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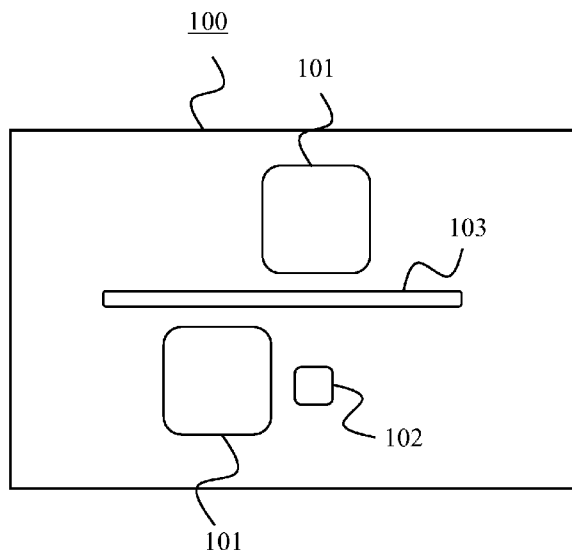


FIG. 1

(57) Abstract: The present invention relates to an antenna for mobile communications, in particular to a dual-band or multi-band antenna. The antenna is configured to radiate in multiple frequency bands. To this end, the antenna comprises two or more first radiating elements configured to radiate in a first frequency band, and one or more second radiating elements configured to radiate in a second frequency band. In order to improve antenna performance, the antenna further comprises a Frequency Selective Device (FSD) arranged between a first and a second subset of the first radiating elements, and configured to at least partially block radiation in the first frequency band and to pass radiation in the second frequency band.



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MULTI-BAND ANTENNA WITH A FREQUENCY SELECTIVE DEVICE FOR IMPROVED ISOLATION OF RADIATING ELEMENTS

5

TECHNICAL FIELD

The present invention relates to an antenna for mobile communications, in particular to a dual-band or a multi-band antenna. The antenna may be configured to radiate in a plurality of frequency bands. Use of a Frequency Selective Device (FSD) gives the antenna an improved
10 isolation between radiating elements associated with at least one of the frequency bands.

BACKGROUND

Ultra-broadband base station antenna systems (featuring a relative bandwidth greater than 30%)
15 typically operate in the 690-960 MHz “Low Band” (LB), in the 1.427-2.4 GHz “Middle Band” (MB), in the 1.7-2.7 GHz “High Band” (HB), and in the 3.3-3.7 GHz C-Band (CB) spectrum. These spectra include most cellular network frequency bands that are used today. With the growing demand for a deeper integration of antennas with radio transceivers, e.g. Active Antenna Systems (AAS), ultra-compact, ultra-broadband multiple-array base station antennas
20 need to be designed without compromising antenna Key Performance Indicators (KPIs).

Such antennas may comprise multiple arrays of radiating elements, e.g. LB, MB, HB and CB arrays. Reducing the overall geometrical antenna dimensions while maintaining the Radio Frequency (RF) KPIs can be challenging. One challenge lies in minimizing electromagnetic
25 coupling (i.e. in optimizing electromagnetic isolation) between radiating elements (e.g. radiating elements pertaining to a certain frequency band) as the size of the platform decreases. Ideally, those radiating elements should be electrically invisible to each other. Especially in massive Multiple Input Multiple Output (mMIMO) modules, where radiating elements for the LB and for the CB are located closely together, there is – without any isolation – a high degree
30 of undesired parasitic coupling between radiating elements. The parasitic coupling can give rise to unwanted resonances.

One design makes use of metal walls to isolate radiating elements of the LB and the HB in a multi-band, dual polarized base station antenna. A drawback of this technique is that it can give rise to unwanted resonances and degrade the overall performance of the antenna.

5 In another design, split ring resonator (SRR) structures are provided between two planar MIMO antennas, in order to improve an isolation between the two antennas. The SRR structure is planar, cavity backed, and improves the isolation between the MIMO antennas at one specific frequency by trapping surface-waves on the ground. However, this requires a significant modification in the ground printed circuit board (PCB).

10

In yet another design, metamaterial-mushroom structured SRRs are arranged to improve the isolation between planar dipoles. The SRR rings are planar and cavity-backed. The idea is to trap surface-waves having a certain frequency, and shunt all the currents to the ground PCB by means of a shunt-via inductance. The mushroom type structure involves a significant
15 modification in the ground PCB.

15

In addition, a variety of frequency selective surfaces (FSSs) have been described in literature. These FSSs and FSS devices can be used for applications such as microwave ovens, military applications and antenna reflectors. These FFS structures are typically planar, cavity backed
20 and rather narrow-band. The FFSs are not suitable for use in base station antennas.

20

SUMMARY

Embodiments of the invention provide antennas, in particular dual-band or multi-band antennas, having an improved performance. In particular, the isolation between radiating
25 elements related to at least one frequency band should be significantly enhanced, without impacting the performance of radiating elements related to other frequency bands, and without impacting the overall desired KPIs of the antenna. For instance, in an antenna with radiating elements for the LB, and with one or more radiating elements for the HB and/or CB, an isolation between at least the LB radiating elements should be improved, without impacting the
30 performance of the HB and/or CB radiating elements.

30

Further, besides being suitable to work in multi-band, the isolation scheme used in the antenna should also be relatively broadband, in order to cover the necessary bands. The antenna should also have a geometry that is compact, robust, and can be accommodated easily within the

antenna platform. Finally, the antenna should not require an altered design or placement of the radiating elements related to the different frequency bands, i.e. when compared to antenna designs without any isolation.

- 5 The objective is achieved by the embodiments of the invention as described in the enclosed independent claims. Advantageous implementations of the embodiments of the invention are further defined in the dependent claims.

10 In particular, embodiments of the invention employ a frequency-selective device (FSD) between radiating elements, which FSD ideally behaves like a metal-wall for a first frequency band, while being transparent for a second frequency band.

15 A first aspect of the invention provides an antenna, comprising: two or more first radiating elements configured to radiate in a first frequency band, one or more second radiating elements configured to radiate in a second frequency band, and an FSD arranged between a first subset and a second subset of the two or more first radiating elements and configured to at least partially block radiation in the first frequency band and to pass radiation in the second frequency band.

20 Thus, the FSD is configured to isolate the first radiating elements from another, without impacting the one or more second radiating elements, or an array of second radiating elements arranged in the vicinity of the first radiating elements. The performance of the antenna is thus improved. Further, the antenna may be compact and robust, and can be accommodated easily within existing antenna platforms. The antenna does also not require any altered design or
25 different placement of the radiating elements compared to an antenna without isolation. Each of the first subset and the second subset may comprise one or more first radiating elements.

In an implementation form of the first aspect, the FSD is opaque for radiation in the first frequency band.

30

Thus, the performance of the antenna is improved in an optimized manner, since the isolation between the first radiating elements is optimized.

In an implementation form of the first aspect, the FSD is transparent for radiation in the second frequency band.

5 Thus, the second frequency band is not affected at all, and the antenna KPIs can be optimally fulfilled.

10 In an implementation form of the first aspect, the FSD comprises a metallic structure. The FSD may be implemented without incorporating any cavity-backing material i.e. without substrate material. Production costs can thus be reduced without compromising the performance.

Thus, the FSD provides a simple and compact structure to achieve the desired isolation between the radiating elements.

15 In an implementation form of the first aspect, the FSD is configured to be polarization-independent.

Thus, the FSD is suitable for a dual-polarized antenna and/or dual-polarized radiating elements.

20 In an implementation form of the first aspect, the FSD comprises a SRR, structure, in particular a rectangular SRR structure.

This structure provides a simple but effective implementation of the FSD.

25 In an implementation form of the first aspect, the FSD comprises a Hilbert-curve structure and/or a spiraled-triangle structure.

These structures provides simple but effective alternative implementations of the FSD.

30 In an implementation form of the first aspect, the FSD comprises an arrangement of a plurality of FSD unit cells.

The FSD is thus well scalable and easily adjustable. In particular, each FSD unit cell can comprise a SRR structure.

In an implementation form of the first aspect, the FSD is arranged at a determined height above an antenna board that carries the first and the second radiating elements.

5 This achieves a high degree of isolation between the radiating elements, and thus improves the performance of the antenna.

In an implementation form of the first aspect, the first radiating elements each comprise a radiating plane arranged at a determined height above an antenna board that carries the first and the second radiating elements, and the FSD is arranged at the same height as the radiating planes.

10

This achieves a high degree of isolation between the radiating elements, and thus improves the performance of the antenna.

15 In an implementation form of the first aspect, the FSD is planar and arranged perpendicular to the radiating planes, and/or the FSD comprises a frequency-selective surface arranged perpendicular to the radiating planes.

This achieves a high degree of isolation between the radiating elements, and thus improves the performance of the antenna.

20

In an implementation form of the first aspect, the FSD is not grounded and/or not electrically connected to any other part of the antenna.

25 In an implementation form of the first aspect, the two or more first radiating elements are LB radiating elements, and/or the one or more second radiating elements are HB or CB radiating elements.

In an implementation form of the first aspect, at least one of the one or more second radiating elements is arranged in a vicinity of and/or is co-located with one of the first radiating elements.

30

In an implementation form of the first aspect, the first subset of first radiating elements is arranged in a first column, and the second subset of first radiating elements is arranged in a second column parallel to the first column, and the FSD is arranged between the first column

and the second column,. In one implementation form, the FSD extends along and between the first and the second columns.

A second aspect of the invention provides a base station comprising an antenna according to the first aspect or any one of its implementation forms, and a radio transmitter connected to the antenna.

The base station of the second aspect thus enjoys all advantages and effects of the antenna of the first aspect.

It has to be noted that all devices, elements, units and means described in the present application could be implemented in the software or hardware elements or any kind of combination thereof. All steps which are performed by the various entities described in the present application as well as the functionalities described to be performed by the various entities are intended to mean that the respective entity is adapted to or configured to perform the respective steps and functionalities. Even if, in the following description of specific embodiments, a specific functionality or step to be performed by external entities is not reflected in the description of a specific detailed element of that entity which performs that specific step or functionality, it should be clear for a skilled person that these methods and functionalities can be implemented in respective software or hardware elements, or any kind of combination thereof.

BRIEF DESCRIPTION OF DRAWINGS

The above described aspects and implementation forms of the present invention will be explained in the following description of specific embodiments in relation to the enclosed drawings, in which

FIG. 1 shows an example of an antenna according to an embodiment of the invention.

FIG. 2 shows an example of a FSD unit-cell for a FSD of an antenna according to an embodiment of the invention.

FIG. 3 shows an example of a FSD for an antenna according to an embodiment of the invention.

FIG. 4 shows various FSD unit-cells for a FSD of antenna according to an embodiment of the invention.

FIG. 5 shows an example of simulated transmission and reflection coefficients of a FSD unit-cell for a FSD of an antenna according to an embodiment of the invention.

FIG. 6 shows simulation results related to an example of a FSD unit-cell, in particular, (a) resonance at 750 MHz (stop-band) and (b) resonance at 3.5 GHz (pass-band).

FIG. 7 shows an example of an antenna according to an embodiment of the invention.

FIG. 8 shows an example of an antenna according to an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 shows an antenna 100 according to an embodiment of the invention. The antenna 100 may be a dual-band antenna or a multi-band antenna. The antenna 100 may be a base station antenna or included in a BTS. The antenna 100 may be a dual-polarized antenna.

The antenna 100 includes two or more first radiating elements 101, which are configured to radiate in a first frequency band, e.g. in the LB. The first radiating elements 101 may be arranged in one or more columns, and may form one or more LB arrays. Further, the antenna 100 includes one or more second radiating elements 102, which are configured to radiate in a second frequency band, e.g. in the HB or CB. The antenna 100 may include multiple second radiating elements 102, e.g. forming an array, e.g. a HB array or CB array.

The antenna 100 includes further an FSD 103 arranged between the first radiating elements 101. In one implementation form, the FSD 103 is a single structure. In another implementation form, the FSD 103 comprises multiple pieces arranged near each other. The FSD 103 is configured to at least partially block radiation in the first frequency band, i.e. radiation generated by the first radiating elements 101, and to pass (at least some) radiation in the second frequency band, i.e. radiation generated by the one or more second radiating elements 102.

The presence of the FSD 103 can significantly improve the performance of the antenna 100 shown in FIG. 1, compared to a hypothetical simpler antenna (not shown) in which the FSD

103 is omitted. The two or more first radiating elements 101 may comprise two or more dual-polarized radiating elements 101 working in the first frequency band. The one or more second radiating elements 102 may comprise two or more further dual-polarized radiating elements 102 working in the second frequency band. The two or more second radiating elements 102
5 may be located in the vicinity of, may be quasi co-located with, or may be co-located with at least some of the first radiating elements 101. The FSD 103 improves the isolation between the first radiating elements 101 operating in the first frequency band, and improves the radiation-performance of the second radiating element(s) 102 operating in the second frequency band.

10 The FSD 103 may be a rectangular, metallic SRR structure with a frequency stop-band of/in the first frequency band and a frequency pass-band of/in the second frequency band. Thus, it works like a frequency selective surface (FSS). The FSD 103 may be a metallic structure without any cavity backing material. The FSD 103 may be polarization-independent, hence it may behave effectively the same for both polarizations of a dual-polarized antenna 100. The
15 FSD 103 may be neither grounded nor electrically connected to any other part of the antenna 100. The FSD 103 may be configured to capture electromagnetic (EM) waves in the nearfield, and not on the surface of the antenna 100.

FIG. 2 shows an example of a FSD unit-cell structure for the FSD 103, as it can be used for an
20 antenna 100 according to an embodiment of the invention. In particular, FIG. 2 shows a unit-cell structure of a metallic FSD 103. The unit-cell structure shown in FIG. 2 is implemented as a rectangular double-slot SRR structure 200. The SRR structure 200 may include a PEC-metal 201 and two slots 202 (air cavities). However, the FSD 103 may generally comprise a SRR structure or even other structures as described below as unit-cells.

25 The rectangular double-slot SRR structure 200 may be the building block for the complete FSD 103 as it is shown in FIG. 3. In FIG. 3, the FSD 103 comprises an arrangement 300 of a plurality of FSD unit-cells realized as rectangular double-slot SRR structures 200 as shown in FIG. 1. Again, these unit-cell structures of the FSD 103 can also be different ones.

30 For example, FIG. 4 shows various possible FSD unit-cell structures for a FSD 103 of an antenna 100 according to an embodiment of the invention. In particular, FIG. 4 shows that a circular SRR structure 401 (e.g. single-slot or double-slot as illustrated), a rectangular single-slot SRR structure 401, or the rectangular double-slot SRR structure 200 of FIG. 2 (with two

concentric slots) can be used as unit-cell structure of the FSD 103. Further, also a Hilbert-curve structure 404 or a spiraled-triangle structure 403 can be used. In summary, the FSD 103 can comprise one or a plurality of a SRR structures 200, 401 and/or 402, and/or a Hilbert-curve structure 404, and/or a spiraled-triangle structure 403. The FSD 103, or a FSS of the FSD 103, could also be created in many other shapes with different shapes of the unit-cell structure.

The working principle of the FSD 103 is simple to understand. The (metallic) unit-cells works as a LC-band pass filter, which stop a certain frequency band at least partially, i.e. the first frequency band, preferably is opaque for the radiation in the first frequency band. Further, it passes at least partially another frequency band, i.e. the second frequency band, preferably is completely transparent for the second frequency band (pass-band). For instance, the unit-cells may be optimized to stop the LB, and to have a complete pass band for the CB.

FIG. 5 shows the behavior of an exemplary FSD 103 of an antenna 100 according to an embodiment of the invention, when energized in certain boundary conditions. It can be seen that the LB is stopped, and the CB is passed in this example.

FIG. 6 shows 3D simulations of the effect of the EM-wave on the FSD 103 (unit-cell). It can be clearly observed in FIG. 6(a) that the FSD 103 behaves opaque for the stop-band, e.g. for the LB, with maximum reflections. FIG. 6(b) shows the pass-band effect i.e. that the FSD 103 behaves as a transparent material for the pass-band, e.g. for the HB or CB.

FIG. 7 shows an antenna 100 according to an embodiment of the invention, which builds on the simplified antenna 100 shown in FIG. 1. Same elements in FIG. 1 and FIG. 7 are labelled with the same reference signs and function likewise. That is, also the antenna 100 shown in FIG. 7 includes the two or more first radiating elements 101, the one or more second radiating elements 102, and the FSD 103.

In the exemplary embodiment of FIG. 7, the two or more first radiating elements 101 are LB radiating elements. These LB radiating elements 101 are arranged in a first column and in a second column, which is parallel to the first column. The FSD 103 is arranged between the first radiating elements 101 (more specifically, between the first column and the second column). The FSD 103 is exemplarily shown to extend along and between the first and the second columns.

The one or more second radiating elements 102 are one or more CB radiating elements in FIG. 7. In particular, in the exemplary embodiment of FIG. 7, a plurality of CB radiating elements 102 form an array. The LB radiating elements 101 are placed within this array. That is, second radiating element(s) 102 is/are arranged in the vicinity of or is/are co-located with one or more of the first radiating elements 101.

Considering the behavior of the FSD unit-cells, the FSD 103 may be placed in an optimal position between different first radiating elements 101, and between first radiating elements 101 and second radiating elements 102. EM energy can thus be trapped at an optimized position in the zenith-nearfield. This can reduce the EM coupling between the first and the second subset of first radiating elements 101, and thus reducing effects of the coupling on the performance of the second radiating elements 102.

A possible arrangement of the FSD 103 for this purpose is shown in FIG. 7. In this example, the first and the second radiating elements 101 and 102 are arranged on an antenna board 700. The FSD 103 is arranged at a certain height above the antenna board 700. For example, if the first radiating elements 101 (as shown in FIG. 7) each comprise a radiating plane 701 that is arranged at a certain height above the antenna board 700, the FSD 103 may be arranged at the same height as the radiating planes 701. To this end, the FSD 103 may be held by support structures 702 at the mentioned height above the antenna board 700. Moreover, the FSD 103 may be planar, and may be arranged perpendicular to the radiating planes 701 of the first radiating elements 101. The FSD 103 may also comprise a FSS arranged perpendicular to the radiating planes 701 of the first radiating elements 101.

FIG. 8 shows a further possible design of the antenna 100 according to embodiments of the invention, which build on the simplified antenna 100 shown in FIG. 1. Same elements in FIG. 1 and FIG. 8 are again labelled with the same reference signs and function likewise. That is, also the antenna 100 shown in FIG. 8 includes the two or more first radiating elements 101, the one or more second radiating elements 102, and the FSD 103.

In FIG. 8, the FSD 103 is exemplarily a metallic FSD 103 with unit-cells formed by a rectangular dual-slot SRR structure 200 as shown in FIG. 2. The FSD 103 may be installed at an optimized location between the first radiating elements 103, here LB radiating elements, and

the second radiating elements 102, here CB radiating elements. The FSD 103 may be arranged and/or held at a determined height above the antenna board 700. The FSD 103 improves the isolation between the LB radiating elements 101, namely by trapping EM-energy in the nearfield. The FSD 103 also improves the cross-polarization in the CB (e.g. MIMO) radiating elements 102, which improves notably the shape of the beam.

As already described above and shown e.g. in FIG. 4, different unit-cells are again possible for the FSD 103 of the antenna 100 shown in FIG. 8.

In summary, compared to the use of a simple metal-wall (for achieving isolation between radiating elements) or an open space (i.e. without any isolation), the embodiments of the invention, employing the FSD 103, have the following advantages, in particular when provided in BTS antennas:

- The FSD 103 can be used to trap EM-waves in the zenith rather than trapping the surface-wave on the ground.
- The FSD 103 does not have to be grounded, but can be arranged in the open space, e.g. orthogonal to the radiating elements 101 or the antenna board 700. This helps to improve the isolation between the first radiating elements 101, e.g. for related to the LB, without changing the spacing between the radiating elements 101, and/or without modifying the ground-plane geometry.
- Beam-patterns and isolations in the second frequency band, e.g. the CB, are also improved without requiring a change of the antenna design.
- Isolation between the first and the second radiating elements 101 and 102, e.g. related to the LB and CB, are also improved.
- Performance of the second radiating elements 102, e.g. CB radiating elements, is improved.
- No extra material needs to be used to fabricate the FSD 103, as it may be a metal wall with one or more slots.
- The FSD 103 may be tunable to a certain extent, as parametrized.
- No special fabrication procedure is required.

The present invention has been described in conjunction with various embodiments as examples as well as implementations. However, other variations can be understood and effected by those persons skilled in the art and practicing the claimed invention, from the studies of the drawings, this disclosure and the independent claims. In the claims as well as in the description the word
5 “comprising” does not exclude other elements or steps and the indefinite article “a” or “an” does not exclude a plurality. A single element or other unit may fulfill the functions of several entities or items recited in the claims. The mere fact that certain measures are recited in the mutual different dependent claims does not indicate that a combination of these measures cannot be used in an advantageous implementation.

CLAIMS

1. An antenna (100), comprising:
two or more first radiating elements (101) configured to radiate in a first frequency band,
5 one or more second radiating elements (102) configured to radiate in a second frequency band, and
a frequency selective device, FSD, (103) arranged between a first subset and a second subset of the two or more first radiating elements (101) and configured to at least partially block radiation in the first frequency band and to pass radiation in the second frequency band.
10
2. The antenna (100) according to claim 1, wherein:
the FSD (103) is opaque for radiation in the first frequency band.
3. The antenna (100) according to claim 1 or 2, wherein:
15 the FSD (103) is transparent for radiation in the second frequency band.
4. The antenna (100) according to one of the claims 1 to 3, wherein:
the FSD (103) comprises a metallic structure.
- 20 5. The antenna (100) according to one of the claims 1 to 4, wherein:
the FSD (103) is configured to be polarization-independent.
6. The antenna (100) according to one of the claims 1 to 5, wherein:
the FSD (103) comprises a split-ring resonator, SRR, (200, 401, 402) structure, in
25 particular a rectangular SRR structure (200).
7. The antenna (100) according to one of the claims 1 to 6, wherein:
the FSD (103) comprises a Hilbert-curve structure (404) and/or a spiraled-triangle structure (403).
30
8. The antenna (100) according to one of the claims 1 to 7, wherein:
the FSD (103) comprises an arrangement (300) of a plurality of FSD unit cells.

9. The antenna (100) according to one of the claims 1 to 8, wherein:
the FSD (103) is arranged at a determined height above an antenna board (700) that carries the first and the second radiating elements (101, 102).

5 10. The antenna (100) according to one of the claims 1 to 9, wherein:
the first radiating elements (101) each comprise a radiating plane (701) arranged at a determined height above an antenna board (700) that carries the first and the second radiating elements (101, 102), and
the FSD (103) is arranged at the same height as the radiating planes (700).

10

11. The antenna (100) according to claim 10, wherein:
the FSD (103) is planar and arranged perpendicular to the radiating planes (701), and/or
the FSD (103) comprises a frequency-selective surface arranged perpendicular to the radiating planes (701).

15

12. The antenna (100) according to one of the claims 1 to 11, wherein:
the FSD (103) is not grounded and/or not electrically connected to any other part of the antenna (100).

20 13. The antenna (100) according to one of the claims 1 to 12, wherein
the two or more first radiating elements (101) are low band, LB, radiating elements, and/or
the one or more second radiating elements (102) are high band, HB, or C-band, CB, radiating elements.

25

14. The antenna (100) according to claim 1 to 13, wherein
at least one of the one or more second radiating elements (102) is arranged in a vicinity of and/or is co-located with one of the first radiating elements (101).

30 15. The antenna (100) according to one of the claims 1 to 14, wherein
the first radiating elements (101) of the first subset are arranged in a first column, and
the first radiating elements (101) of the second subset are arranged in a second column parallel to the first column,
wherein the FSD (103) is arranged between the first column and the second column.

16. A base station comprising an antenna (100) according to any one of the claims 1 to 15 and a radio transmitter connected to the antenna (100).

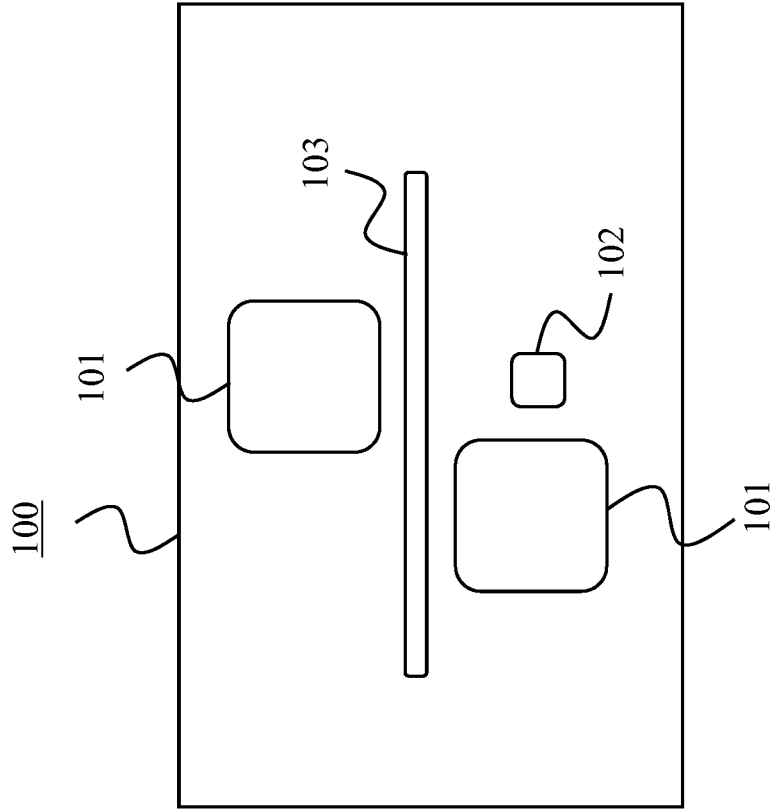
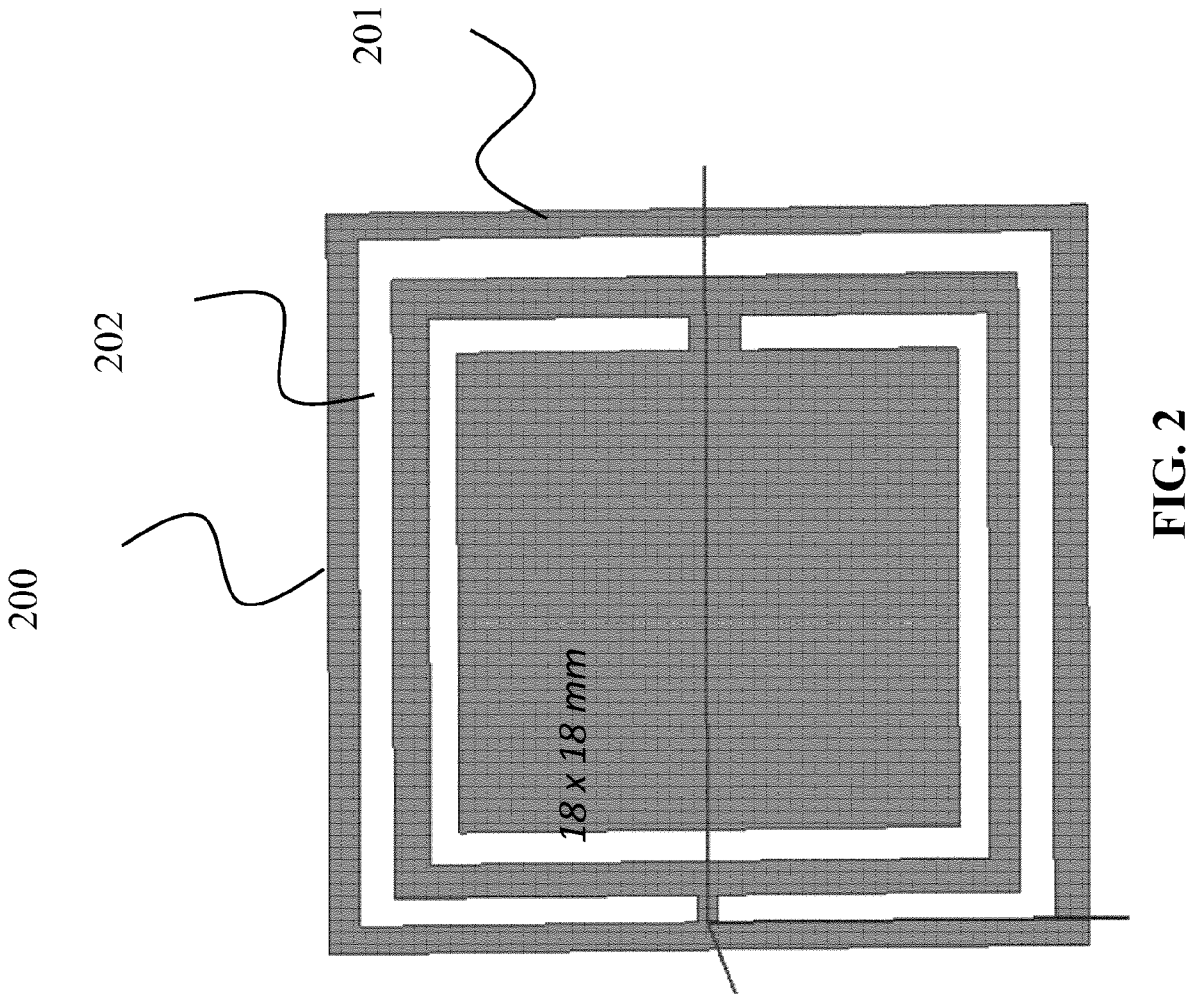


FIG. 1



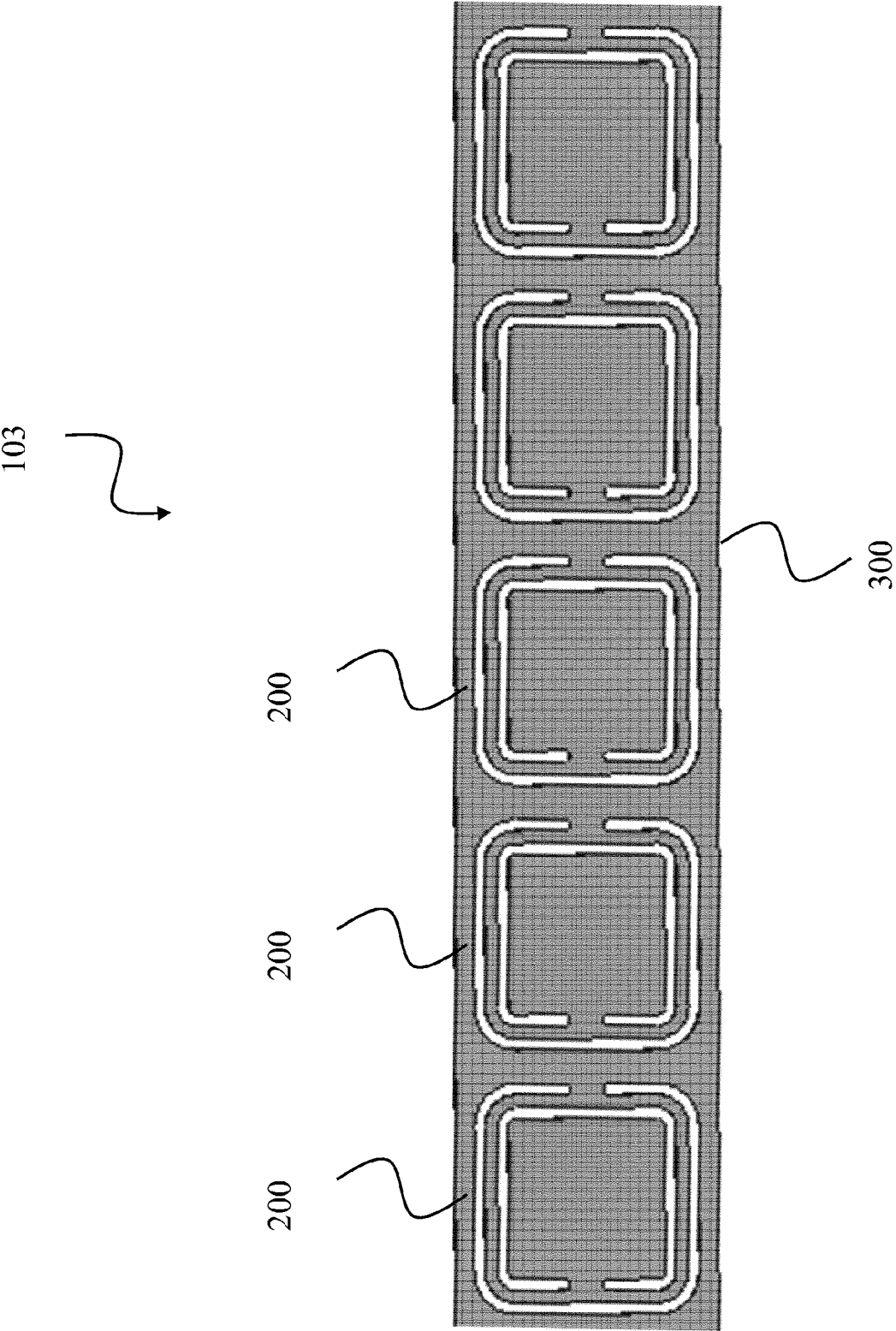


FIG. 3

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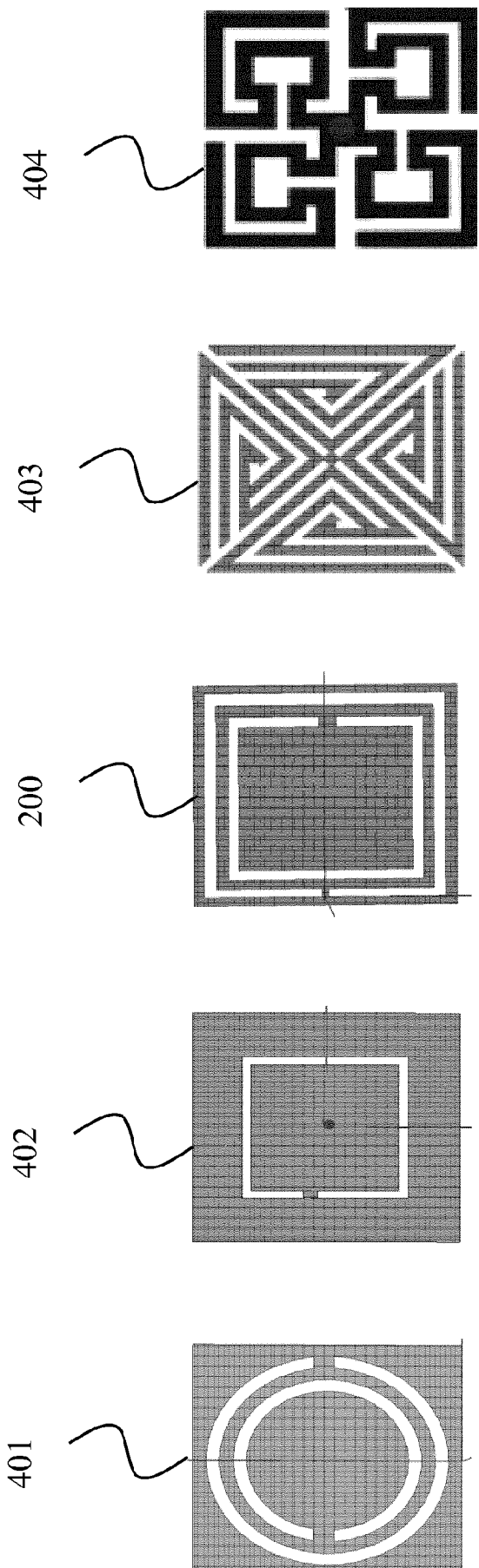


FIG. 4

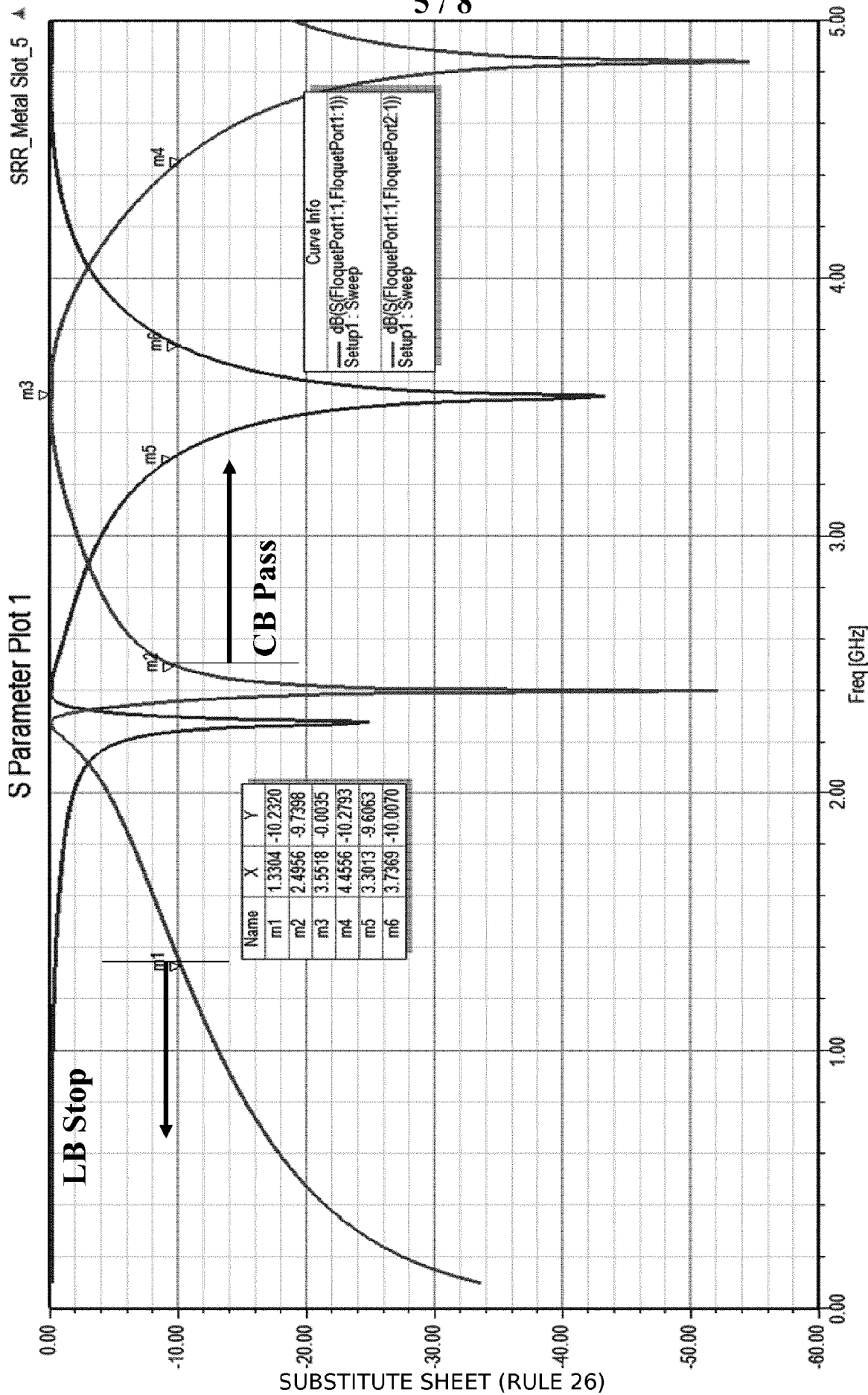


FIG. 5

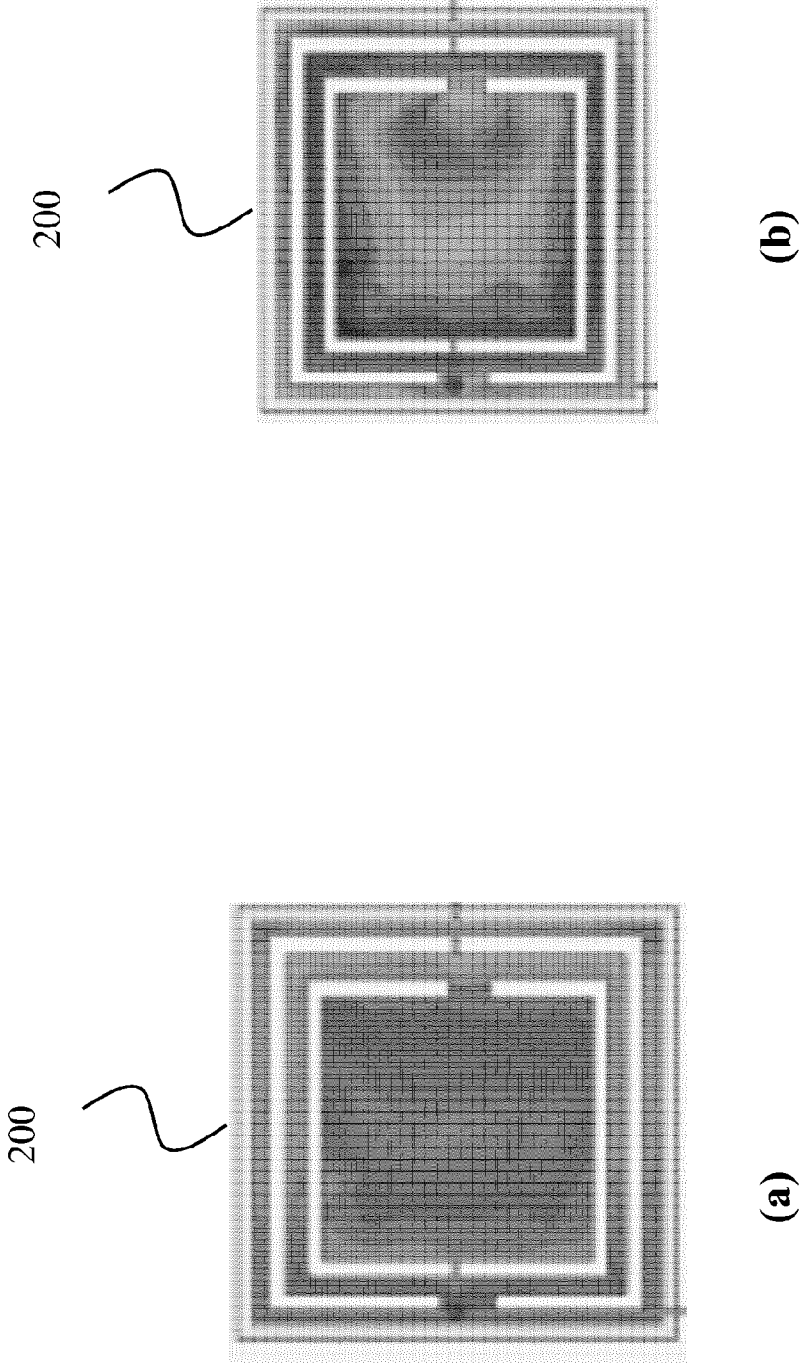


FIG. 6

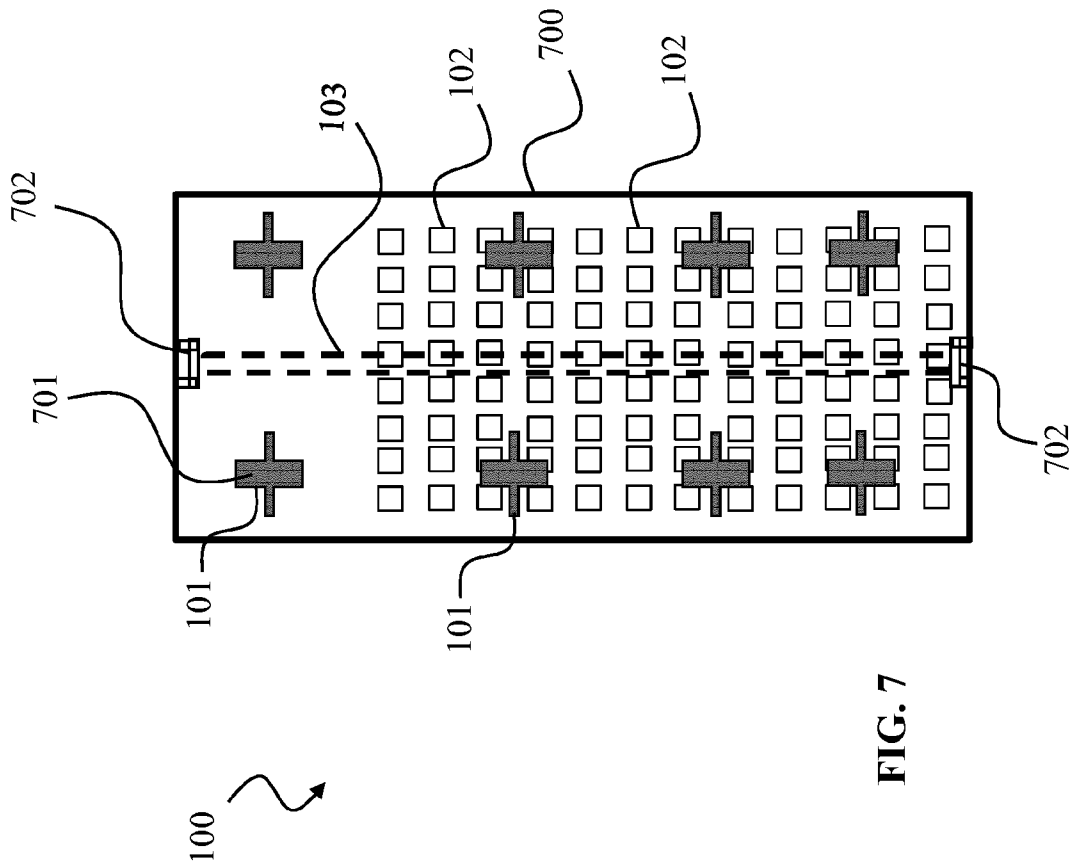
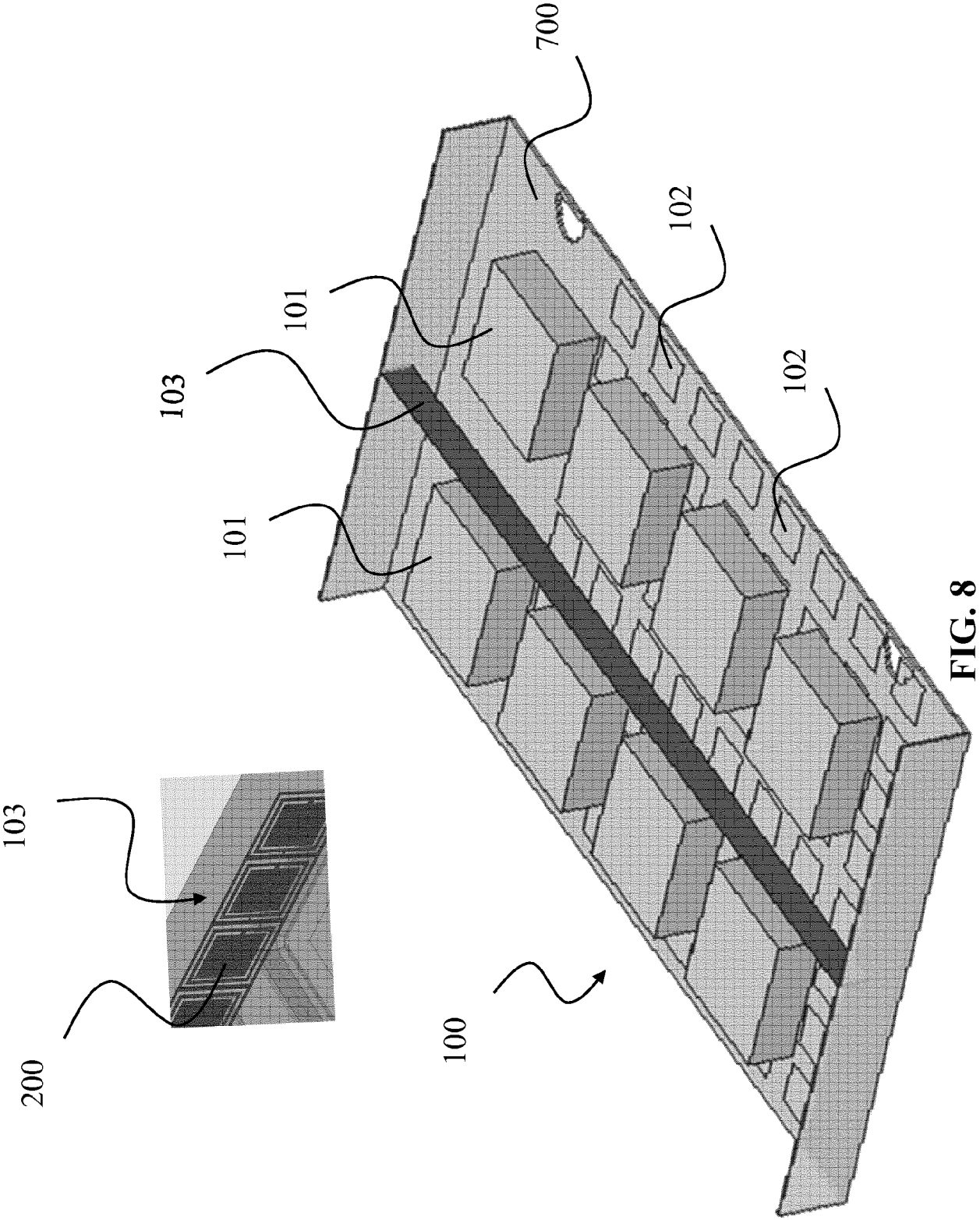


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2019/063499

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01Q1/24 H01Q1/52 H01Q15/00 H01Q5/42
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	WO 2018/180766 A1 (NEC CORP [JP]) 4 October 2018 (2018-10-04) paragraphs [0103] - [0105], [0136] - paragraph [0154]; figures 7-10, 26, 28, 30 & US 2019/393597 A1 (KOSAKA KEISHI [JP] ET AL) 26 December 2019 (2019-12-26) -----	1-11, 13-16 12
X	US 2018/331419 A1 (VARNOOSFADERANI MOHAMMAD VATANKHAH [AU] ET AL) 15 November 2018 (2018-11-15) paragraph [0042] - paragraph [0070]; figures 3-8 -----	1-16
X A	US 2018/248257 A1 (THOTAHEWA KASUN M S [AU] ET AL) 30 August 2018 (2018-08-30) paragraph [0046] - paragraph [0065]; figures 3, 6, 7 -----	1, 2, 4, 8-10, 13-16 3



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

5 February 2020

Date of mailing of the international search report

13/02/2020

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/063499

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2018180766 A1	04-10-2018	EP 3605727 A1 KR 20190112332 A US 2019393597 A1 WO 2018180766 A1	05-02-2020 04-10-2019 26-12-2019 04-10-2018
US 2018331419 A1	15-11-2018	CN 110612639 A US 2018331419 A1 US 2019372204 A1 WO 2018208363 A1	24-12-2019 15-11-2018 05-12-2019 15-11-2018
US 2018248257 A1	30-08-2018	CN 108028462 A EP 3381084 A1 US 2018248257 A1 WO 2017091307 A1	11-05-2018 03-10-2018 30-08-2018 01-06-2017