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(54) A DUAL-POLARIZED ANTENNA ARRAY

(57) An apparatus comprising:
a first group of first clusters of separately fed radiators configured to provide first electric fields parallel to a first direction,
wherein a first cluster of the first group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and
wherein a second cluster of the first group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions; and
a second group of second clusters of separately fed radiators configured to provide second electric fields parallel to a second direction, orthogonal to the first direction,
wherein a first cluster of the second group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and
wherein a second cluster of the second group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions.

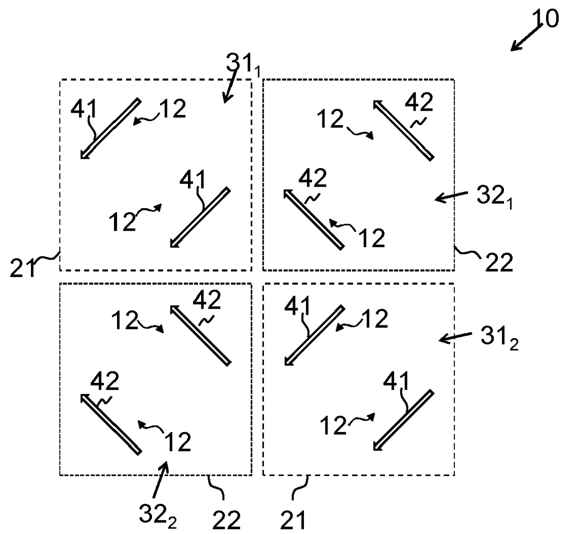

FIG 1

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Description

TECHNOLOGICAL FIELD

[0001] Embodiments of the present disclosure relate to a dual-polarized antenna array.

BACKGROUND

[0002] Access to radio resources can be via distinct, orthogonal polarization channels. For example, a first physical layer channel can be transmitted with and received with a first linear polarization and a second physical layer channel can be transmitted and received with a second linear polarization. The first and second linear polarizations are orthogonal. The linear polarization describes an orientation of the electric field of the transmitted radio signal.

BRIEF SUMMARY

[0003] According to various, but not necessarily all, embodiments there is providedan apparatus comprising:

> a first group of first clusters of separately fed radiators configured to provide first electric fields parallel to a first direction,
> wherein a first cluster of the first group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and
> wherein a second cluster of the first group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions; and
> a second group of second clusters of separately fed radiators configured to provide second electric fields parallel to a second direction, orthogonal to the first direction, wherein a first cluster of the second group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and
> wherein a second cluster of the second group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions.

[0004] In some but not necessarily all examples, the apparatus comprises a planar panel substrate having a length and a width; wherein one or more bent dipole radiators of one or more first clusters and one or more bent dipole radiators of one or more second clusters are positioned at width-wise extremities of the planar panel substrate.

[0005] In some but not necessarily all examples, the separately fed radiators that are configured to provide the first electric fields parallel to the first direction are comprised in printed circuit boards and/or
wherein the separately fed radiators that are configured to provide the second electric fields parallel to the second direction are dipole radiators are comprised in printed circuit boards.

[0006] In some but not necessarily all examples, the separately fed radiators that are configured to provide the first electric fields parallel to the first direction are dipole radiators and wherein the separately fed radiators that are configured to provide the second electric fields parallel to the second direction are dipole radiators.

[0007] In some but not necessarily all examples, in a first cluster, a separately fed radiator, that is a dipole radiator, is offset from the at least one bent dipole radiator of the first cluster parallel to the second direction and wherein, in a second cluster, a separately fed radiator, that is a dipole radiator, is offset from the at least one bent dipole radiator of the second cluster parallel to the first direction

[0008] In some but not necessarily all examples, the further dipole radiator is a bent dipole radiator comprising conductive pole portions extending in different directions.

[0009] In some but not necessarily all examples, the further dipole radiator is an unbent dipole radiator comprising conductive pole portions extending along a common line.

[0010] In some but not necessarily all examples, for at least one bent dipole radiator, the conductive pole portions of the bent dipole radiator extend in different orthogonal directions.

[0011] In some but not necessarily all examples, for at least one bent dipole radiator, at least one of the conductive pole portions of the bent dipole radiator is unitary or non-unitary and interrupted by a dielectric gap.

[0012] In some but not necessarily all examples, the apparatus is configured for dual polarized operation, wherein the multiple separately fed radiators of the first group are configured to provide physically separated clusters of first electric fields parallel to the first direction that sum to create a combined first electric field parallel to the first direction,
wherein the multiple separately fed radiators of the second group are configured to provide physically separated clusters of second electric fields parallel to the second direction that sum to create a combined second electric field parallel to the second direction.

[0013] In some but not necessarily all examples, a cluster of radiators is a physical association of the bent dipole radiator of the cluster and a physically closest radiator of the same group as the bent dipole radiator.

[0014] In some but not necessarily all examples, the first group of first clusters of separately fed radiators, including at least the bent dipole radiator, are lower-frequency radiators configured to operate in a first lower frequency passband with a first polarization, wherein the second group of second clusters of separately fed radiators, including at least the bent dipole radiator, are lower-frequency radiators configured to operate in the first lower frequency passband with a second polarization, orthogonal to the first polarization, and wherein at least some clusters comprise at least one higher-frequency radiator configured to operate in a second frequency passband that is distinct from the first frequency passband and is at a higher frequency that the first frequency passband.

[0015] In some but not necessarily all examples, a bent dipole radiator of a cluster of the first group and a bent-dipole radiator of a cluster of the second group share a common conductive pole portion.

[0016] In some but not necessarily all examples, the first group of first clusters of separately fed radiators are comprised in a first antenna, wherein the second group of second clusters of separately fed radiators are comprised in the first antenna, wherein the first clusters of the first group and the second clusters of the second group alternate in a single line comprising the first clusters of the first group and the second clusters of the second group.

[0017] In some but not necessarily all examples, the apparatus comprises:

a third group of first clusters of separately fed radiators configured to provide first electric fields parallel to a first direction,

wherein a first cluster of the third group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and

wherein a second cluster of the third group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions; and

a fourth group of second clusters of separately fed radiators configured to provide second electric fields parallel to a second direction, orthogonal to the first direction,

wherein a first cluster of the fourth group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and

wherein a second cluster of the fourth group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions,

wherein the first clusters of the first group and the second clusters of the second group alternate in a first single line comprising the first clusters of the first group and the second clusters of the second group, and

wherein the first clusters of the third group and the second clusters of the fourth group alternate in a further second single line comprising the first clusters of the third group and the second clusters of the fourth group.

[0018] According to various, but not necessarily all, embodiments there is provided examples as claimed in the appended claims.

BRIEF DESCRIPTION

[0019] Some examples will now be described with reference to the accompanying drawings in which:

FIG. 1 shows another example of the subject matter described herein;
FIG. 2A, 2B, 2C show other examples of the subject matter described herein;
FIG. 3A, 3B show other examples of the subject matter described herein;
FIG. 4A, 4B, 4C show other examples of the subject matter described herein;
FIG. 5A, 5B show other examples of the subject matter described herein;
FIG. 6 shows another example of the subject matter described herein; FIG. 7A, 7B show other examples of the subject matter described herein;
FIG. 8 shows another example of the subject matter described herein;
FIG. 9 shows another example of the subject matter described herein;
FIG. 10A, 10B show other examples of the subject matter described herein;
FIG. 11A, 11B show other examples of the subject matter described herein;

DETAILED DESCRIPTION

[0020] The drawings illustrate and the following text describes examples of an apparatus 10. The apparatus 10 can, for example, be an antenna arrangement such as an antenna array or panel for a node in a radio telecommunications network. In some examples, the node can be a user equipment and in other examples the node can be a base station such as, for example a gNB.

[0021] FIG. 1 is a schematic illustration of clusters 31, 32 of radiators. The radiators are not illustrated.

[0022] Each first cluster 31 provides an electric field 41 parallel to a first direction. This defines a first polarization. The first clusters 31 form a first group 21 of clusters. In the illustrated example two first clusters 31_1, 31_2 are illustrated.

[0023] Each second cluster 32 provides an electric field 42 parallel to a second direction. This defines a second polarization. The second clusters 32 form a second group 22. In the illustrated example two second clusters 32_1,

32_2 are illustrated.

[0024] The first direction is orthogonal to the second direction. Consequently, the first polarization and the second polarization are orthogonal. There are consequently two groups 21, 22 for two orthogonal polarizations as illustrated by the direction of the respective electric fields 41, 42. Each of the groups 21, 22, in these examples, comprises the same number of clusters 31, 32. The number of clusters in each group, in this example, is an even number.

[0025] Each cluster 31 in the first group 21 of clusters 31_1, 31_2 provides an electric field 41 that is parallel to the first direction and each cluster 32 in the second group 22 of second clusters 32_1, 32_2 provides an electric field 42 that is parallel to a second direction.

[0026] In the example illustrated, the clusters are arranged in an array comprising rows and column, however other arrangements are possible. For example the array can comprise a single row/column or the clusters need not be arranged in rows/columns.

[0027] In the example illustrated, every first cluster 31 is adjacent at least another first cluster 31 aligned along a first line. Every second cluster 32 is adjacent at least another second cluster aligned along a second line orthogonal to the first line. In FIG. 1, the first clusters 31_1, 31_2 are diagonally offset and the second clusters 32_1, 32_2 are diagonally offset. The first and second lines are diagonal.

[0028] In other arrangements the first clusters 31_1, 31_2 could be vertically offset and the second clusters 32_1, 32_2 could be vertically offset (the first and second lines are vertical (columns)). In other arrangements the first clusters 31_1, 31_2 could be horizontally offset and the second clusters 32_1, 32_2 could be horizontally offset (the first and second lines are horizontal (rows)).

[0029] In FIG. 1 the presence of radiators 12 is indicated but the radiators, and in particular their shape, are not shown.

[0030] Electric fields 41 are illustrated as being parallel but offset however in other examples they can be aligned. Electric fields 42 are illustrated as being parallel but offset however in other examples they can be aligned

[0031] Each first cluster 31 comprises separately fed radiators 12. The radiators 12 of a first cluster 31 are arranged for a mutual electromagnetic coupling and for providing an electric field 41 parallel to the first direction. Each separately fed radiator 12 can be configured to provide an electric field 41 parallel to the first direction. The electric fields 41, of the radiators 12 in a cluster 31, sum to form the electric field 41 of the first cluster 31 illustrated in FIG. 2A.

[0032] Each second cluster 32 comprises separately fed radiators 12. The radiators 12 of a second cluster 32 are arranged for a mutual electromagnetic coupling and for providing an electric field 42 parallel to the second direction. Each separately fed radiator 12 can be configured to provide an electric field 42 parallel to the second direction. The electric fields 42, of the radiators 12 in a cluster 32, sum to form the electric field 42 of the first cluster 31 illustrated in FIG 2A.

[0033] It will therefore be appreciated that the multiple separately fed radiators 12 of the first group 21 are configured to provide physically separated clusters 31 of first electric fields 41 parallel to the first direction that sum to create a combined first electric field parallel to the first direction. Also, the multiple separately fed radiators 12 of the second group 22 are configured to provide physically separated clusters 32 of second electric fields 42 parallel to the second direction that sum to create a combined second electric field 42 parallel to the second direction.

[0034] The radiators 12 can operate at the same frequency, however the first group 21 and the second group 22 operate with different polarizations.

[0035] In the following examples, the separately fed radiators 12 that are configured to provide the first electric field 41 parallel to the first direction are dipole radiators and the separately fed radiators 12 that are configured to provide the second electric fields 42 parallel to the second direction are dipole radiators. The dipole radiators 12 can be half-wavelength dipole radiators.

[0036] FIGS. 2A, 2B and 2C illustrate an example of the apparatus 10. The apparatus 10 comprises a first group 21 of first clusters 31 of separately fed radiators 12 configured to provide electric fields 41 parallel to a first direction and a second group 22 of second clusters 32 of separately fed radiators 12 configured to provide electric fields 42 parallel to a second direction, orthogonal to the first direction.

[0037] Each cluster 31, 32 comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14. In the examples illustrated there are a pair of opposing bent dipole radiators 14 per cluster 31, 32. A bent dipole radiator 14 comprises conductive pole portions 18 extending substantially in different directions from a central feed or feeds 16, as illustrated in FIG. 4A. The conductive pole portions 18 are not labelled for every bent dipole radiator 14 in FIG. 2A, 2B, 2C for clarity of illustration.

The conductive pole portions 18 can lie in a common plane. A conductive pole portion 18 can be straight. A straight conductive pole portion 18 can be a rectilinear conductive pole portion and comprise a single part in the common plane (FIG. 4A). A straight conductive pole portion 18 can comprise multiple straight parts that are either separated by gaps (FIGS 4B, 4C) or interconnected (FIG. 3B). The two adjacent straight parts of the conductive pole portion 18 can, in some example, be interconnected at a bend (FIG 3B).

[0038] In the examples illustrated, the apparatus 10 comprises a planar substrate 100 having a length and a width. At least one of the bent dipole radiators 14 of a first cluster 31 is positioned at a width-wise extremity of the planar substrate 100. At least one of the bent dipole radiators 14 of a second cluster 32 is positioned at a width-wise extremity of the planar substrate 100. This enables maximum use of the area of the planar substrate 100 in the width-wise direction.

[0039] In some but not necessarily all examples, the bent dipole radiators 14 are center-fed half-wavelength dipole radiators. In such an example the conductive pole portions 18 can be quarter-wavelength conductive pole portions with the feed between the two quarter-wavelength conductive pole portions 18.

[0040] The vector current in the conductive pole portions 18, at bandpass frequencies, defines a direction of the electric field. If one considers a bent dipole radiator 14 in a cluster 31, 32, then the other separately fed radiator 12 (for example the other bent dipole radiator 14) is physically offset in a direction orthogonal to that direction. For first clusters 31, the offset is orthogonal to the first direction (parallel to the second direction). For second clusters 32, the offset is orthogonal to the second direction (parallel to the first direction).

[0041] In the examples illustrated in FIGS 2A, 2B and 2C the other separately fed radiator 12 is a bent dipole radiator 14 comprising conductive pole portions extending, substantially, in different directions. Thus, in some examples each of the clusters 31, 32 comprises a pair of bent dipole radiators 14. Each cluster can have 180° rotation symmetry. In the examples illustrated in FIGS. 2A, 2B and 2C the straight conductive pole portions of the bent dipole radiators 14 each comprise a single part that extend in orthogonal directions.

[0042] In contrast, in the examples illustrated in FIGS 10A, 10B, the other separately fed radiator 12 that is offset from the bent dipole radiator 14 in a cluster is a straight, unbent dipole radiator comprising straight conductive pole portions 18 extending along a common line.

[0043] In the example illustrated in FIG. 2C, the separately fed radiators 12 that are configured, in FIG 2B, to provide the first electric field parallel to the first direction are comprised in printed circuit boards 102 in FIG 3C and the separately fed radiators 12 that are configured, in FIG 3B, to provide the second electric fields parallel to the second direction are comprised in printed circuit boards 102.

[0044] In other examples, the radiators 12 can be made of aluminum sheets, molded parts or bent metal parts.

[0045] In FIGS 2A (and also FIGS 2B and 2C), the apparatus 10 comprises:

a first group 21 of first clusters 31_1, 31_2 of separately fed radiators 12 configured to provide first electric fields 41 parallel to a first direction,

wherein a first cluster 31_1 of the first group 21 comprises multiple separately fed radiators 12including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions, and

wherein a second cluster 31_2 of the first group 21 comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions; and

a second group 22 of second clusters 32_1, 32_2 of separately fed radiators 12 configured to provide second electric fields 42 parallel to a second direction, orthogonal to the first direction,

wherein a first cluster 32_1 of the second group 22 comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions, and

wherein a second cluster 32_2 of the second group 22 comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions.

[0046] FIGS 3A and 3B each illustrate an example of a cluster which can be a first cluster 31 or a second cluster 32. In these examples, the separately fed radiators 12 of the cluster 31, 32 comprises a pair of bent dipole radiators 14 comprising conductive pole portions 18 that extend, at least partially, for example substantially, in orthogonal directions. In the example of FIG. 3A, the conductive pole portions lie on a square shape and in FIG. 3B the conductive pole portions 18 lie on a rectangular shape. In the example of FIG. 3B, one of the conductive pole portions 18 has a bend around a corner. It will therefore be appreciated that the term 'straight conductive pole portion' can refer to a part that is substantially but not necessarily entirely straight in one direction or to a part that is entirely straight in one direction.

[0047] In the example of FIG. 3B, the conductive pole portions 18 of the bent dipole radiators 14 of the cluster do not connect and there is a gap between them. In the example of FIG. 4A, the conductive pole portions 18 of the pair of bent dipole radiators 14 of the cluster connect and there is no gap between them.

[0048] In the example illustrated in FIG. 3A and 3B, the conductive pole portions 18 of the bent dipole radiators 14 of a cluster 31, 32 extend in a common plane. In the example of FIG 3A the conductive pole portions 18 of different bent dipole radiators 14 are unitary and are not interrupted by a dielectric gap. The bent dipole radiators 14 of the cluster 31, 32 are not distinct but interconnected. In the example illustrated in FIG. 3B the conductive pole portions 18 of different dipole radiators 14 are not unitary and are interrupted by a dielectric gap. The bent dipole radiators 14 of the cluster 31, 32 are distinct. The dielectric gap can be filled by dielectric material or, for example, by air.

[0049] FIG. 4A schematically illustrates an example of a bent dipole radiator 14 comprising conductive pole portions 18_1, 18_2. The conductive pole portions 18_1, 18_2 subtend an angle θ. In the example illustrated the angle θ is 90°. However, in other examples the angle θ can be less than or greater than 90° (see FIGS 11A, 11B).

[0050] FIGS. 4B and 4C illustrate an alternative example of FIG. 4A, in which one of the straight conductive pole portions 18 comprises a dielectric gap 15. In the example of FIG. 4B, at least one of the straight conductive pole portions 18_2 of the bent dipole radiator is non-unitary and is interrupted by a gap 15. In this example the other straight conductive pole portion is unitary and is not interrupted by a dielectric gap 15. In FIG. 4C the other straight conductive pole portion 18_1 is non-unitary and is interrupted by a dielectric gap 15. The dielectric gap 15 can be filled by dielectric material or, for example, by air.

[0051] In some but not necessarily all examples, the bent dipole radiators 14 are center-fed half-wavelength dipole radiators. In such an example the conductive pole portions 18 can be quarter-wavelength conductive pole portions with the feed between the two quarter-wavelength conductive pole portions 18.

[0052] The examples illustrated in FIGS. 4A, 4B and 4C illustrate a feed 16 of the bent dipole antenna 14. The feed 16 can, for example, operate as either an input or an output for alternating currents in both the conductive pole portions 18. The vector sum of the electric currents in the respective conductive pole portions 18 produces a resultant virtual electric current which defines the electric field of the bent dipole radiator 14.

[0053] In the preceding examples, the first clusters 31 and the second clusters 32 were physically separate. In the example illustrated in FIG. 5A, a first cluster 31_1 is physically separated from a first cluster 31_2 but is not physically separated from the second clusters 32_1, 32_2. Also, the second cluster 32_1 is physically separated from the second cluster 32_2 but is not physically separated from the first clusters 31_1, 31_2.

[0054] A possible arrangement, where each of the clusters 31_1, 31_2, 32_1, 32_2 comprises a pair of bent dipole radiators 14 is illustrated in FIG. 5B. In this example, a first bent dipole radiator 14_1 of the cluster 31_1 shares a conductive pole portion 18 with a first bent dipole radiator 14_1 of the adjacent cluster 32_1, a first bent dipole radiator 14_1 of the cluster 31_2 shares a conductive pole portion 18 with a first bent dipole radiator 14_1 of the adjacent cluster 32_2, a second bent dipole radiator 14_2 of the cluster 31_1 shares a conductive pole portion 18 with a second bent dipole radiator 14_2 of the adjacent cluster 32_2, and a second bent dipole radiator 14_2 of the cluster 31_2 shares a conductive pole portion 18 with a second bent dipole radiator 14_2 of the adjacent cluster 32_1.

[0055] In examples of the apparatus 10 the first group 21 of first clusters 31 of separately fed radiators 12 including at least the bent dipole radiators 14, are configured to operate in a first passband with a first polarization and the second group 22 of second clusters 32 of separately fed radiators 12, including at least the bent dipole radiators 14 are configured to operate in the first passband with a second polarization, orthogonal to the first polarization. Operating in the first passband means operating with a passband that is the same bandwidth as or substantially overlaps a bandwidth of the first passband.

[0056] A group 21/22 can be any suitable shape. It can for example be a single row/column array or an array comprising multiple row/columns. It can for example be the set of all first clusters 31/32 or it can be a sub-set of all clusters 31/32. In some examples all clusters 31/32 in the group 21/22 are operated simultaneously or operated with the same spatial filtering (beam-forming) weighting e.g. same phase offset. In some other examples only some of the clusters 31/32 in the group 21/22, for example a row or column, are operated simultaneously or with the same spatial filtering (beam-forming) weighting e.g. same phase offset.

[0057] The unit cell illustrated in FIG 2A (also 2B, 2C) can be repeated to form an antenna array. The unit cell illustrated in FIG 2A (also 2B, 2C) can be repeated along a single line, with a constant repeat distance, to form an antenna array. In some but not necessarily all examples, the repeat distance is approximately 0.9 times an operational wavelength of the antenna array.

[0058] In the example illustrated in FIG 6, the unit cell illustrated in FIG 2A has been repeated three times vertically with constant spacing to create two antenna arrays 40_1, 40_2. In other examples, the unit cell illustrated in FIG 2A can be repeated multiple times horizontally and/or vertically.

[0059] The clusters 31_1, 32_2 of a first column of the unit cells form the first antenna array 40_1. The clusters 31_1 have a first polarization and the clusters 32_2 have a second polarization that is orthogonal to the first polarization.

[0060] The clusters 31_2, 32_1 of a second column of the unit cells form the second antenna array 40_2. The clusters 31_2 have a first polarization and the clusters 32_1 have a second polarization that is orthogonal to the first polarization.

[0061] The first antenna array 40_1 comprises a first group of first clusters 31_1 of separately fed radiators 12 configured to provide first electric fields parallel to a first direction,

wherein a first cluster 31_1 of the first group 21 comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions, and

wherein a second cluster 31_1 of the first group 21 comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions; and

a second group of second clusters 32_2 of separately fed radiators 12 configured to provide second electric fields 42 parallel to a second direction, orthogonal to the first direction,

wherein a first cluster 32_2 of the second group 22 comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions, and

wherein a second cluster 32_2 of the second group 22 comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions.

[0062] The second antenna array 40_2 comprises a third group of first clusters 31_2 of separately fed radiators 12 configured to provide first electric fields parallel to a first direction,

wherein a first cluster 31_2 of the third group comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions, and

wherein a second cluster 31_2 of the third group comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions; and

a fourth group of second clusters 32_1 of separately fed radiators 12 configured to provide second electric fields 42 parallel to a second direction, orthogonal to the first direction,

wherein a first cluster 32_1 of the fourth group comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions, and

wherein a second cluster 32_1 of the fourth group comprises multiple separately fed radiators 12 including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions.

[0063] The first clusters 31_1 of the first group and the second clusters 32_2 of the second group can alternate in a first single line comprising the first clusters 31_1 of the first group and the second clusters 31_2 of the second group

[0064] The first clusters 31_2 of the third group and the second clusters 32_1 of the fourth group alternate, in a further second single line, comprising the first clusters 31_2 of the third group and the second clusters 32_1 of the fourth group.

[0065] In at least some examples, all clusters 31_1 in the first antenna array 40_1 are operated with a first phase offset and all clusters 32_2 in the first antenna 40_1 are operated with a second phase offset.

[0066] In at least some examples, all clusters 31_2 in a second antenna 40_2 are operated with a third phase offset and all clusters 32_1 in the second antenna 40_2 are operated with a fourth phase offset.

[0067] FIGS. 7A, 7B, 9 illustrate an example in which the apparatus 10 further comprises at least some additional radiators 110 configured to operate in a second frequency passband that is distinct from the first passband. Only some of the additional radiators 110 are labelled in the FIGS. Distinct means that the passbands do not overlap. In the example illustrated, the separately fed radiators 12 are lower frequency radiators configured to operate in a lower-frequency passband. The second frequency passband is a higher frequency passband that is higher than and distinct from the lower frequency passband.

[0068] The clusters 31, 32 of radiators 12 (labelled as bent dipole radiators 14 in these examples) are arranged in an array of rows and columns.

[0069] The additional radiators 110 are arranged in an array of rows and columns. In the FIGs only some of the additional radiators 110 are labelled. The spacing between the additional radiators 110 in at least one direction is less than a spacing between first clusters 31 in that direction.

[0070] At least some of the higher-frequency radiators 110 are comprised within clusters 31, 32. Also, in these examples at least some of the higher-frequency radiators 110 are located outside of the clusters 31, 32.

[0071] It will be appreciated that at least some of the higher-frequency radiators 110 are positioned in a space between the bent dipole radiators 14 of adjacent clusters 31, 32.

[0072] FIG. 7B illustrates an example similar to that illustrated in FIG. 7A. In this example, the radiator elements 12, that is the bent dipole radiators 14 of the clusters 31, 32 are supported and formed within printed circuit boards 102. Printed circuit boards 102 are also used to support the separately fed radiators 12 in FIG 9.

[0073] FIG. 8 illustrates an apparatus 10 similar to that illustrated in FIG. 6B, in which the bent dipole radiators 14 are supported by and formed within printed circuit boards. FIG. 9 illustrates an example similar to that illustrated in FIGS. 7A and 7B except that the adjacent bent dipole radiators 14 of adjacent first and second clusters 31, 32 share a common conductive pole portion 18 as previously described in relation to FIG. 6B. Thus, a bent dipole radiator 14 of a cluster 31 of the first group 21 and a bent dipole radiator 14 of a cluster 31 of the second group 22 share a common conductive portion 18.

[0074] In the examples illustrated in FIGS. 10A and 10B each cluster 31, 32 comprises a bent dipole radiator 14 and a straight dipole radiator 12. FIGS. 10A and 10B illustrate the same apparatus 10 that has been rotated by 90°. The straight dipole radiator 12 comprises straight conductive pole portions 18 that extend along a common line. In the first clusters 31, the flat dipole radiator 12 is offset from the bent dipole radiator 14 parallel to the first direction. In the second clusters 32, the flat dipole radiator 12 is offset from the bent dipole radiator 14 parallel to the second direction. The straight dipole radiator 12 is a straight, unbent dipole radiator comprising straight conductive pole portions 18 extending in opposite directions along a common line. In FIG 5A the angle θ is 180°.

[0075] The example illustrated in FIGS. 11A and 11B demonstrates that the bent dipole radiator 14 need not have its straight conductive pole portions 18 extending in orthogonal directions. That is $\theta \neq 90°$. In this example the angle θ between the straight conductive pole portions 18 of the bent dipole radiator 14 is greater than 90°. Each of the pair of bent dipole radiators 14 in a cluster 31, 32 has the same angle θ between the straight conductive pole portions 18 of the bent dipole radiator 14.

[0076] The preceding examples (including FIG 2A and FIG 6) illustrate and describe an apparatus 10 comprising:

a first group 21 [e.g. an array or column] of first clusters 31 of separately fed radiators 12 [e.g. dipole radiators] configured to provide first electric fields 41 parallel to a first direction,

wherein a first cluster 31_1 of the first group 21 comprises multiple separately fed radiators 12 [e.g. dipole radiators] including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions, and wherein a second cluster $31_1/31_2$ of the first group 21 comprises multiple separately fed radiators 12 [e.g. dipole radiators] including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions; and

a second group 22 [e.g. an array or column] of second clusters 32 of separately fed radiators 12 [e.g. dipole radiators] configured to provide second electric fields 42 parallel to a second direction, orthogonal to the first direction,

wherein a first cluster 32_2 of the second group 22 comprises multiple separately fed radiators 12 [e.g. dipole radiators] including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions, and

wherein a second cluster $32_1/32_2$ of the second group 22 comprises multiple separately fed radiators 12 [e.g. dipole radiators] including at least one bent dipole radiator 14 comprising conductive pole portions 18 extending in different directions.

[0077] In FIG 2A, the first clusters 31 of the first group 21 are arranged diagonally in the unit cell and the second clusters 32 of the second group 22 are arranged diagonally (in an orthogonal direction) in the unit cell.

[0078] In FIG 6, the first clusters 31 of the first group 21 are arranged in a column formed by repeated unit cells and the second clusters 32 of the second group 22 are arranged in the same column. The first clusters 31 and the second clusters 32 of the same column are interleaved.

[0079] Where a structural feature has been described, it may be replaced by means for performing one or more of the functions of the structural feature whether that function or those functions are explicitly or implicitly described.

[0080] A bandpass (operational bandwidth) is a frequency range over which an antenna can efficiently operate. A bandpass (operational bandwidth) may be defined as where the return loss S11 of the antenna is greater than an operational threshold T.

[0081] The above described examples find application as enabling components of: automotive systems; telecommunication systems; electronic systems including consumer electronic products; distributed computing systems; media systems for generating or rendering media content including audio, visual and audio visual content and mixed, mediated, virtual and/or augmented reality; personal systems including personal health systems or personal fitness systems; navigation systems; user interfaces also known as human machine interfaces; networks including cellular, non-cellular, and optical networks; ad-hoc networks; the internet; the internet of things; virtualized networks; and related software and services.

[0082] The term 'comprise' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising Y indicates that X may comprise only one Y or may comprise more than one Y. If it is intended to use 'comprise' with an exclusive meaning then it will be made clear in the context by referring to "comprising only one" or by using "consisting".

[0083] In this description, reference has been made to various examples. The description of features or functions in relation to an example indicates that those features or functions are present in that example. The use of the term 'example' or 'for example' or 'can' or 'may' in the text denotes, whether explicitly stated or not, that such features or functions are present in at least the described example, whether described as an example or not, and that they can be, but are not necessarily, present in some of or all other examples. Thus 'example', 'for example', 'can' or 'may' refers to a particular instance in a class of examples. A property of the instance can be a property of only that instance or a property of the class or a property of a sub-class of the class that includes some but not all of the instances in the class. It is therefore implicitly disclosed that a feature described with reference to one example but not with reference to another example, can where possible be used in that other example as part of a working combination but does not necessarily have to be used in that other example.

[0084] Although examples have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the claims.

[0085] Features described in the preceding description may be used in combinations other than the combinations explicitly described above.

[0086] Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

[0087] Although features have been described with reference to certain examples, those features may also be present in other examples whether described or not.

[0088] The term 'a' or 'the' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising a/the Y indicates that X may comprise only one Y or may comprise more than one Y unless the context clearly indicates the contrary. If it is intended to use 'a' or 'the' with an exclusive meaning then it will be made clear in the context. In some circumstances the use of 'at least one' or 'one or more' may be used to emphasis an inclusive meaning but the absence of these terms should not be taken to infer any exclusive meaning.

[0089] The presence of a feature (or combination of features) in a claim is a reference to that feature or (combination of features) itself and also to features that achieve substantially the same technical effect (equivalent features). The equivalent features include, for example, features that are variants and achieve substantially the same result in substantially the same way. The equivalent features include, for example, features that perform substantially the same function, in substantially the same way to achieve substantially the same result.

[0090] In this description, reference has been made to various examples using adjectives or adjectival phrases to describe characteristics of the examples. Such a description of a characteristic in relation to an example indicates that the characteristic is present in some examples exactly as described and is present in other examples substantially as described.

[0091] Whilst endeavoring in the foregoing specification to draw attention to those features believed to be of importance it should be understood that the Applicant may seek protection via the claims in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not emphasis has been placed thereon.

Claims

1. An apparatus comprising:

a first group of first clusters of separately fed radiators configured to provide first electric fields parallel to a first direction,
wherein a first cluster of the first group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and
wherein a second cluster of the first group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions; and
a second group of second clusters of separately fed radiators configured to provide second electric fields parallel to a second direction, orthogonal to the first direction,
wherein a first cluster of the second group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and
wherein a second cluster of the second group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions.

2. An apparatus as claimed in claim 1, comprising a planar panel substrate having a length and a width; wherein one or more bent dipole radiators of one or more first clusters and one or more bent dipole radiators of one or more second clusters are positioned at width-wise extremities of the planar panel substrate.

3. An apparatus as claimed in claim 2, wherein the separately fed radiators that are configured to provide the first electric fields parallel to the first direction are comprised in printed circuit boards and/or
wherein the separately fed radiators that are configured to provide the second electric fields parallel to the second direction are dipole radiators are comprised in printed circuit boards.

4. An apparatus as claimed in any preceding claim, wherein the separately fed radiators that are configured to provide the first electric fields parallel to the first direction are dipole radiators and wherein the separately fed radiators that are configured to provide the second electric fields parallel to the second direction are dipole radiators.

5. An apparatus as claimed in any preceding claim, wherein, in a first cluster, a separately fed radiator, that is a dipole radiator, is offset from the at least one bent dipole radiator of the first cluster parallel to the second direction and wherein, in a second cluster, a separately fed radiator, that is a dipole radiator, is offset from the at least one bent dipole radiator of the second cluster parallel to the first direction

6. An apparatus as claimed in claim 5, wherein the further dipole radiator is a bent dipole radiator comprising conductive pole portions extending in different directions.

7. An apparatus as claimed in claim 5, wherein the further dipole radiator is a , unbent dipole radiator comprising conductive pole portions extending along a common line.

8. An apparatus as claimed in any preceding claim wherein, for at least one bent dipole radiator, the conductive pole portions of the bent dipole radiator extend in different orthogonal directions.

9. An apparatus as claimed in any preceding claim wherein, for at least one bent dipole radiator, at least one of the conductive pole portions of the bent dipole radiator is unitary or non-unitary and interrupted by a dielectric gap.

10. An apparatus as claimed in any preceding claim configured for dual polarized operation, wherein the multiple separately fed radiators of the first group are configured to provide physically separated clusters of first electric fields parallel to the first direction that sum to create a combined first electric field parallel to the first direction,
wherein the multiple separately fed radiators of the second group are configured to provide physically separated clusters of second electric fields parallel to the second direction that sum to create a combined second electric field parallel to the second direction.

11. An apparatus as claimed in any preceding claim, wherein a cluster of radiators is a physical association of the bent dipole radiator of the cluster and a physically closest radiator of the same group as the bent dipole radiator.

12. An apparatus as claimed in any preceding claim wherein, the first group of first clusters of separately fed radiators, including at least the bent dipole radiator, are lower-frequency radiators configured to operate in a first lower frequency passband with a first polarization, wherein the second group of second clusters of separately fed radiators, including at least the bent dipole radiator, are lower-frequency radiators configured to operate in the first lower frequency passband with a second polarization, orthogonal to the first polarization, and wherein at least some clusters comprise at least one higher-frequency radiator configured to operate in a second frequency passband that is distinct from the first frequency passband and is at a higher frequency that the first frequency passband.

13. An apparatus as claimed in any preceding claim wherein, a bent dipole radiator of a cluster of the first group and a bent-dipole radiator of a cluster of the second group share a common conductive pole portion.

14. An apparatus as claimed in any preceding claim, wherein the first group of first clusters of separately fed radiators are comprised in a first antenna wherein the second group of second clusters of separately fed radiators are comprised in the first antenna, wherein the first clusters of the first group and the second clusters of the second group alternate in a single line comprising the first clusters of the first group and the second clusters of the second group.

15. An apparatus as claimed in any preceding claim, comprising:

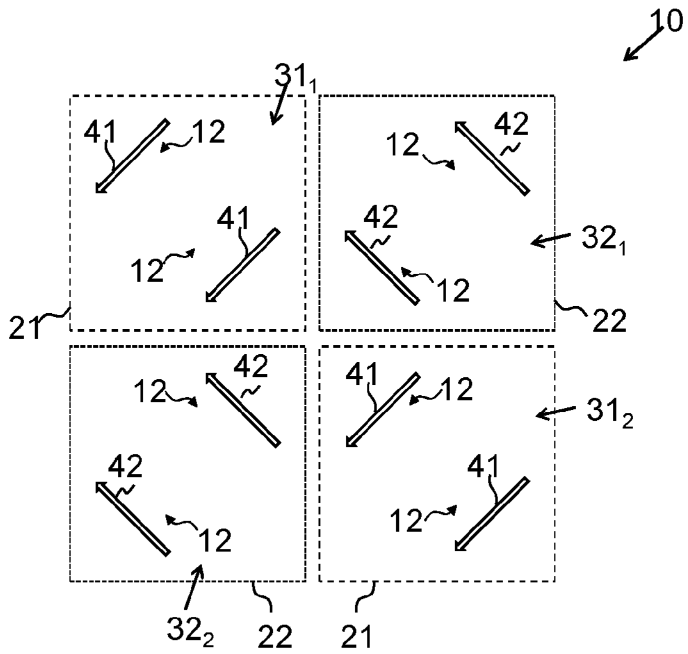
a third group of first clusters of separately fed radiators configured to provide first electric fields parallel to a first direction,

wherein a first cluster of the third group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and
wherein a second cluster of the third group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions; and

a fourth group of second clusters of separately fed radiators configured to provide second electric fields parallel to a second direction, orthogonal to the first direction,

wherein a first cluster of the fourth group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions, and
wherein a second cluster of the fourth group comprises multiple separately fed radiators including at least one bent dipole radiator comprising conductive pole portions extending in different directions,

wherein the first clusters of the first group and the second clusters of the second group alternate in a first single line comprising the first clusters of the first group and the second clusters of the second group, and
wherein the first clusters of the third group and the second clusters of the fourth group alternate in a further second single line comprising the first clusters of the third group and the second clusters of the fourth group.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31_1
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12
42
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32_1
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31_2
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12
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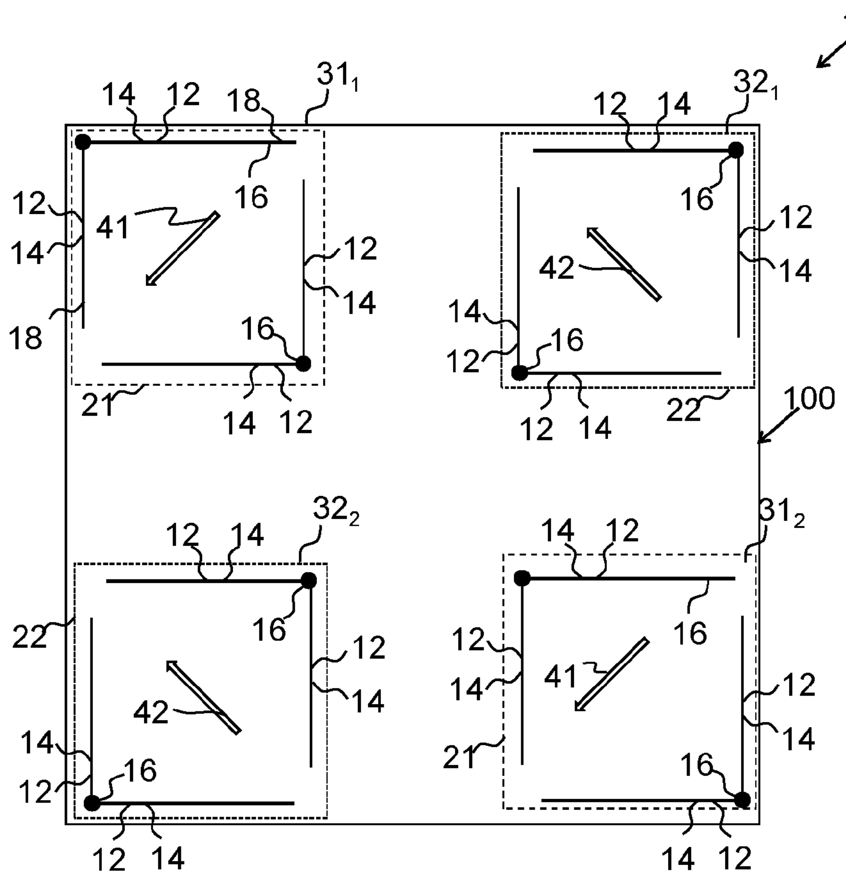
32_2
22
21

FIG 1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14
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32_1
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42
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14
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12
12
21
22
100
14
12
12
14
32_2
14
12
31_2
22
16
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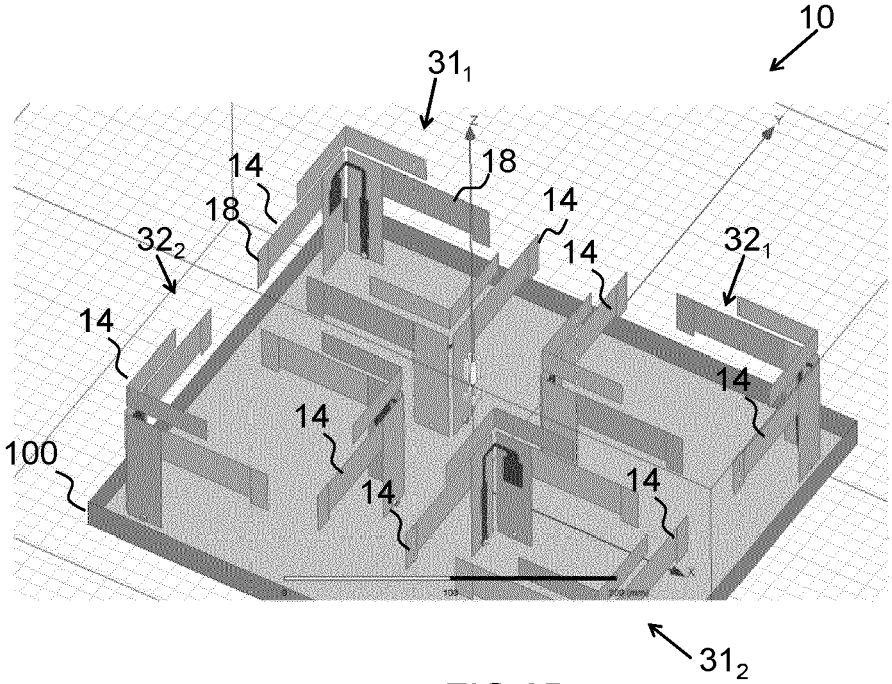
12

FIG 2A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32_2
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32_1
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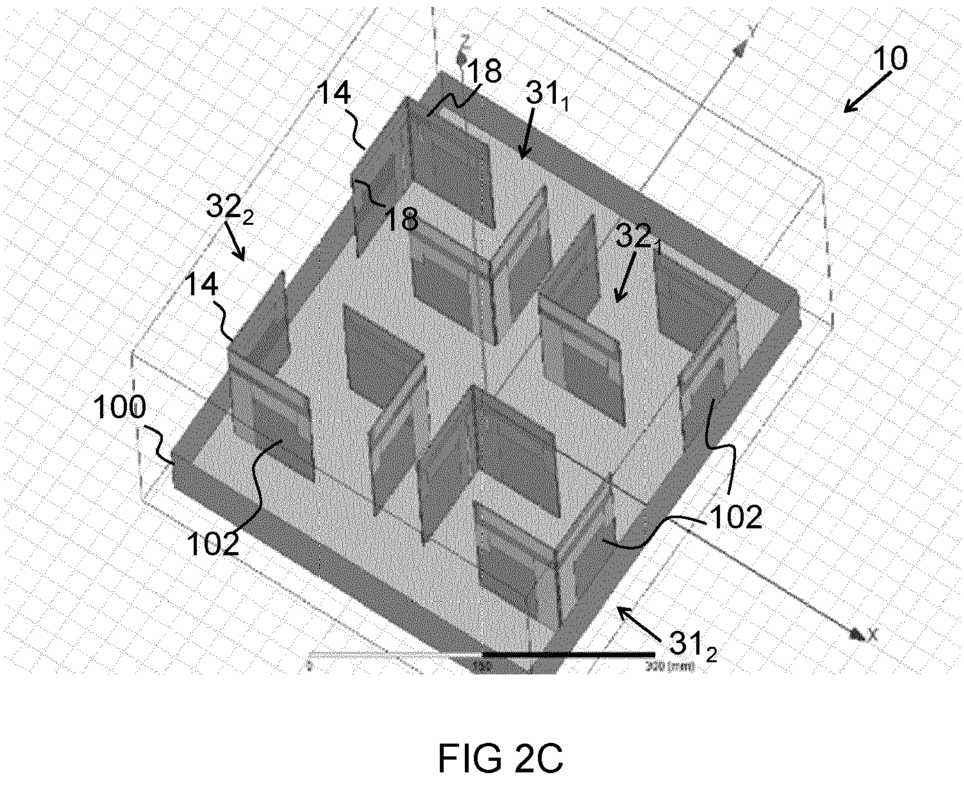
14
14
14
31_2

FIG 2B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18
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31_1
32_2
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32_1
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102
31_2

FIG 2C

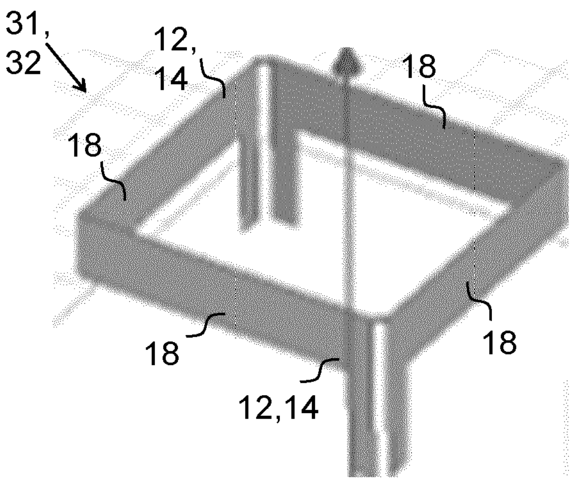


FIG 3A

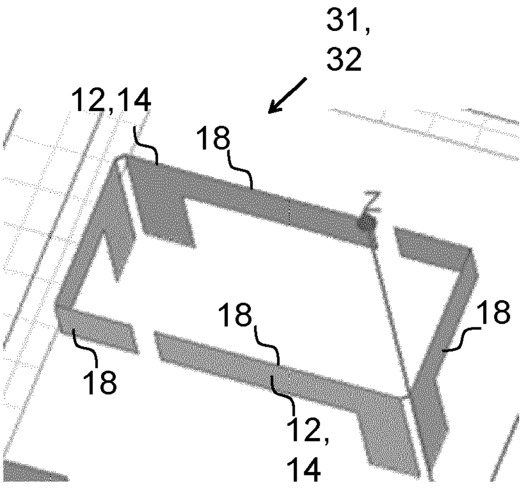


FIG 3B

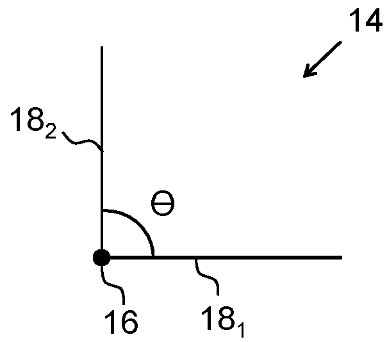


FIG 4A

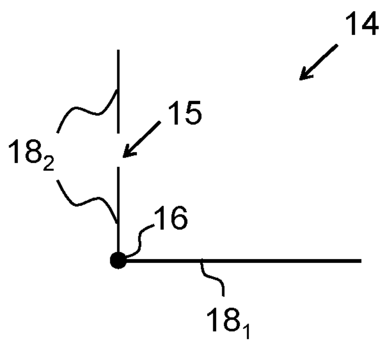


FIG 4B

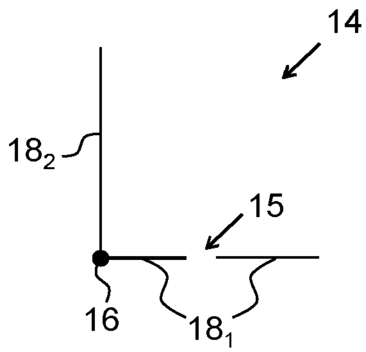
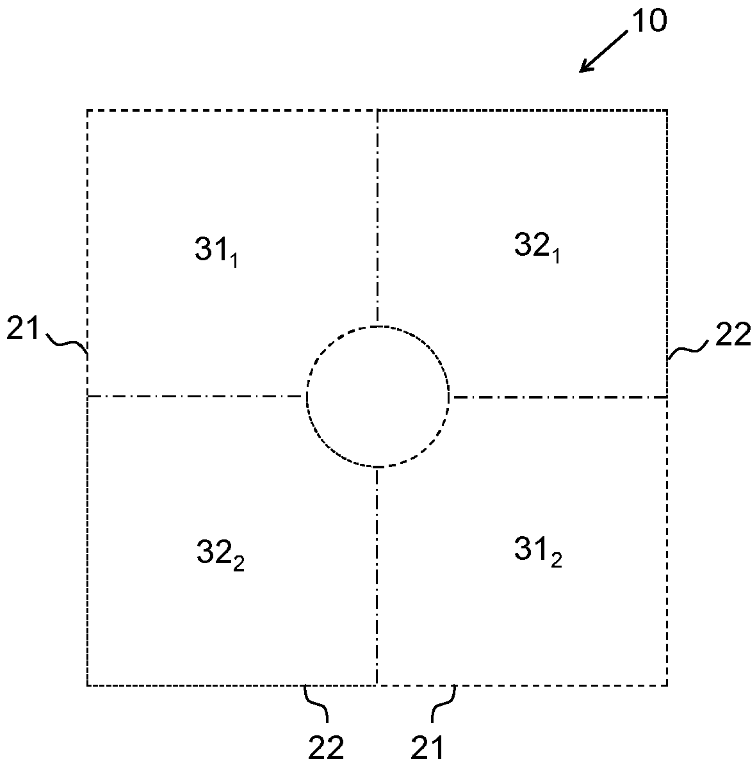


FIG 4C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32_1
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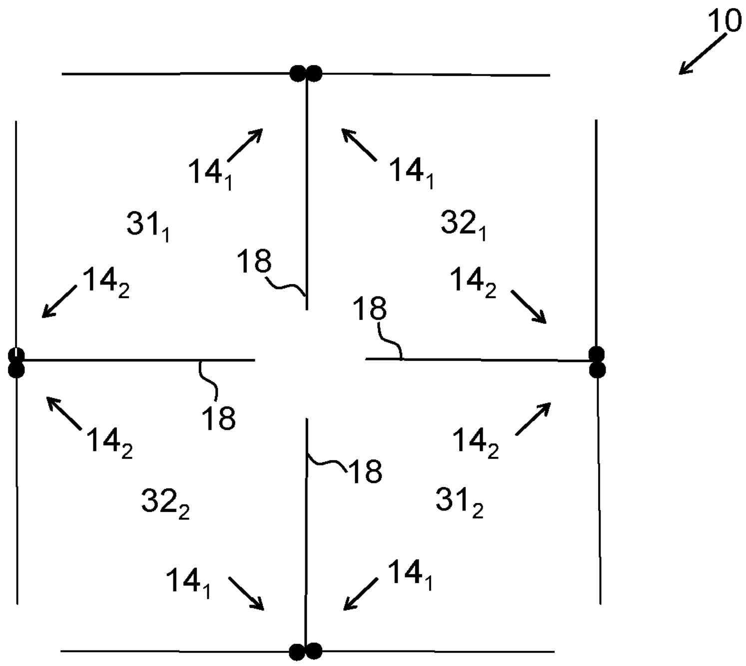
22
32_2
31_2
22
21

FIG 5A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14_1
14_1
31_1
32_1
18
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14_2
18
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14_2
14_2
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32_2
31_2
14_1
14_1

FIG 5B

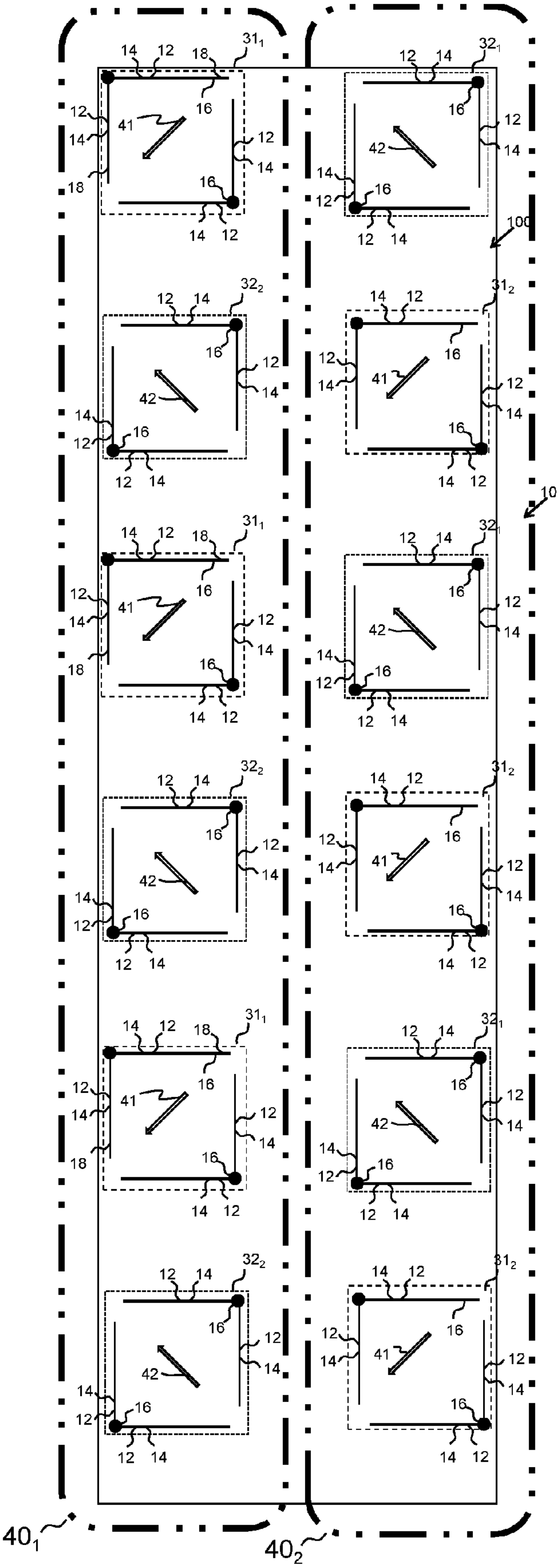
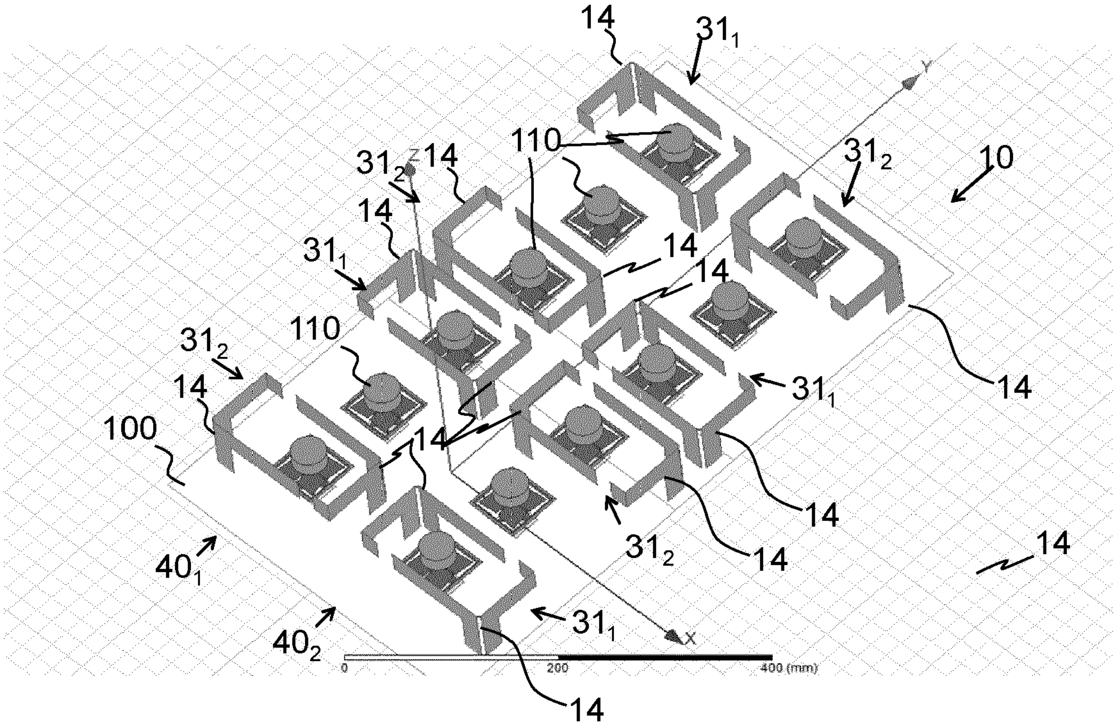


FIG 6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31₁
110
31₂
14
10
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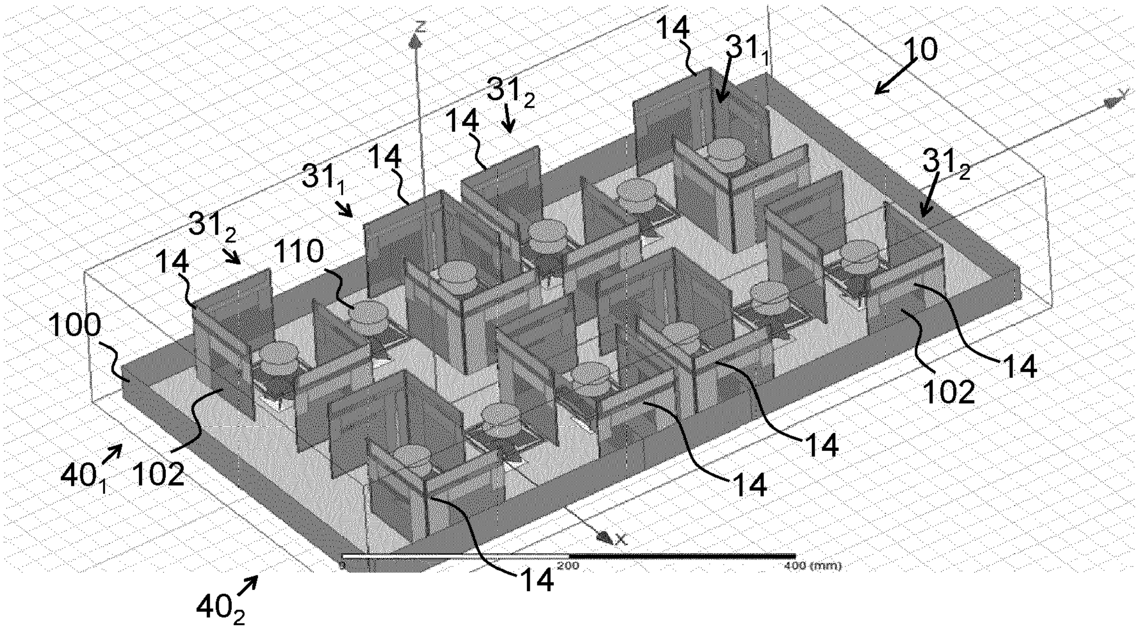
31₁
14
14
110
31₂
14
100
14
31₁
14
14
14
40₁
31₂
14
14
40₂
31₁
0
200
400 (mm)
14

FIG 7A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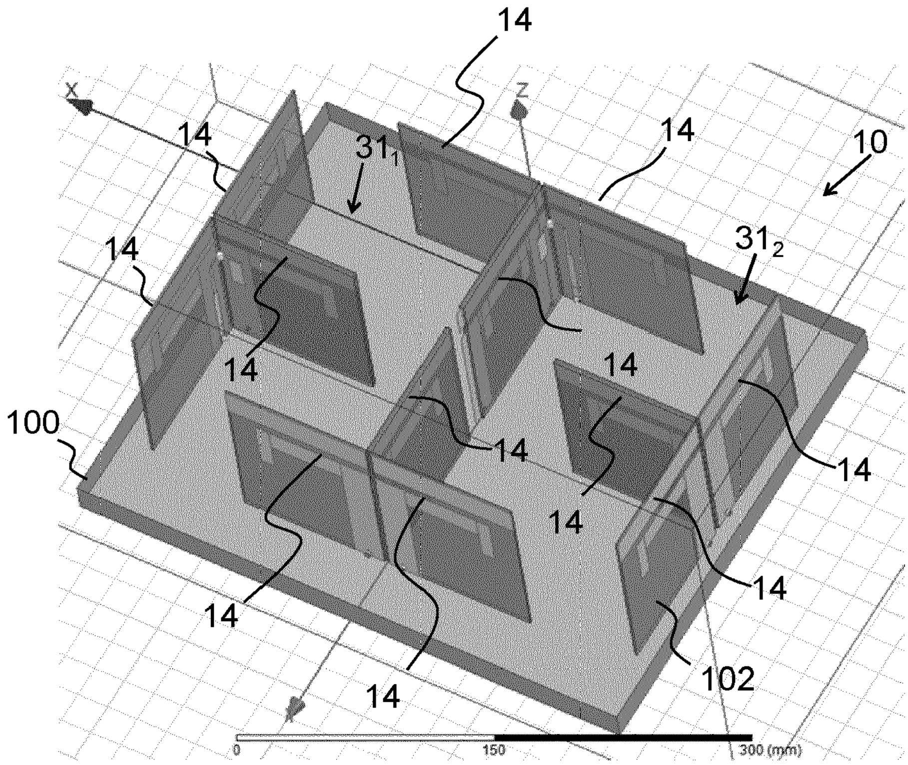
31₁
10
31₂
14
31₁
14
31₂
31₂
14
110
100
102
14
14
14
40₁
102
14
0
200
400 (mm)
40₂

FIG 7B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14
14
31_1
14
10
31_2
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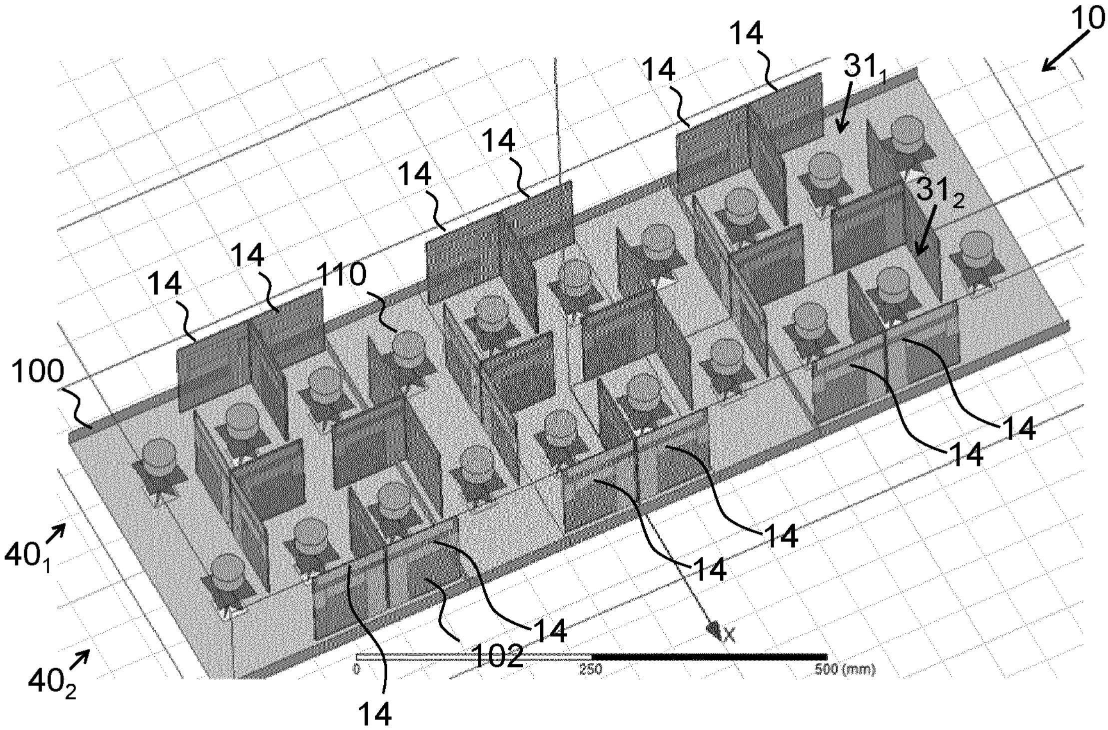
14
14
100
14
14
14
14
14
14
102
0
150
300 (mm)

FIG 8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10
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31_1
14
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31_2
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14
110
100
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14
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14
14
40_1
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40_2
0
250
500 (mm)
14

FIG 9

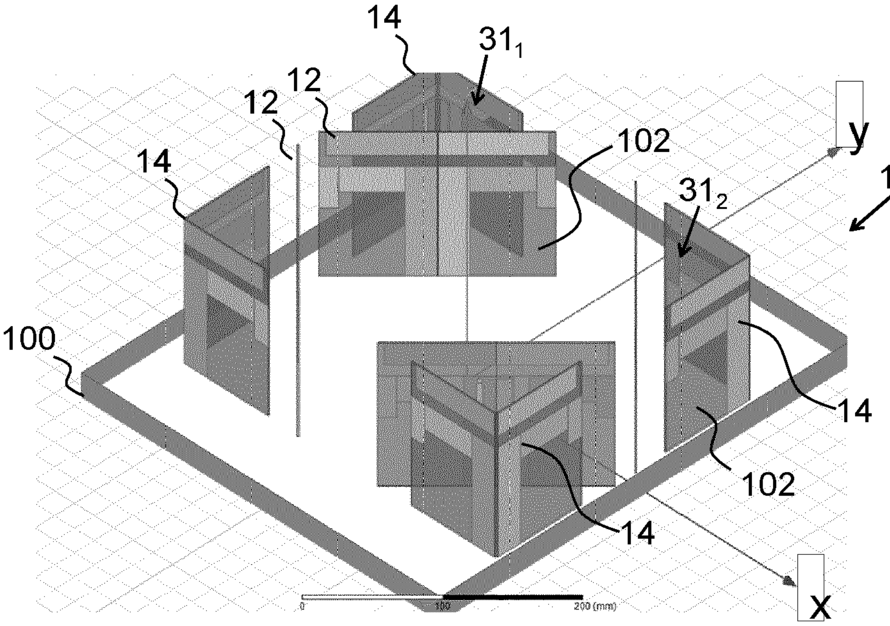

FIG 10A

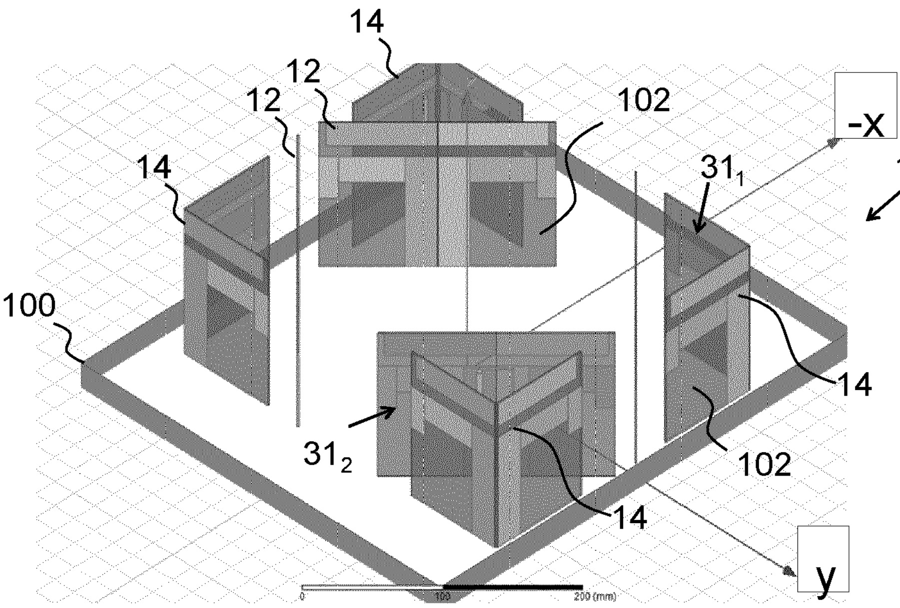

FIG 10B

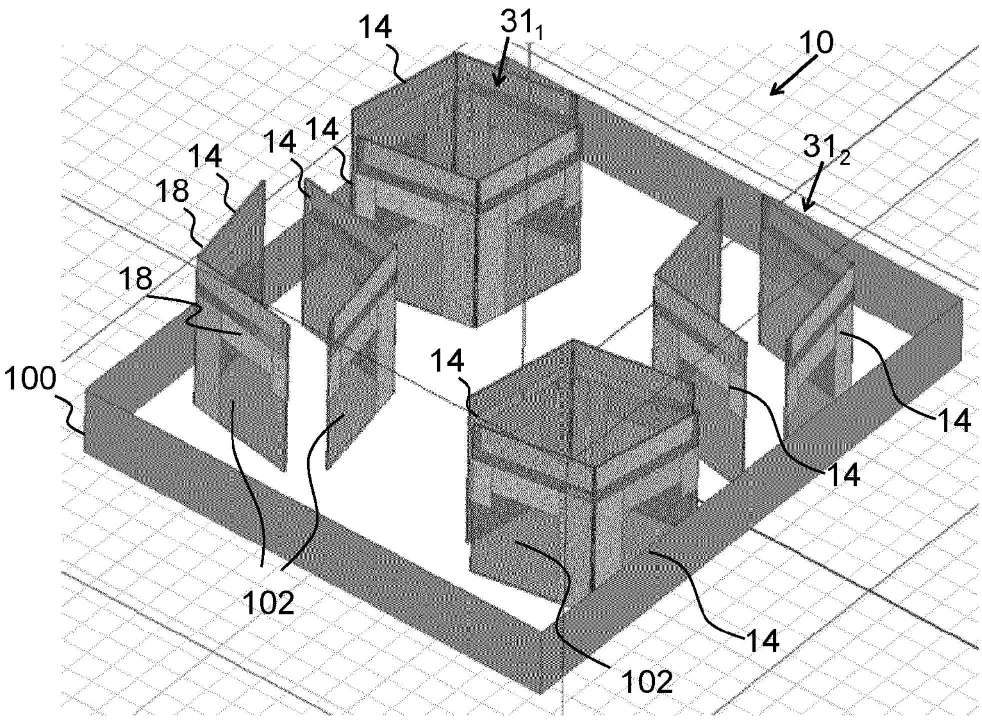

FIG 11A

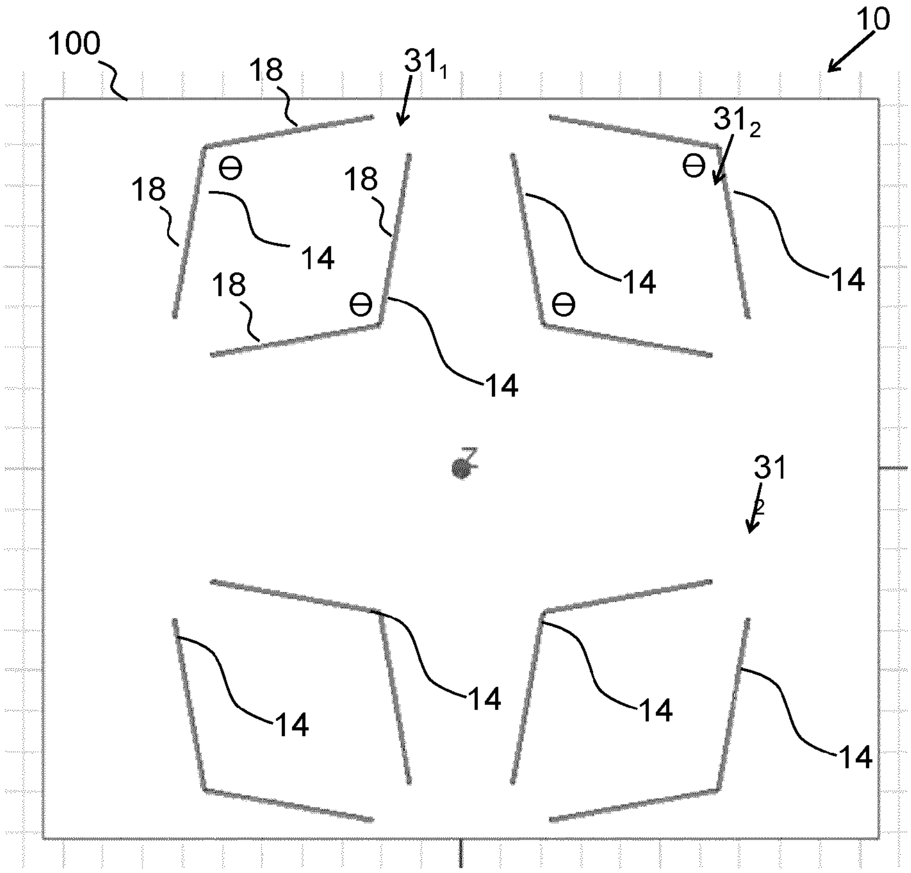

FIG 11B

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EUROPEAN SEARCH REPORT

Application Number
EP 20 19 7063

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 3 067 987 A1 (KMW INC [KR]) 14 September 2016 (2016-09-14) * paragraphs [0020] - [0028] * * figures 1, 2 * * paragraphs [0039] - [0045] * * figure 14 * -----	1-15	INV. H01Q1/24 H01Q9/26 H01Q19/10 H01Q21/06 H01Q21/24 H01Q21/28
A	US 2017/358870 A1 (HOJJAT NASRIN [CA] ET AL) 14 December 2017 (2017-12-14) * paragraph [0041] * * figure 2 * -----	1-15	
A	US 10 224 643 B2 (KMW INC [KR]) 5 March 2019 (2019-03-05) * column 5, line 53 - column 6, line 13 * * figure 9 * -----	1-15	
A	CN 105 977 652 A (COMBA TELECOM TECH (GUANGZHOU) CO LTD) 28 September 2016 (2016-09-28) * figures 7, 8 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC)
A	EP 3 089 270 A1 (HUAWEI TECH CO LTD [CN]) 2 November 2016 (2016-11-02) * paragraphs [0025] - [0027] * * figure 4 * -----	1-15	H01Q

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	1 March 2021	Culhaoglu, Ali

CATEGORY OF CITED DOCUMENTS

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

EP 20 19 7063

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