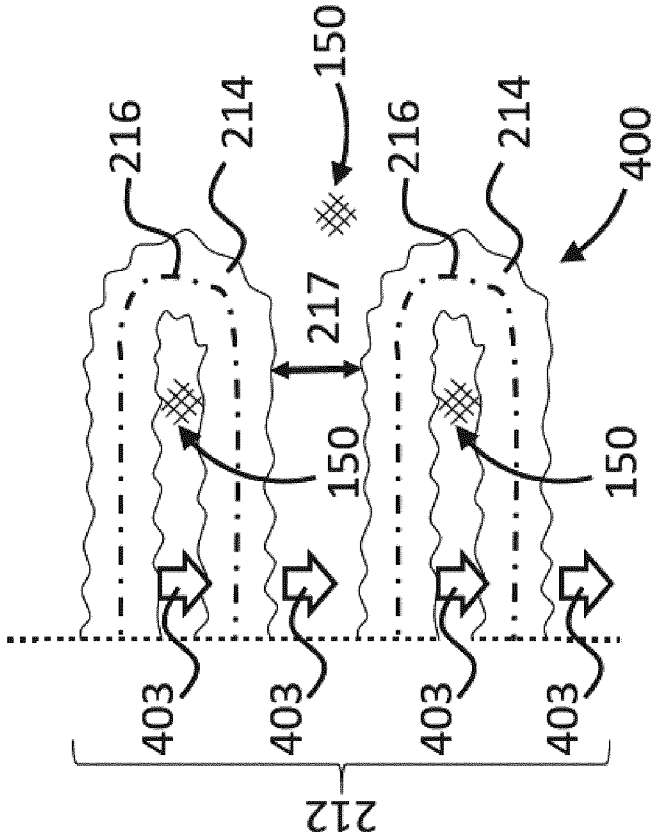

216
214
150
217
400
403
212

Fig. 9a

20195349 PRH 29 -04- 2019

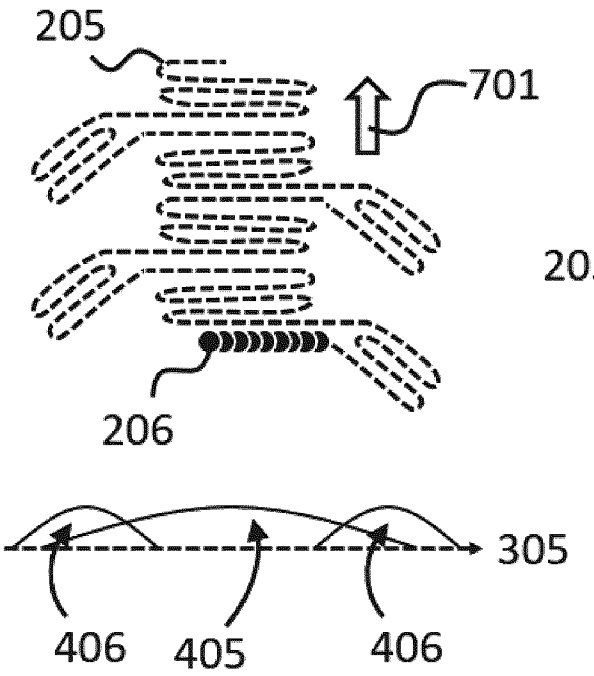



Fig. 9c

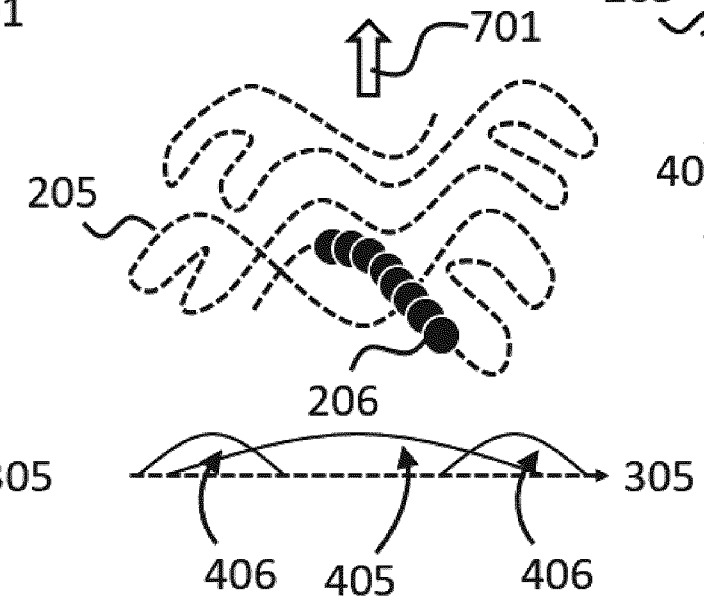



Fig. 9d

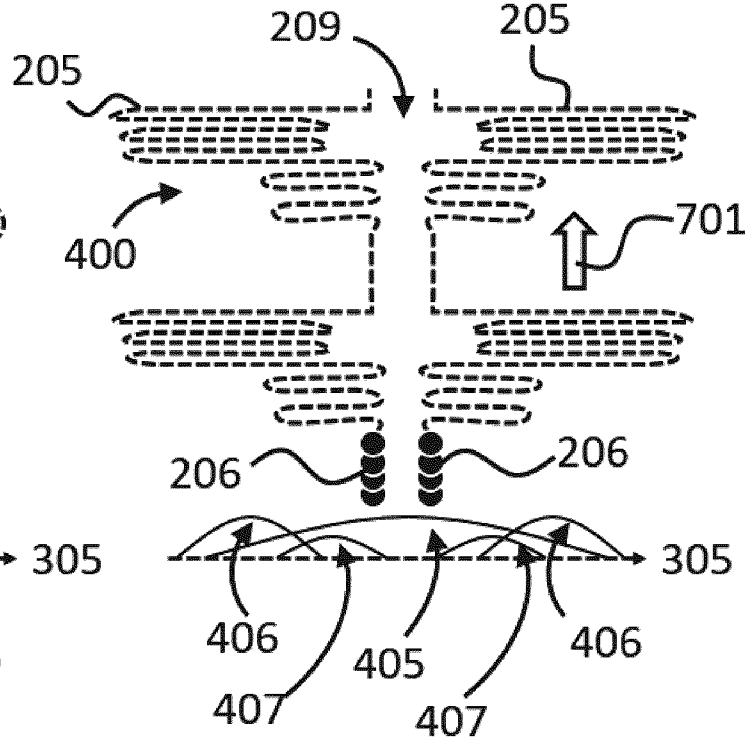



Fig. 9e

20195349 PRH 29 -04- 2019

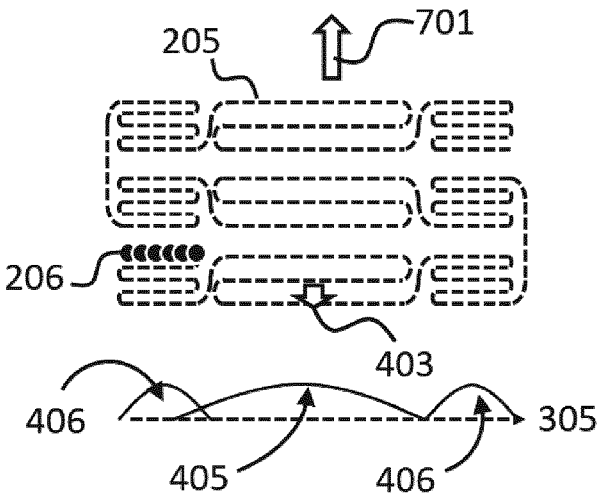



Fig. 9f

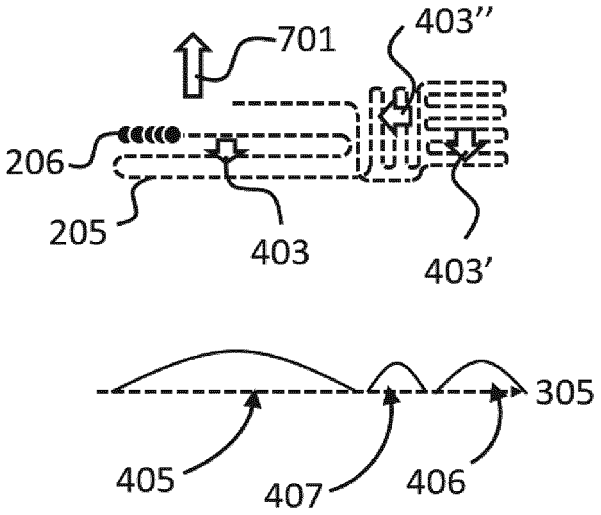



Fig. 9g

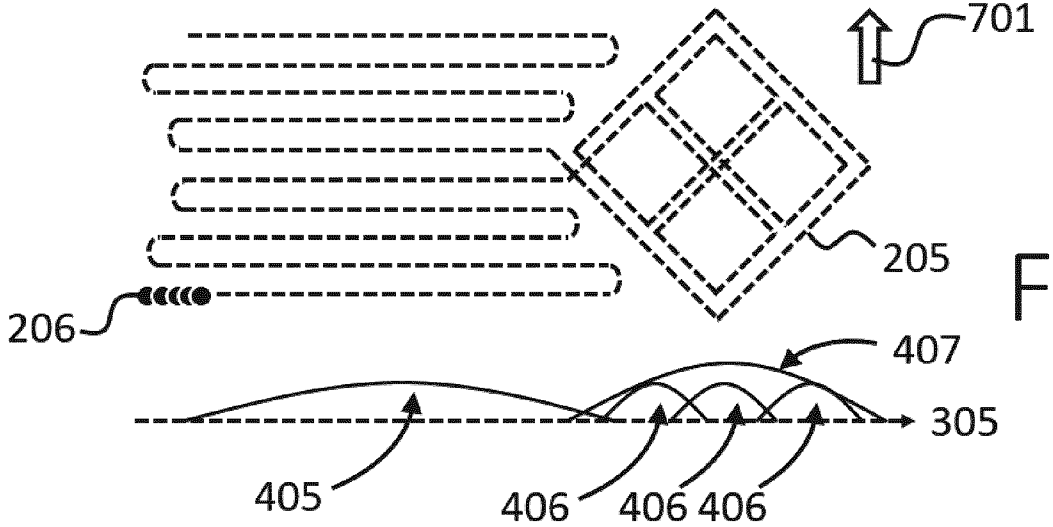



Fig. 9h