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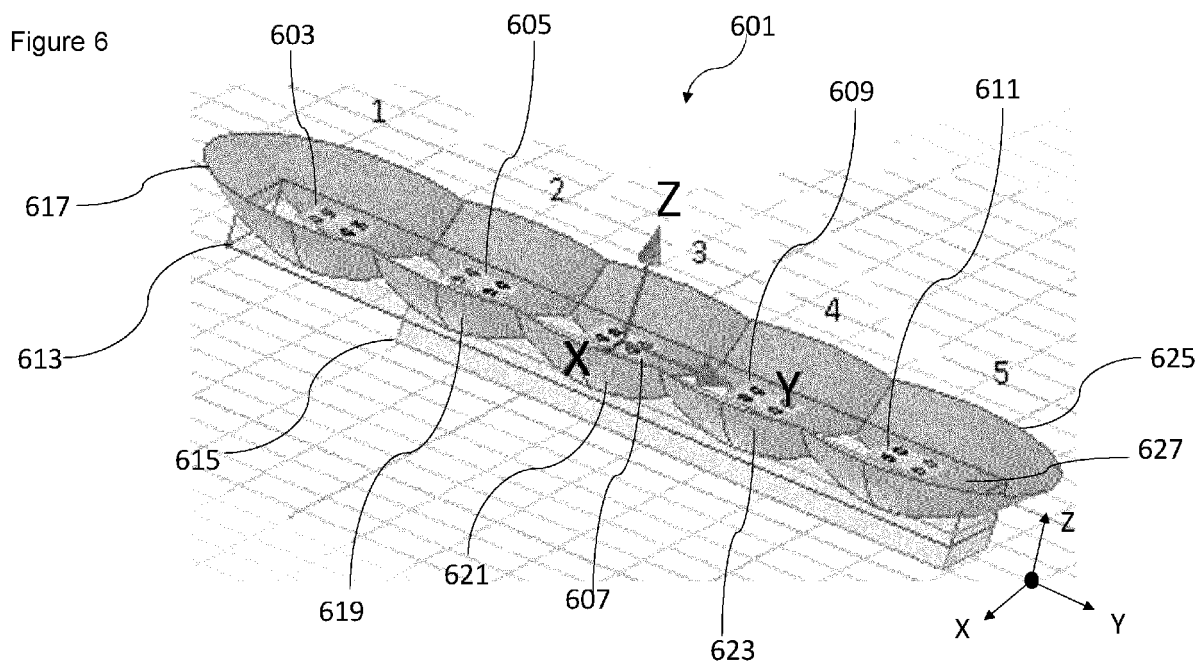
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ANTENNA APPARATUS

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There is provided an apparatus comprising: a first antenna element and a second antenna element, the first antenna element and the second antenna element being arranged to form an antenna array, and a first reflector and a second reflector, the first reflector and the second reflector being arranged to form a single reflector for the antenna array. The first reflector is associated with the first antenna element and the second reflector is associated with the second antenna element. In the apparatus, at least one of: a shape, a size, and a distance away from the associated antenna element, of the first reflector and the second reflector, is different between the first and second reflectors.



Description

Field

[0001] The present application relates to an antenna apparatus for a wireless communication system.

Background

[0002] A communication system may be a facility that enables communication sessions between two or more entities such as user terminals, base stations/access points and/or other nodes by providing carriers between the various entities involved in the communications path. A communication system may be provided, for example, by means of a communication network and one or more compatible communication devices. The communication sessions may comprise, for example, communication of data for carrying communications such as voice, electronic mail (email), text message, multimedia and/or content data and so on. Non-limiting examples of services provided comprise two-way or multi-way calls, data communication or multimedia services and access to a data network system, such as the Internet.

Summary

[0003] According to an aspect, there is provided an apparatus comprising: a first antenna element and a second antenna element, the first antenna element and the second antenna element being arranged to form an antenna array; and a first reflector and a second reflector, the first reflector and the second reflector being arranged to form a single reflector for the antenna array, wherein the first reflector is associated with the first antenna element and the second reflector is associated with the second antenna element, and wherein at least one of: a shape, a size, and a distance away from the associated antenna element, of the first reflector and the second reflector, is different between the first and second reflectors.

[0004] In an example, the first reflector is located at or behind the first antenna element, and the second reflector is located at or behind the second antenna element.

[0005] In an example, the distance away from the associated antenna element, is a distance away from the associated antenna element within the antenna array, that the reflector is located.

[0006] In an example, the first reflector is mounted at or behind the first antenna element, and the second reflector is mounted at or behind the second antenna element.

[0007] In an example, the first antenna element is a first patch antenna, and the second antenna element is a second patch antenna.

[0008] In an example, the antenna comprises five antenna elements, the five antenna elements being arranged in a 5x1 antenna array arrangement.

[0009] In an example, at least two of the reflectors are substantially the same.

[0010] In an example, the first reflector being located at or behind the first antenna element, and the second reflector being located at or behind the second antenna element is with respect to an emitting surface of the first and second antenna elements respectively. In an example, a plane of the emitting surface of the first antenna element and a plane of the emitting surface of the second antenna element is common between the first and second antenna elements.

[0011] In an example, the first antenna element and the second antenna element are substantially identical.

[0012] In an example, the first and the second antenna elements are adjacent to each other.

[0013] In an example, the first and the second antenna elements are parallel with each other.

[0014] In an example, the first and the second reflectors are adjacent to each other.

[0015] In an example, the first reflector is located behind the first antenna element in a z-direction with respect to an emitting surface of the first antenna element, and wherein the second reflector is located behind the second antenna element in the z-direction with respect to an emitting surface of the second antenna element.

[0016] In an example, the shape and the size of the first reflector is different to the second reflector.

[0017] In an example, at least one of the first and second reflectors are hyperbolic reflectors.

[0018] In an example, at least one of: the first reflector and the second reflector, each comprise a first part, and a second part, wherein the first part has at least one of: a shape, and a size, which is different to at least one of: a shape, and a size, of the second part.

[0019] In an example, the apparatus comprises: three or more antenna elements, each of the three or more antenna elements being associated with an individual reflector, wherein at least two of the individual reflectors are different in at least one of: a shape, a size, and a distance away from the associated antenna element.

[0020] In an example, the two or more antenna elements are arranged in a strip, each of the antenna elements positioned in parallel to each other, each of the antenna elements having an emitting surface on a plane that is common to the two or more antenna elements.

[0021] In an example, the first reflector and the second reflector are fixed, within the antenna module, at offset angles from one another, such that the first and second reflectors have a different radiation direction.

[0022] In an example, the antenna array is comprised within a fixed wireless access device.

[0023] According to an aspect, there is provided a user equipment comprising an apparatus, the apparatus comprising: a first antenna element and a second antenna element, the first antenna element and the second antenna element being arranged to form an antenna array; and a first reflector and a second reflector, the first reflector and the second reflector being arranged to form

a single reflector for the antenna array, wherein the first reflector is associated with the first antenna element and the second reflector is associated with the second antenna element, and wherein at least one of: a shape, a size, and a distance away from the associated antenna element, of the first reflector and the second reflector, is different between the first and second reflectors.

[0024] In an example, the first reflector is located at or behind the first antenna element, and the second reflector is located at or behind the second antenna element.

[0025] In an example, the distance away from the associated antenna element, is a distance away from the associated antenna element within the antenna array, that the reflector is located.

[0026] In an example, the first reflector is mounted at or behind the first antenna element, and the second reflector is mounted at or behind the second antenna element.

[0027] In an example, the first antenna element is a first patch antenna, and the second antenna element is a second patch antenna.

[0028] In an example, the antenna comprises five antenna elements, the five antenna elements being arranged in a 5x1 antenna array arrangement.

[0029] In an example, at least two of the reflectors are substantially the same.

[0030] In an example, the first reflector being located at or behind the first antenna element, and the second reflector being located at or behind the second antenna element is with respect to an emitting surface of the first and second antenna elements respectively. In an example, a plane of the emitting surface of the first antenna element and a plane of the emitting surface of the second antenna element is common between the first and second antenna elements.

[0031] In an example, the first antenna element and the second antenna element are substantially identical.

[0032] In an example, the first and the second antenna elements are adjacent to each other.

[0033] In an example, the first and the second antenna elements are parallel with each other.

[0034] In an example, the first and the second reflectors are adjacent to each other.

[0035] In an example, the first reflector is located behind the first antenna element in a z-direction with respect to an emitting surface of the first antenna element, and wherein the second reflector is located behind the second antenna element in the z-direction with respect to an emitting surface of the second antenna element.

[0036] In an example, the shape and the size of the first reflector is different to the second reflector.

[0037] In an example, at least one of the first and second reflectors are hyperbolic reflectors.

[0038] In an example, at least one of: the first reflector and the second reflector, each comprise a first part, and a second part, wherein the first part has at least one of: a shape, and a size, which is different to at least one of: a shape, and a size, of the second part.

[0039] In an example, the apparatus comprises: three or more antenna elements, each of the three or more antenna elements being associated with an individual reflector, wherein at least two of the individual reflectors are different in at least one of: a shape, a size, and a distance away from the associated antenna element.

[0040] In an example, the two or more antenna elements are arranged in a strip, each of the antenna elements positioned in parallel to each other, each of the antenna elements having an emitting surface on a plane that is common to the two or more antenna elements.

[0041] In an example, the first reflector and the second reflector are fixed, within the antenna module, at offset angles from one another, such that the first and second reflectors have a different radiation direction.

[0042] In an example, the antenna array is comprised within a fixed wireless access device. An electronic device may comprise the apparatus as described herein.

[0043] In the above, various aspects have been described. It should be appreciated that further aspects may be provided by the combination of any two or more of the various aspects described above.

[0044] Various other aspects and further embodiments are also described in the following detailed description and in the attached claims.

[0045] According to some aspects, there is provided the subject matter of the independent claims. Some further aspects are defined in the dependent claims. The embodiments that do not fall under the scope of the claims are to be interpreted as examples useful for understanding the disclosure.

List of abbreviations:

[0046]

AF:	Application Function
AMF:	Access Management Function
AN:	Access Network
BS:	Base Station
CN:	Core Network
DL:	Downlink
eNB:	eNodeB
FWA:	Fixed Wireless Access
gNB:	gNodeB
IIoT:	Industrial Internet of Things
LTE:	Long Term Evolution
NEF:	Network Exposure Function
NG-RAN:	Next Generation Radio Access Network
NF:	Network Function
NR:	New Radio
NRF:	Network Repository Function
NW:	Network
MIMO:	Multiple Input Multiple Output
mmWave:	Millimetre Wave
MS:	Mobile Station
PCF:	Policy Control Function
PLMN:	Public Land Mobile Network

RAN:	Radio Access Network
RF:	Radio Frequency
SMF:	Session Management Function
TP:	Throughput
UAV:	Unmanned Aerial Vehicle
UE:	User Equipment
UDR:	Unified Data Repository
UDM:	Unified Data Management
UL:	Uplink
UPF:	User Plane Function
XPD:	Cross Polar Discrimination
3GPP:	3 rd Generation Partnership Project
5G:	5 th Generation
5GC:	5G Core network
5G-AN:	5G Radio Access Network
5GS:	5G System

Description of Figures

[0047] Embodiments will now be described, by way of example only, with reference to the accompanying Figures in which:

Figure 1 shows a schematic representation of a 5G system;
 Figure 2 shows a schematic representation of a control apparatus;
 Figure 3 shows a schematic representation of a terminal;
 Figure 4 shows a schematic representation of a fixed wireless access system;
 Figure 5 shows a schematic representation of an antenna module, shown with an isometric view;
 Figure 6 shows a schematic representation of an antenna module with reflectors associated with each antenna of the module, shown with an isometric view;
 Figure 7 shows a graphical representation of a simulated performance of the antenna module according to Figure 5;
 Figure 8 shows a graphical representation of a simulated performance of the antenna module according to Figure 6;
 Figures 9a and 9b show graphical representations of a simulated performance of the antenna modules according to Figures 5 and 6;
 Figure 10a shows a schematic representation of a mobile device comprising an antenna module, shown with an isometric view;
 Figure 10b shows a schematic representation of an antenna module, suitable for a mobile device; and
 Figure 11 shows a schematic representation of an antenna module with optimised half reflectors, shown with a top (plan) view.

Detailed description

[0048] Before explaining in detail some examples of

the present disclosure, certain general principles of a wireless communication system and mobile communication devices are briefly explained with reference to Figures 1 to 3 to assist in understanding the technology underlying the described examples.

[0049] In a wireless communication system 100, such as that shown in Figure 1, mobile communication devices/terminals or user apparatuses, and/or user equipments (UE), and/or machine-type communication devices 102 are provided wireless access via at least one base station (not shown) or similar wireless transmitting and/or receiving node or point. A communication device is provided with an appropriate signal receiving and transmitting apparatus for enabling communications, for example enabling access to a communication network or communications directly with other devices. The communication device may access a carrier provided by a station or access point, and transmit and/or receive communications on the carrier.

[0050] In the following certain examples are explained with reference to mobile communication devices capable of communication via a wireless cellular system and mobile communication systems serving such mobile communication devices. Before explaining in detail the examples of the disclosure, certain general principles of a wireless communication system, access systems thereof, and mobile communication devices are briefly explained with reference to Figures 1, 2 and 3 to assist in understanding the technology underlying the described examples.

[0051] Figure 1 shows a schematic representation of a 5G system (5GS) 100. The 5GS may comprise a device 102 such as user equipment or terminal, a 5G radio access network (5G-RAN) 106, a 5G core network (5GC) 104, one or more network functions (NF), one or more application function (AF) 108 and one or more data networks (DN) 110.

[0052] The 5G-RAN 106 may comprise one or more gNodeB (gNB) distributed unit functions connected to one or more gNodeB (gNB) centralized unit functions.

[0053] The 5GC 104 may comprise an access management function (AMF) 112, a session management function (SMF) 114, an authentication server function (AUSF) 116, a user data management (UDM) 118, a user plane function (UPF) 120, a network exposure function (NEF) 122 and/or other NFs. Some of the examples as shown below may be applicable to 3GPP 5G standards. However, some examples may also be applicable to 4G, 3G and other 3GPP standards.

[0054] In a communication system, such as that shown in Figure 1, mobile communication devices/terminals or user apparatuses, and/or user equipments (UE), and/or machine-type communication devices are provided with wireless access via at least one base station, such as and not limited to a gNB, or similar wireless transmitting and/or receiving node or point. The terminal is provided with an appropriate signal receiving and transmitting apparatus for enabling communications, for example ena-

bling access to a communication network or communications directly with other devices. The communication device may access a carrier provided by a base station or access point, and transmit and/or receive communications on the carrier.

[0055] Figure 2 illustrates an example of a control apparatus 200 for controlling a function of the 5G-RAN or the 5GC as illustrated on Figure 1. The control apparatus may comprise at least one random access memory (RAM) 211a, at least one read only memory (ROM) 211b, at least one processor 212, 213 and an input/output interface 214. The at least one processor 212, 213 may be coupled to the RAM 211a and the ROM 211b. The at least one processor 212, 213 may be configured to execute an appropriate software code 215. The software code 215 may for example allow to perform one or more steps to perform one or more of the present aspects. The software code 215 may be stored in the ROM 211b. The control apparatus 200 may be interconnected with another control apparatus 200 controlling another function of the 5G-RAN or the 5GC. In some examples, each function of the 5G-RAN or the 5GC comprises a control apparatus 200. In alternative examples, two or more functions of the 5G-RAN or the 5GC may share a control apparatus.

[0056] Figure 3 illustrates an example of a terminal 300, such as the terminal illustrated on Figure 1. The terminal 300 may be provided by any device capable of sending and receiving radio signals. Non-limiting examples comprise a user equipment, a mobile station (MS) or mobile device such as a mobile phone or what is known as a 'smart phone', a computer provided with a wireless interface card or other wireless interface facility (e.g., USB dongle), a personal data assistant (PDA) or a tablet provided with wireless communication capabilities, a machine-type communications (MTC) device, a Cellular Internet of things (CIoT) device or any combinations of these or the like. The terminal 300 may provide, for example, communication of data for carrying communications. The communications may be one or more of voice, electronic mail (email), text message, multimedia, data, machine data and so on.

[0057] The terminal 300 may receive signals over an air or radio interface 307 via appropriate apparatus for receiving and may transmit signals via appropriate apparatus for transmitting radio signals. In Figure 3, an apparatus is designated schematically by block 306. The apparatus may be configured as a transmitter, a receiver, or a transceiver. The apparatus 306 may be provided for example by means of a radio part and associated antenna arrangement. The antenna arrangement may be arranged internally, externally, or both internally and externally to the mobile device. The apparatus 306 may be configured for cellular communications in some systems. The apparatus 306 may be configured to use to non-cellular radio systems in some systems.

[0058] The terminal 300 may be provided with at least one processor 301, at least one memory ROM 302a, at least one RAM 302b and other possible components 303

for use in software and hardware aided execution of tasks it is designed to perform, including control of access to and communications with access systems and other communication devices. The at least one processor 301 is coupled to the RAM 302b and the ROM 302a. The at least one processor 301 may be configured to execute an appropriate software code 308. The software code 308 may for example allow to perform one or more of the present aspects. The software code 308 may be stored in the ROM 302a.

[0059] The processor, storage and other relevant control apparatus may be provided on an appropriate circuit board and/or in chipsets. This feature is denoted by reference 304. The device may optionally have a user interface such as keypad 305, touch sensitive screen or pad, combinations thereof or the like. Optionally one or more of a display, a speaker and a microphone may be provided depending on the type of the device.

[0060] Some of the following examples are applicable to fixed wireless access (FWA). FWA is a way of providing connectivity through radio links between two fixed points, in a wireless manner. FWA is a way to provide wireless internet access to homes/businesses without providing cables (e.g. fibre or telephone cables) to provide connectivity. FWA enables network operators to provide ultra-high-speed broadband to sub-urban and rural areas where the cost of providing network cables is prohibitively expensive. Other fixed wireless technologies, such as WiMAX, have had challenges because they demanded a completely new overlay infrastructure and expensive proprietary equipment.

[0061] Figure 4 shows a schematic representation a fixed wireless access system. The system comprises a house, or other type of building, 401 that has wireless devices 403. The wireless devices 403 may include a laptop, a user equipment, a television or a computer. The wireless devices 403 connect to a router device 405 wirelessly. The router device 405 is connected to an antenna (antenna module) 407. The router device 405 may be connected to the antenna 407 with a wired, or wireless connection (or both).

[0062] The antenna 407 is able to communicate with a base station (gNB) 409. The base station 409 is connected to a network 411 (i.e. the internet). In this way, in comparison to a typical (DSL) broadband connection, the house 401 is provided with an internet connection in a wireless manner (i.e. the router device 405 does not need to be connected to a wired fibre or telephone cable).

[0063] Many communication devices comprise one or more antennas. The antennas may be part of array modules. In devices with array modules, the designer of said device may determine a compromise between cost and size. The smaller and less costly the array module, the more the device will suffer performance wise, compared to a larger and more expensive array module. Furthermore, in some systems, the array module may be designed to be used in a plurality of devices (rather than designed for a specific use/certain device). The effects

on the performance of the array module from other components in the device can be substantial.

[0064] For example, viable commercial FWA millimetre wave (mmWave) devices currently rely on mmWave modules aimed for mobile devices. The cheaper modules are often preferred because large FWA-specific modules can be very expensive. Development of FWA-specific modules can be expensive and/or complicated. In many cases, designers of devices may not even consider FWA-specific modules.

[0065] However, one of the mobile mmWave module problems is low polarization isolation/cross polarization discrimination (XPD). XPD is an antenna parameter. XPD is important for a low level of correlation between the orthogonally polarized propagation channels. Correlation generated by the antenna can negatively affect receive diversity and MIMO downlink/uplink performance of the system. In short, XPD is a measure of how polar an antenna element is, and is used to measure the rejection of an orthogonally polarised transmission. A high XPD figure means a cleaner signal in co-located transmission environments.

[0066] In some examples, XPD is the ratio of i) the signals (desired) on the desired polarization to ii) the signals (undesired) signals on the opposite polarization. In other examples XPD (in decibels) is the difference between the peak of the co-polarized main beam, and the maximum cross-polarized signal over an angle twice the 3dB beamwidth of the co-polarized main beam.

[0067] Mobile antenna array modules may often suffer from a less than optimal XPD/polarization isolation when located in a larger device, which is close by to other components/mechanics within that larger device. Optimization may be suboptimal due to the cost and size restrictions, as well as multiband environment requirements. Polarization isolation is one of the defining parameters of communication link rank.

[0068] An antenna module is illustrated in Figure 5. Figure 5 shows a schematic representation of the antenna module, shown with an isometric view. Figure 5 is shown with a Cartesian coordinate system for a three-dimensional space which comprises an ordered triplet of lines (the axes) that go through a common point (the origin), and are pair-wise perpendicular; an orientation for each axis; and a single unit of length for all three axes. In this example, the axes are represented with 'x', 'y', and 'z'.

[0069] In this antenna module 501 there are provided five antenna elements, including a first antenna element 503, a second antenna element 505, a third antenna element 507, a fourth antenna element 509, and a fifth antenna element 511. It is noted that in Figure 5, the full antenna structure is not shown. Each of the five antenna elements 503, 505, 507, 509, 511 comprise four antenna feeds. Two of the antenna feeds may be provided for different polarizations, with the other two antenna feeds being provided for different frequency bands and two polarizations. The five antenna elements 503, 505, 507,

509, 511 are arranged adjacently to each other. The 'x' and 'y' plane define an emitting surface for the five antenna elements 503, 505, 507, 509, 511. The five antenna elements 503, 505, 507, 509, 511 may propagate signals outwards in the 'z' plane direction. The five antenna elements 503, 505, 507, 509, 511 are mounted/fixed to a substrate 513. The substrate is fixed to a base 515. The base 515 may include antenna module sub circuits. For example, and not limited to, low-noise amplifiers (LNAs), power amplifiers (PAs), filters, and wiring.

[0070] This antenna module may suffer one or more of the problems identified above such as a low XPD figure. This low XPD figure may mean that this type of antenna module may perform poorly in some use cases, such as for example FWA.

[0071] One or more of the following examples aim to address one or more of the problems discussed above.

[0072] In examples, there is provided an apparatus comprising: a first antenna element and a second antenna element, the first antenna element and the second antenna element being arranged to form an antenna array; and a first reflector and a second reflector, the first reflector and the second reflector being arranged to form a single reflector for the antenna array, wherein the first reflector is associated with the first antenna element and the second reflector is associated with the second antenna element, and wherein at least one of: a shape, a size, and a distance away from the associated antenna element, of the first reflector and the second reflector, is different between the first and second reflectors. This will be described in more detail below.

[0073] Figure 6 shows a schematic representation of an antenna module with reflectors associated with each antenna of the module, shown with an isometric view. Figure 6 is shown with a Cartesian coordinate system for a three-dimensional space, with 'x', 'y', and 'z'.

[0074] The antenna module 601 comprises five antenna elements, including a first antenna element 603, a second antenna element 605, a third antenna element 607, a fourth antenna element 609, and a fifth antenna element 611. The five antenna elements 603, 605, 607, 609, 611 are mounted/fixed to a substrate 613. The substrate is fixed to a base 615. The base 615 may include antenna module sub circuits, such as for example, and not limited to, LNAs, PAs, filters, wiring, etc.

[0075] The five antenna elements 603, 605, 607, 609, 611 together form a (single) antenna array. The (single) antenna array generates a single radiation pattern or beam.

[0076] The first antenna element 603 is associated with a first reflector 617. The second antenna element 605 is associated with a second reflector 619. The third antenna element 607 is associated with a third reflector 621. The fourth antenna element 609 is associated with a fourth reflector 623. The fifth antenna element 611 is associated with a fifth reflector 625. In this way, a separate reflector is provided for each antenna element. An (antenna) reflector is a device that reflects electromagnetic (EM)

waves. When integrated into an antenna array/module, the reflector serves to modify the radiation pattern of the antenna, increasing gain in a given direction.

[0077] In this example antenna module 601 of Figure 6, the five antenna elements 603, 605, 607, 609, 611 are arranged next to each other in the 'y' direction. A primary radiation direction from the five antenna elements 603, 605, 607, 609, 611 is in the 'z' direction. It should be understood that the antenna elements may radiate in other direction than solely the 'z' direction.

[0078] An overall radiation pattern of the antenna module 601 is due to a combination, or sum of, all of the antenna elements 603, 605, 607, 609, 611 and their respective reflectors 617, 619, 621, 623, 625. This may include any optional weighting in amplitude and/or phase at each antenna element 603, 605, 607, 609, 611.

[0079] Each reflector 617, 619, 621, 623, 625 may be in close proximity to the respective antenna element 603, 605, 607, 609, 611 that each reflector 617, 619, 621, 623, 625 is associated with. For example each reflector 617, 619, 621, 623, 625 may be arranged such that each reflector is between 1 millimetre (mm) and 10mm from the respective antenna element 603, 605, 607, 609, 611 that each reflector 617, 619, 621, 623, 625 is associated with. In other examples, each reflector may be arranged with less than 1mm distance, or more than 10mm distance. It should be understood that the distance between the reflector and the antenna array may be dependent on the overall dimensions of the antenna array, and/or the larger device that the antenna array is to fit into.

[0080] The reflectors 617, 619, 621, 623, 625 may be combined into a single reflector for the (single) antenna array. In this way, each of the reflectors 617, 619, 621, 623, 625 may be considered as a reflector portion of the single reflector. In other words, the single or overall reflector for the (single) antenna array comprises the reflectors 617, 619, 621, 623, 625 which work together with the single antenna array to generate and direct a radio frequency radiation pattern or beam in a certain direction and over an operational frequency band.

[0081] The reflectors 617, 619, 621, 623, 625 may be electrically coupled to one another to form a single reflector.

[0082] At least one of the reflectors 617, 619, 621, 623, 625 may be grounded to a ground plane at one or more points/locations. The reflectors 617, 619, 621, 623, 625 may be combined into a single reflector, wherein the single reflector is grounded to a ground plane at one or more points/locations.

[0083] At least one of the reflectors 617, 619, 621, 623, 625 may be electrically floating. When electrically floating, no electric potential is coupled to the reflector(s). The reflectors 617, 619, 621, 623, 625 may be combined into a single reflector, wherein the single reflector is electrically floating.

[0084] Each of the reflectors 617, 619, 621, 623, 625 may be optimised for each antenna element that they are associated with, within the module 601. The shape of the

reflector may be determined to best suit the antenna element that the reflector is associated with. The size of the reflector may be determined to best suit the antenna element that the reflector is associated with. The distance of the reflector away from the associated antenna module, within the module, may be determined to best suit the antenna element that the reflector is associated with.

[0085] In Figure 6, the shape and size of the first reflector 617 is different to the shape and size of the second reflector 619. The shape and size of the second reflector 619 and the third reflector 621 is substantially the same.

[0086] In Figure 6, the reflectors 617, 619, 621, 623, 625 are located within the substrate 613 approximately equidistant from the respective antenna elements 603, 605, 607, 609, 611. Said another way, the distance between each reflector and the associated antenna element is the same. In other examples, one or more of the distances may be different. The distance may be selected in order to optimise the performance of that reflector and antenna element pair.

[0087] The first reflector 617 is mounted behind the first antenna element 603. In this context, the first reflector 617 is mounted behind the first antenna element 603 in the 'z' direction (plane) of the antenna module 601 relative to the (primary) direction of radiation from the first antenna element 603. The second reflector 619 is mounted behind the second antenna element 605. The third reflector 621 is mounted behind the third antenna element 607. The fourth reflector 623 is mounted behind the fourth antenna element 609. The fifth reflector 625 is mounted behind the fifth antenna element 611. In other examples, each reflector is mounted at the associated antenna element. The reflectors may be centred behind or at the associated antenna element. The centring of the reflector with respect to the antenna elements improves the reflection of EM waves from the antennas.

[0088] The reflectors are behind the associated antenna elements in a sense that the radiation direction/pattern is away from the reflectors, in the 'z' direction.

[0089] The five antenna elements 603, 605, 607, 609, 611 are arranged adjacently to each other. In this way, the first antenna element 603 is adjacent to the second antenna element 605, which is adjacent to the third antenna element 607, which is adjacent to the fourth antenna element 609, which is adjacent to the fifth antenna element 611. In this way, the arrangement of the five antenna elements 603, 605, 607, 609, 611 may be referred to as a 'strip' arrangement. In this way, the arrangement of the five antenna elements 603, 605, 607, 609, 611 may be referred to as a '5×1' array arrangement. This may be termed a linear array, in some examples.

[0090] The five reflectors 617, 619, 621, 623, 625 are arranged adjacently to each other. In this way, the first reflector 617 is adjacent to the second reflector 619, which is adjacent to the third reflector 621, which is adjacent to the fourth reflector 623, which is adjacent to the fifth reflector 625.

[0091] The five antenna elements 603, 605, 607, 609, 611 are arranged in parallel to each other within the antenna module 601.

[0092] Each of the five antenna elements 603, 605, 607, 609, 611 comprise four antenna feeds, in this example. Other antenna elements in other antenna array designs may have more feeds, or less feeds, than in this example.

[0093] The different antenna feeds may be configured for different polarizations and/or different frequency bands. Each of the five antenna elements 603, 605, 607, 609, 611 is a patch antenna. A patch antenna is a type of antenna with a low profile, which can be mounted on a surface. A patch antenna comprises a planar rectangular, circular, triangular, or any geometrical sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane. In this example, the five antenna elements 603, 605, 607, 609, 611 are mounted on a first surface of the substrate 613 (i.e. the same surface). In this way, the five antenna elements 603, 605, 607, 609, 611 have a common emitting surface 627. The emitting surface 627 is in the 'x' and 'y' planes of the antenna module 601. The five antenna elements 603, 605, 607, 609, 611 may be configured for transmitting/receiving signals via the emitting surface 627.

[0094] The five antenna elements 603, 605, 607, 609, 611 may be arranged to transmit or receive radio frequency (RF) signals in a particular direction, the direction being defined, at least in part, by the weighting (amplitude and/or phase) applied to each antenna element of the antenna module 601. Each antenna element in the antenna module 601 may have the same or a different amplitude and/or phase applied to it than an adjacent antenna element of the antenna module 601. The antenna radiation pattern "beam" may be steered by applying different weights to each of the five antenna elements 603, 605, 607, 609, 611 of the module 601, therefore giving the beam a specific direction, gain and/or beamwidth. The use of weighting is optional in some examples. For example (and not limited to), adaptive beam-steering in any example described herein, since the antenna array and reflector(s) may be designed to generate a directional radiation pattern, the main beam of which propagates in a pre-determined direction. In an adaptive beam-steering situation the beam may be adaptively steered, with respect to time, away from its initial direction (due to no weighting applied). If no beam-steering is performed in a given example, then the weighting may be omitted and a fixed beam and fixed direction of the beam is generated by the antenna array and reflector(s).

[0095] Each of the five antenna elements 603, 605, 607, 609, 611 are substantially identical. In other examples, the five antenna elements 603, 605, 607, 609, 611 may be different.

[0096] In Figure 6, each reflector 617, 619, 621, 623, 625 is located behind the associated antenna element with respect to the emitting surface 627 of the antenna element. One or more of the reflectors 617, 619, 621,

623, 625 may be located behind the associated antenna element at different distances with respect to the emitting surface 627 of the associated antenna element 603, 605, 607, 609, 611, in some examples.

[0097] In Figure 6, the reflectors 617, 619, 621, 623, 625 are arranged within the antenna module 601 and are fixed at substantially common angles within the module 601. In this way, the radiation direction from the reflectors 617, 619, 621, 623, 625 is similar/the same (not including any differences in radiation direction that would occur from the different shape/size of the reflectors). In other examples, at least two of the reflectors 617, 619, 621, 623, 625 may be fixed, within the antenna module 601, at offset angles from one another. In this way, the different angles (offset angles within the module) that the reflectors have, will lead to different radiation directions from those reflectors. The different angles of the reflectors refers to how the reflector is fixed at or behind the antenna elements, within the substrate.

[0098] In Figure 6, one or more of the reflectors are hyperbolic reflectors. Hyperbolic refers to the shape of the reflector. In other examples, other suitable shapes of reflectors are used.

[0099] The antenna module 601 (also known as an antenna array) may be suitable to use for FWA applications. For example, the antenna module 601 may be suitable for an antenna such as antenna 407 in Figure 4. For example, the antenna module 601 may be suitable for the wireless devices 403, or the router 405 in Figure 4.

[0100] It should be understood that in this example there are five antenna elements. However, in other examples, there may be more or less than five antenna elements in the antenna module 601. In this example, the antenna elements 603, 605, 607, 609, 611 are patch antennas. However, in other examples, other types of antenna are used.

[0101] Although an antenna module 601 has been described in this example of Figure 6, it should be understood that the design of the antenna array is not limited to just antenna modules. The antenna array may be produced with printed conductors used as antenna elements on a printed wiring board (PWB)/printed circuit board (PCB). Either the main PWB of the end product (for example, a mobile device, or smartphone), or an additional small PWB which has just the array elements. The conductive reflectors may be manufactured separately and then soldered to the PWB, in one other non-limiting example.

[0102] Figure 7 shows a graphical representation of a simulated performance of the antenna module according to Figure 5.

[0103] A first graphical representation 701 shows simulated measurements of the antenna module 501, when the antenna module 501 is a dual-polarised antenna module, for a polarisation with a negative (-) 45 degrees slant.

[0104] A second graphical representation 703 shows simulated measurements of the antenna module 501,

when the antenna module 501 is a dual polarising module, for a polarisation with a positive (+) 45 degrees slant.

[0105] In both the first graphical representation 701 and the second graphical representation 703, the y-axis ("Y1") is the gain, measured in decibels (dBs). The x-axis ("Theta (deg)") is the scanning angle of the antenna module 501, measured in degrees.

[0106] The simulated measurements of the antenna module 501 illustrate the polarisation performance of the module. Antenna polarization is the orientation of the antenna's dipole or dipoles. In this example, the antenna module 501 is a patch antenna array. All antenna types have one or more polarisations. Some antenna types have a single polarisation, for example, a vertically polarised dipole. Other antenna types, like a patch antenna, may be single-polarised, dual-polarised or circularly polarised. Some antennas are elliptically/circularly polarised. Physical orientation is one factor which determines the polarisation.

[0107] This orientation of the antenna's dipole or dipoles affects the orientation of the electromagnetic field and the radio waves that the antenna transmits and/or receives through space. Cross-polarization (XPol) is when two dipoles form a plus (+) sign or a cross (x) shape. Said another way, the two dipoles are oriented at right angles (90°) to each other. Co-polarization (CoPol) is when two dipoles are oriented in the same direction.

[0108] XPol, in the example of having two dipoles, is the difference between the orientation of the two dipoles, and the dipoles would usually be disposed orthogonal to one another (90 degrees orientation difference between them).

[0109] CoPol is when, in the same example of two dipoles, the two dipoles are both oriented in the same orientation. The dipoles are both vertically polarised, or both horizontally polarised.

[0110] When there is a measure/test/simulation of polarisation of antennas, there is a setup of an antenna-under-test (AUT), for example, on a rotating platform in an anechoic chamber. At a distance from the AUT, there is another antenna (a so-called 'test antenna') which transmits towards the AUT, which maybe a dipole. The AUT may be 'set' in a particular orientation, and the test antenna 'set' in a particular orientation. The antennas may be set such that they are being co-polar or cross-polar. From there, a measure of the radiation pattern (antenna gain) of the AUT in both co-polar and cross-polar cases may be made by rotating the AUT (which gives the angular axis of the graphs 701, 703).

[0111] The graphs 701, 703 show a simulated test of the array module (AUT) by using the other antenna (the test antenna) and transmitting towards the AUT. The AUT positioned in a vertically polarised manner (+45 degree slant in the graph 703) and measuring the co-polar gain (test ant vertically polarised orientation) and cross-polar gain (test ant rotated to be orthogonal to AUT, i.e. horizontally polarised (-45 degree slant in the graph 701)).

[0112] In the first graphical representation 701, there

is seen a CoPol gain (dB) scanned from -45 degrees to 45 degrees, with the lines labelled 705. There is also seen an XPol gain (dB) scanned from -45 degrees to 45 degrees, with the lines labelled 707.

[0113] In the second graphical representation 703, there is seen a CoPol gain (dB) scanned from -45 degrees to 45 degrees, with the lines labelled 709. There is also seen an XPol gain (dB) scanned from -45 degrees to 45 degrees, with the lines labelled 711.

[0114] In the first graphical representation 701 and the second graphical representation 703, there is an XPD of approximately -12.1 and -12.3dBc for both co-polar and cross-polar. These measurements are for one delta between markers m1 and m2 at that angle.

[0115] Figure 8 shows a graphical representation of a simulated performance of the antenna module according to Figure 6.

[0116] A first graphical representation 801 shows measurements performed by the antenna module 601, when the antenna module 601 is a dual-polarised module, for a polarisation with a negative (-) 45 degrees slant.

[0117] A second graphical representation 803 shows measurements performed by the antenna module 601, when the antenna module 601 is a dual-polarised module, for a polarisation with a positive (+) 45 degrees slant.

[0118] In both the first graphical representation 801 and the second graphical representation 803, the y-axis ("Y1") is the gain, measured in decibels (dBs). The x-axis ("Theta (deg)") is the scanning angle of the antenna module 501, measured in degrees.

[0119] In the first graphical representation 801, there is seen a CoPol gain (dB) scanned from -45 degrees to 45 degrees, with the lines labelled 805. There is also seen an XPol gain (dB) scanned from -45 degrees to 45 degrees, with the lines labelled 807.

[0120] In the second graphical representation 803, there is seen a CoPol gain (dB) scanned from -45 degrees to 45 degrees, with the lines labelled 809. There is also seen an XPol gain (dB) scanned from -45 degrees to 45 degrees, with the lines labelled 811.

[0121] In the first graphical representation 801, and the second graphical representation 803, there is an XPD of approximately -15.7 (for +45 degree slant) and -16.7dBc (for -45 degree slant) for both co-polar and cross-polar. These measurements are for one delta between markers m1 and m2.

[0122] When comparing the graphical representations for the antenna module 501 (without reflectors) in Figure 7, to the graphical representations for the antenna module 601 (with reflectors) in Figure 8, the following observations can be made.

[0123] In Figure 8, there is an XPD improvement of about 4.6dB (-16.7 dBc compared to -12.1 dBc) for the antenna module 601 (with reflectors) compared to the 5x1 antenna module 501 without the reflector structure. In Figure 7, for the antenna module 501, the XPD is reduced when the scanning angle is changed. However, in Figure 8, the scanning angle has little to no effect on

the XPD for the antenna module 601. This is indicative of improved antenna performance, over a range of scanning angles. Furthermore, these simulated measurement results are for the standalone antenna modules 501, 601, in other words there are no other objects or components surrounding the antenna modules 501, 601. When the antenna module 501, 601 are used in a real environment, the benefit of the design of the antenna module 601 in Figure 6 may be even greater, as un-optimized surroundings will cause polarization degradation.

[0124] Figures 9a and 9b show graphical representations of a simulated performance of the antenna modules according to Figures 5 and 6. Figure 9a shows graphical representations of the performance of the antenna modules in the downlink (DL), while Figure 9b shows graphical representations of the performance of the antenna modules in the uplink (UL). The y-axis in both graphs is a measured throughput value in Megabits per second (Mbits/s). The x-axis in both graphs shows two discrete choices, either the antenna module 501 of Figure 5 (the left-hand side), and the antenna module 601 of Figure 6 (the right-hand side).

[0125] The measurements shown are when the antenna modules 501, 601 are implemented in an FWA mmWave gateway.

[0126] For the downlink, in Figure 9a, there is a TP value 901 of 1000 Mbits/s for the antenna module 501. There is a higher TP value 903 of 1410 Mbits/sec for the antenna module 601.

[0127] For the uplink, in Figure 9b, there is a TP value 905 of 28 Mbits/s for the antenna module 501. There is a higher TP value 907 of 45 Mbits/sec for the antenna module 601.

[0128] Therefore, in both the uplink and downlink there is a considerable improvement in TP for the antenna module 601 with reflectors, when compared to the antenna module 501. Preliminary measured DL and UL throughput increases when the antenna module 601 is implemented on a FWA mmW gateway as shown in Figures 9a and 9b.

[0129] Total system performance improvement of the antenna module 601 (compared to antenna module 501) may be as high as double the throughput. A doubled throughput may be achieved for the cases where the antenna module polarization impurity is initially low. An expected TP improvement from this structure may be around 30%-40%. The reflectors included in the antenna module 601 of Figure 6 may lead to effects on the antenna radiation pattern. For example, the individual antenna gain is increased, and/or a radiation pattern is more narrow. The effects on the antenna radiation patterns may, in FWA use case, be useful. This is because, for FWA, the scanning range can be less due to the fixed nature of the location, and that the reduced scanning range can be converted to an increased gain.

[0130] The antenna module 601 as shown in Figure 6 improves the module performance regardless of the device it is in. The antenna module 601 is suitable for use

in mobile/fixed devices, UEs, mobile phones, tablets, laptops, automotive/vehicular RF solutions, drones, robots, unmanned aerial vehicles (UAVs), routers, access points, RF repeaters etc.

[0131] Using a commercial antenna module size as a reference, $24\text{mm} \times 4.7\text{mm} \times 2\text{mm}$ with the reflectors of the antenna array of Figure 6, used for FWA case, increases the size only by 6mm height and width making the total size 30mm long, 4mm thick and less than 10.7mm wide fitting to almost any formfactor device. For implementation of the commercial antenna module and the reflectors of the invention in a mobile phone, the size would be $27\text{mm} \times 7.4\text{mm} \times 3\text{mm}$. See Figure 10 illustration of a mobile phone and the size conscious module. Mechanically, the structure may be a moulded plastic member having a conductive coating, or any type of conductive material suitable for making the reflectors.

[0132] Figure 10a shows a schematic representation of a mobile device 1001 comprising an antenna module 1003, shown with an isometric view. The mobile device 1001 is indicative of a known mobile device/UE.

[0133] In Figure 10a, the antenna module 1003 is located on the side of the mobile device 1001. In this example, the dimensions of the antenna module 1003 are $24\text{mm} \times 4.7\text{mm} \times 2\text{mm}$ (length, width, depth). The antenna module 1003 of Figure 10a may be similar to the antenna module 501 of Figure 5.

[0134] Figure 10b shows a schematic representation of an antenna module 1051, suitable for a mobile device.

[0135] The antenna module 1051 has similar components to the antenna module 601 of Figure 6. The antenna module 1051 has reflectors 1053 associated with each antenna element 1055. The reflectors 1053 add an additional volume to the antenna module, compared to an antenna module that does not have reflectors (such as antenna module 1003). However, in some examples, the addition of the reflectors 1053 may add only 6mm to the height and width, so that the dimensions of the antenna module 1051 is $30\text{mm} \times 4\text{mm} \times 10.7\text{mm}$ (length, width, depth). In other examples, the antenna module 1051 may be even smaller, to have dimensions of $27\text{mm} \times 7.4\text{mm} \times 3\text{mm}$. In some examples, depending on the operating frequency, as the operational frequency increases above, for example, 40GHz, the antenna size may be reduced in addition to the size of the reflectors, which may make the antenna array/antenna module suitable for smaller handheld electronic devices.

[0136] It should be understood that these dimensions are given as examples only, to help understand the disclosure. In other examples, the antenna module 1051 will have dimensions larger or smaller than those described above.

[0137] Figure 11 shows a schematic representation of an antenna module with optimised half reflectors, shown with a top (plan) view. While this example is of an antenna module, in other examples, the various constituent parts may be provided individually, or in two or more assemblies, or in any known way of manufacturing each indi-

vidual part of the array and reflectors.

[0138] The antenna module 1101 of Figure 11 has a similar arrangement to the antenna module 601 of Figure 6. In the antenna module 1101 of Figure 11, the reflectors associated with each antenna element comprise a first part, and a second part. Said another way, each antenna element has two half reflectors. This is described in more detail below.

[0139] The antenna module 1101 comprises a plurality of antenna elements 1103. In this example, there are five antenna elements 1103. Each of the antenna elements 1103 is a patch antenna. In other examples, other suitable types of antenna are used.

[0140] The antenna elements 1103 are mounted to a substrate 1113. In other examples, the antenna elements are mounted to any means suitable for holding the antenna elements 1103 in place.

[0141] Each patch antenna 1103 comprises one or more antenna feeds 1105. In this example, each patch antenna comprises four antenna feeds.

[0142] Each antenna element 1103 is associated with a reflector 1107. Each reflector 1107 comprises a first part 1109, and a second part 1111. The first and second parts 1109, 1111 may be referred to as half reflectors. Each of the first 1109 and second 1111 parts may be different from each other. The size of the first 1109 and second 1111 parts may be different from each other. The shape of the first 1109 and second 1111 parts may be different from each other. In this way, the first and second parts 1109, 1111 are individually designed for each antenna element. However, in some examples, the first 1109 and second 1111 parts may be the same.

[0143] In this example, the antenna module 1101 is arranged as a 5x1 array of antenna elements 1103. The reflectors 1107 on the ends of the arrangement are larger than the reflectors 1107 in the middle. The reflectors 1107 in the middle are similar in shape and size to each other. The reflectors at the end of the array are similar in shape and size to each other.

[0144] The antenna module 1101 may be configured as a dual polarised antenna. A first polarisation feed may be provided into a first antenna feed 1115 of the four antenna feeds within one of the antenna elements 1103. A second polarisation feed may be provided into a second (different to the first) antenna feed 1117 of the four antenna feeds. The parts of the reflectors 1107 that are hashed may be designed to match the first polarisation feed. The parts of the reflectors 1107 that are not hashed may be designed to match the second polarisation feed. The first polarisation feeds, associated with the hashed parts of the reflectors, are labelled 1119. The second polarisation feeds, associated with the non-hashed parts of the reflectors, are labelled 1121. Depending on the location of the different polarization feeds (in the 'x', 'y', and 'z' planes) the reflector's shape, size and location may be optimized. For example, in Figure 5, an upper polarization feed (pol1) are for the antenna elements 503 and 505 right-hand side, and for the antenna elements

507, 509, 511 on the left-hand side. Similarly, in Figure 11, the reflector 1109 is optimized for the upper antenna feeds for three antenna elements from the left (pol1), and lower antenna feeds (pol2) for the last two patches on the right-hand side.

[0145] In this way, for a dual polarized antenna structure the module polarization can be improved further by individually designing each half/part reflector. In other examples, there may be further separation of the reflector into parts, into more than two parts per reflector, associated with a respective antenna element.

[0146] One or more of the previously described examples show an improved antenna module design. The improved antenna module design may lead to an improved XPD. This means that the antenna module may be particularly suitable for FWA applications. Furthermore, the throughput may be improved, when using the improved antenna module. Furthermore, the size of the improved antenna module is small enough to still be used in applications/devices where size is an important factor, such as in mobile devices/UEs. Furthermore, the antenna module is able to achieve a gain improvement, as discussed previously.

[0147] It is noted that while the above describes example embodiments, there are several variations and modifications which may be made to the disclosed solution without departing from the scope of the present invention.

[0148] The examples may thus vary within the scope of the attached claims. In general, some embodiments may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. For example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, micro-processor or other computing device, although embodiments are not limited thereto. While various embodiments may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[0149] The examples may be implemented by computer software stored in a memory and executable by at least one data processor of the involved entities or by hardware, or by a combination of software and hardware. Further in this regard it should be noted that any procedures may represent program steps, or interconnected logic circuits, blocks and functions, or a combination of program steps and logic circuits, blocks and functions. The software may be stored on such physical media as memory chips, or memory blocks implemented within the processor, magnetic media such as hard disk or floppy disks, and optical media such as for example DVD and the data variants thereof, CD.

[0150] The term "non-transitory", as used herein, is a

limitation of the medium itself (i.e. tangible, not a signal) as opposed to a limitation on data storage persistency (e.g. RAM vs ROM).

[0151] As used herein, "at least one of the following: <a list of two or more elements>" and "at least one of: <a list of two or more elements>" and similar wording, where the list of two or more elements are joined by "and", or "or", mean at least any one of the elements, or at least any two or more of the elements, or at least all of the elements.

[0152] The memory may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor-based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The data processors may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), application specific integrated circuits (ASIC), gate level circuits and processors based on multi core processor architecture, as non-limiting examples.

[0153] Alternatively, or additionally some examples may be implemented using circuitry. The circuitry may be configured to perform one or more of the functions and/or method steps previously described. That circuitry may be provided in the base station and/or in the communications device.

[0154] As used in this application, the term "circuitry" may refer to one or more or all of the following: (a) hardware-only circuit implementations (such as implementations in only analogue and/or digital circuitry); (b) combinations of hardware circuits and software, such as: (i) a combination of analogue and/or digital hardware circuit(s) with software/firmware and (ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as the communications device or base station to perform the various functions previously described; and (c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

[0155] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example integrated device.

[0156] The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of some embodiments. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the fore-

going description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings will still fall within the scope as defined in the appended claims.

Claims

1. An apparatus comprising:
 - a first antenna element and a second antenna element, the first antenna element and the second antenna element being arranged to form an antenna array; and
 - a first reflector and a second reflector, the first reflector and the second reflector being arranged to form a single reflector for the antenna array,
 - wherein the first reflector is associated with the first antenna element and the second reflector is associated with the second antenna element, and
 - wherein at least one of: a shape, a size, and a distance away from the associated antenna element, of the first reflector and the second reflector, is different between the first and second reflectors.
2. The apparatus according to claim 1, wherein the first reflector is located at or behind the first antenna element, and the second reflector is located at or behind the second antenna element.
3. The apparatus according to claim 1 or claim 2, wherein the first antenna element and the second antenna element are substantially identical.
4. The apparatus according to any of claims 1 to 3, wherein the first and the second antenna elements are adjacent to each other.
5. The apparatus according to any of claims 1 to 4, wherein the first and the second antenna elements are parallel with each other.
6. The apparatus according to any of claims 1 to 5, wherein the first and the second reflectors are adjacent to each other.
7. The apparatus according to any of claims 1 to 6, wherein the first reflector is located behind the first antenna element in a z-direction with respect to an emitting surface of the first antenna element, and wherein the second reflector is located behind the second antenna element in the z-direction with respect to an emitting surface of the second antenna element.

8. The apparatus according to any of claims 1 to 7, wherein the shape and the size of the first reflector is different to the second reflector.
9. The apparatus according to any of claims 1 to 8, wherein at least one of the first and second reflectors are hyperbolic reflectors. 5
10. The apparatus according to any of claims 1 to 9, wherein at least one of: the first reflector and the second reflector, each comprise a first part, and a second part, wherein the first part has at least one of: a shape, and a size, which is different to at least one of: a shape, and a size, of the second part. 10
11. The apparatus according to any of claims 1 to 10, wherein the apparatus comprises: 15
three or more antenna elements, each of the three or more antenna elements being associated with an individual reflector, wherein at least two of the individual reflectors are different in at least one of: a shape, a size, and a distance away from the associated antenna element. 20
12. The apparatus according to claim 11, wherein the two or more antenna elements are arranged in a strip, each of the antenna elements positioned in parallel to each other, each of the antenna elements having an emitting surface on a plane that is common to the two or more antenna elements. 25 30
13. The apparatus according to any of claims 1 to 12, wherein the first reflector and the second reflector are fixed, within the antenna module, at offset angles from one another, such that the first and second reflectors have a different radiation direction. 35
14. The apparatus according to any of claims 1 to 13, wherein the antenna array is comprised within a fixed wireless access device. 40
15. A user equipment comprising the apparatus according to any of claims 1 to 14. 45

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Figure 1

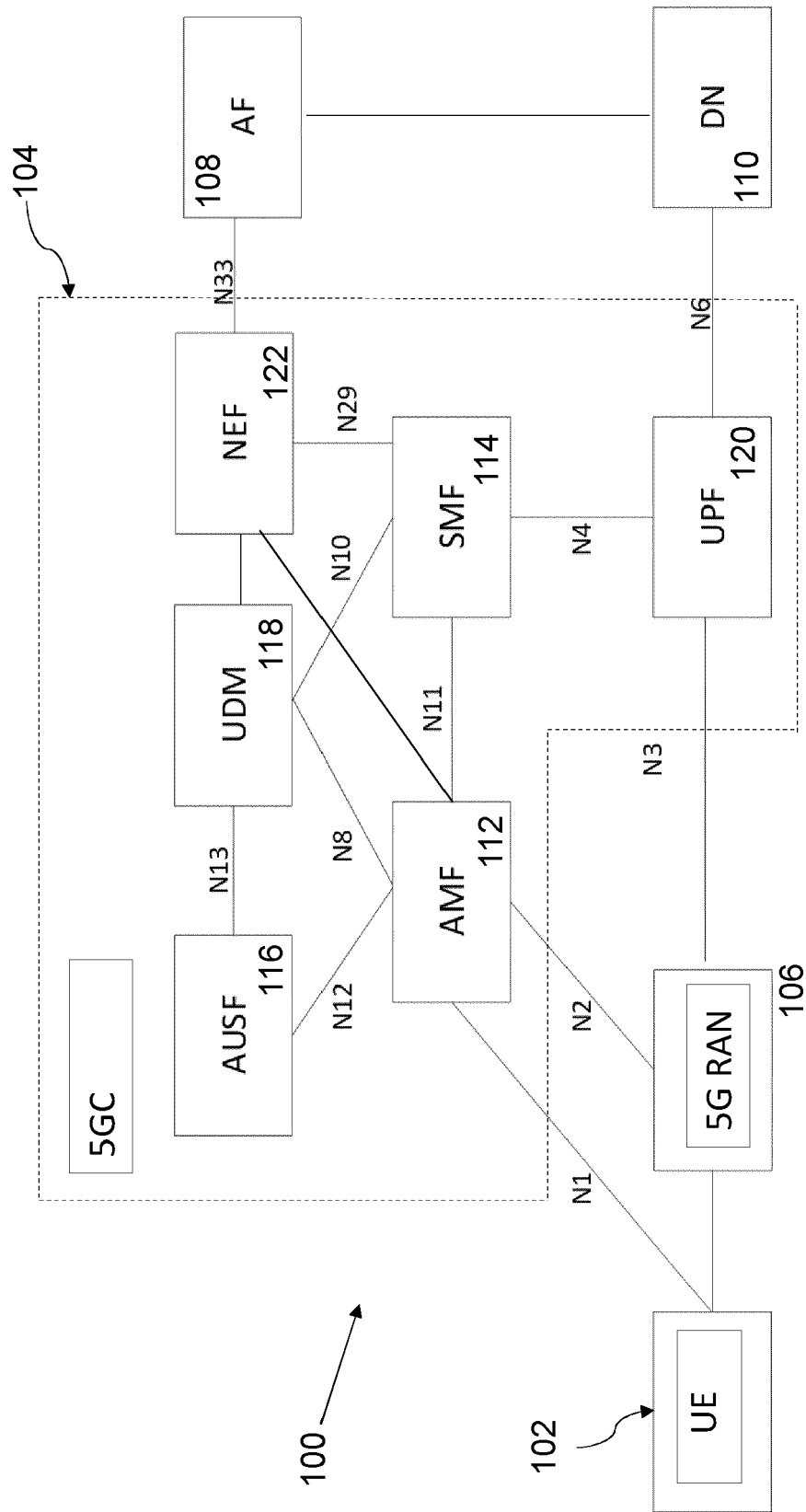
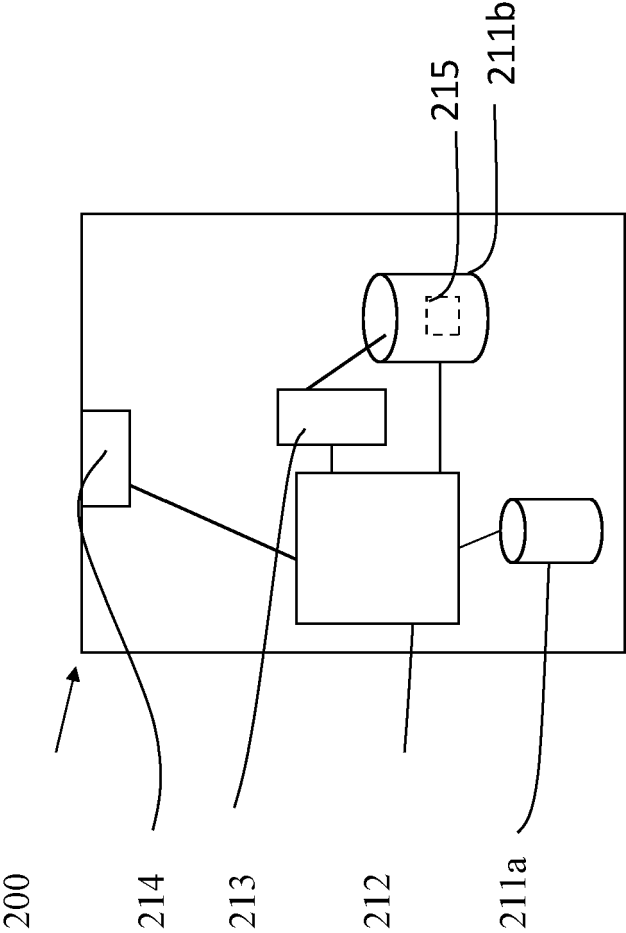


Figure 2



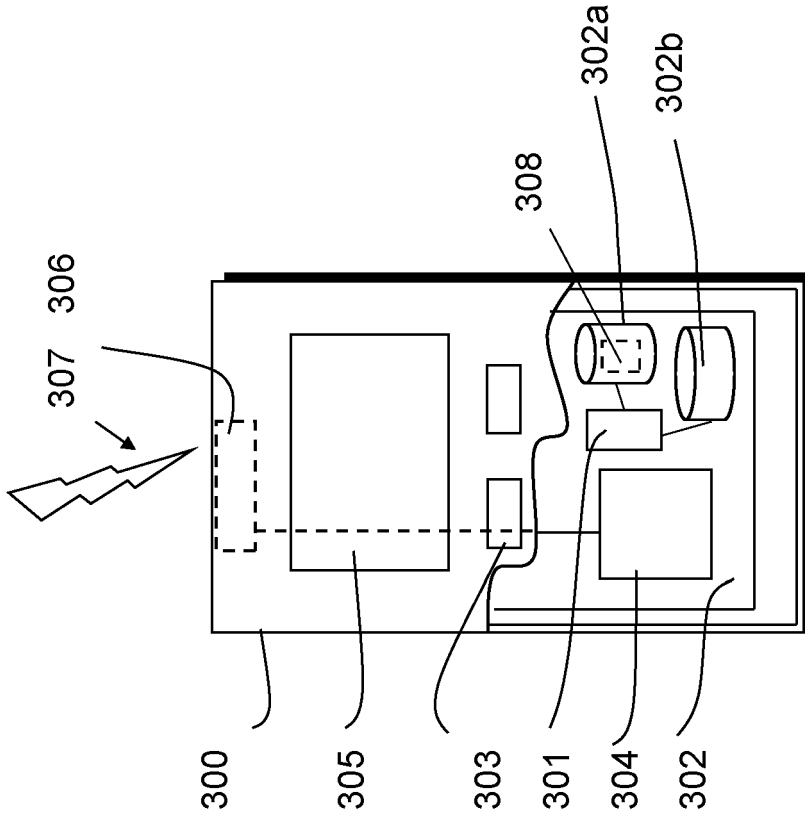


Figure 3

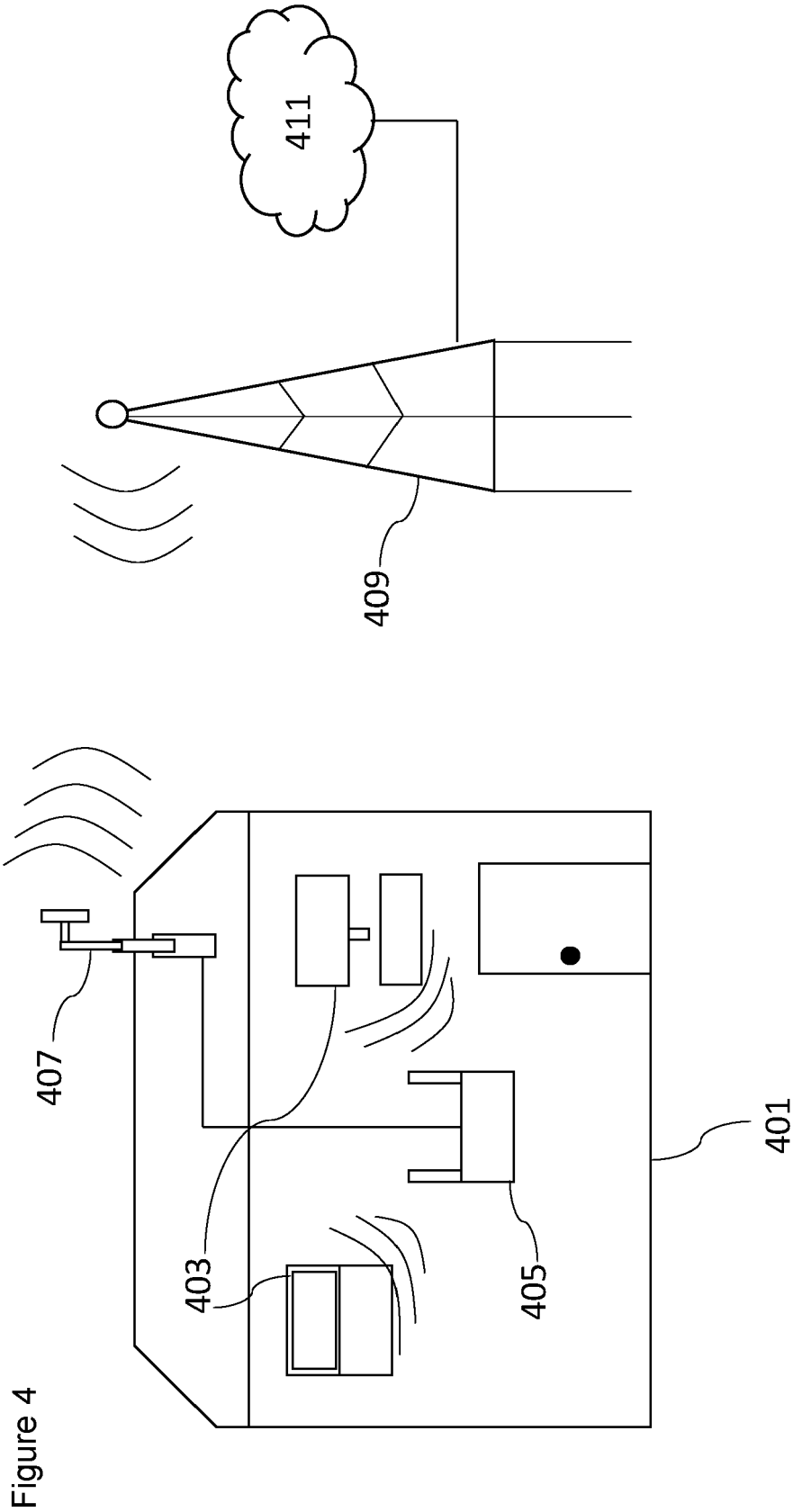
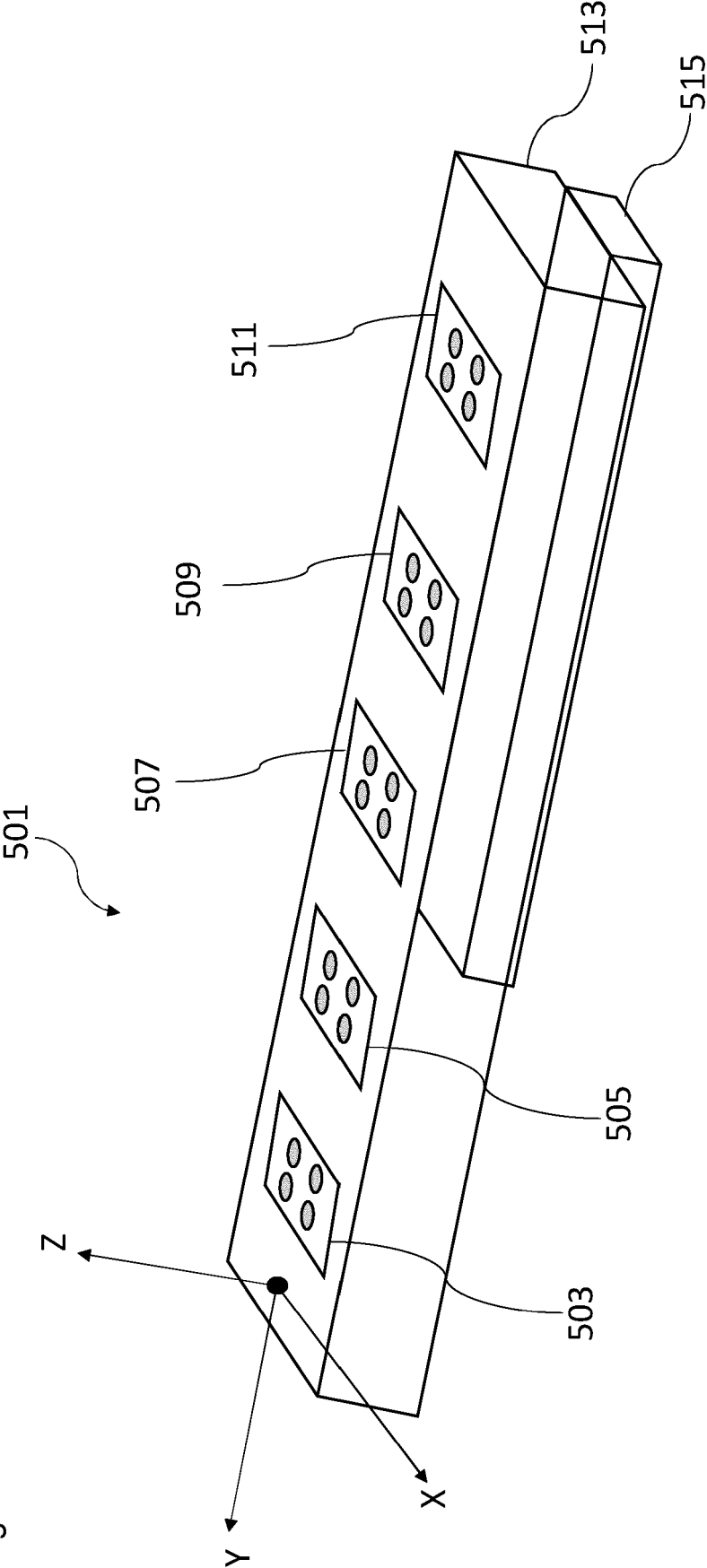


Figure 5



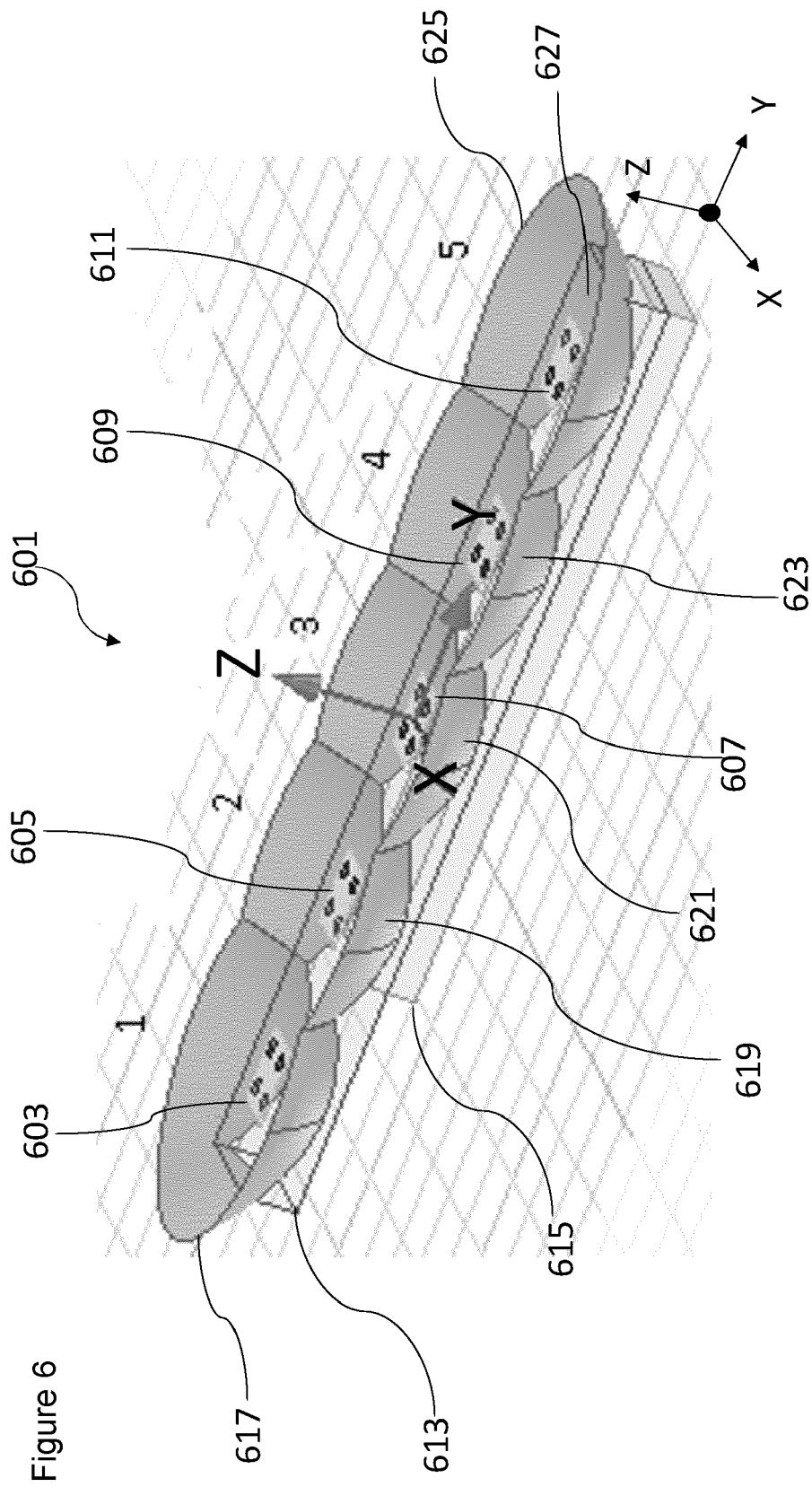


Figure 6

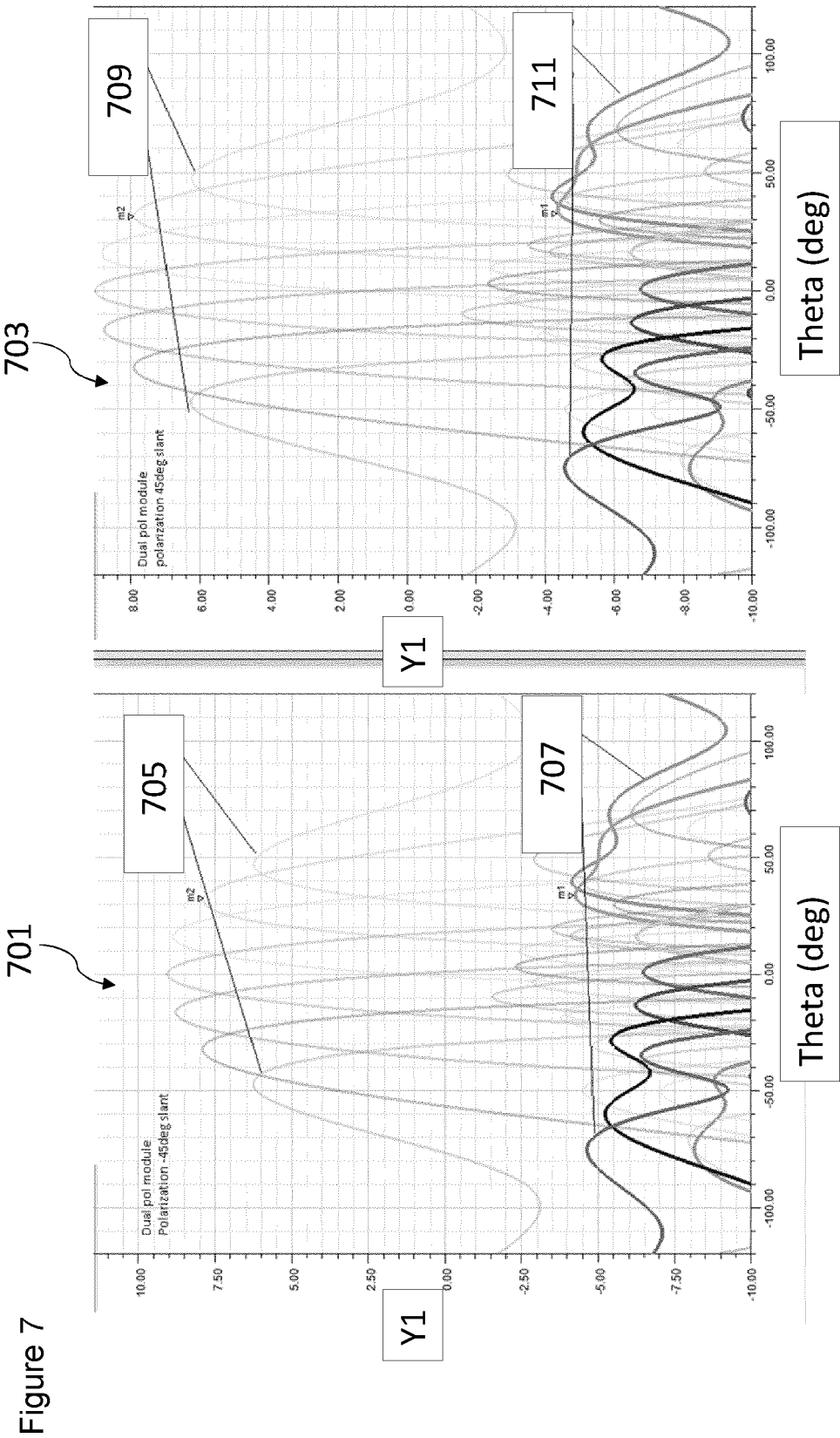
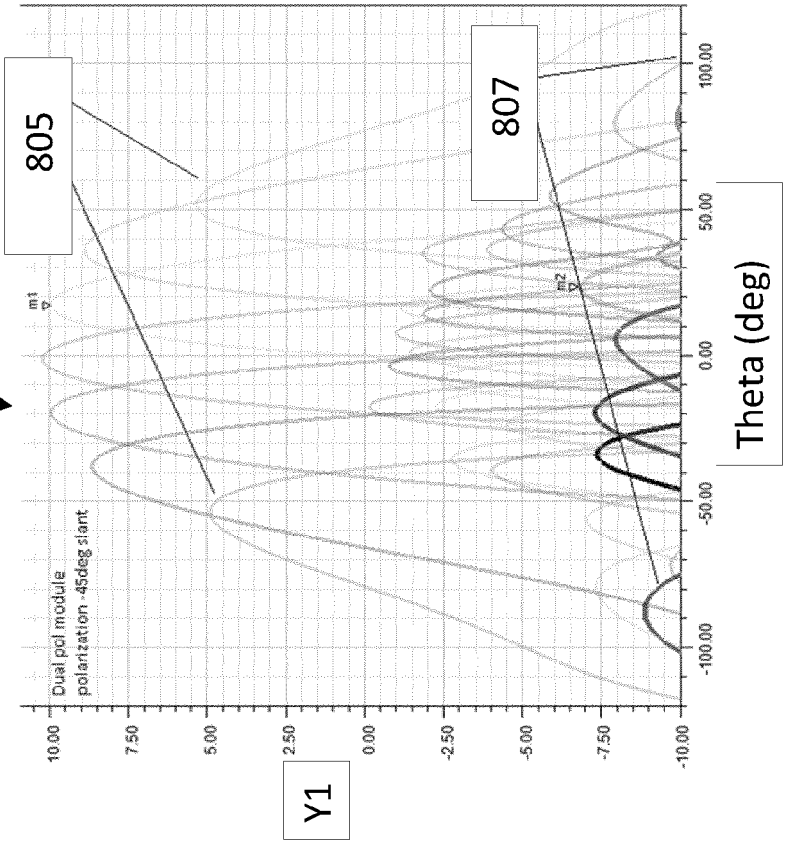


Figure 8

801



803

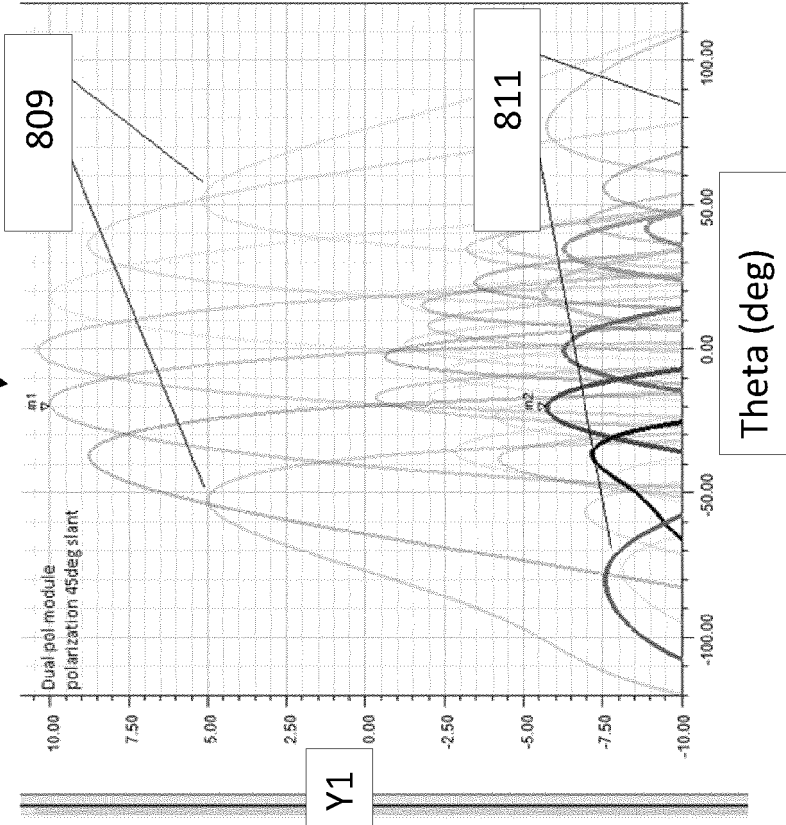
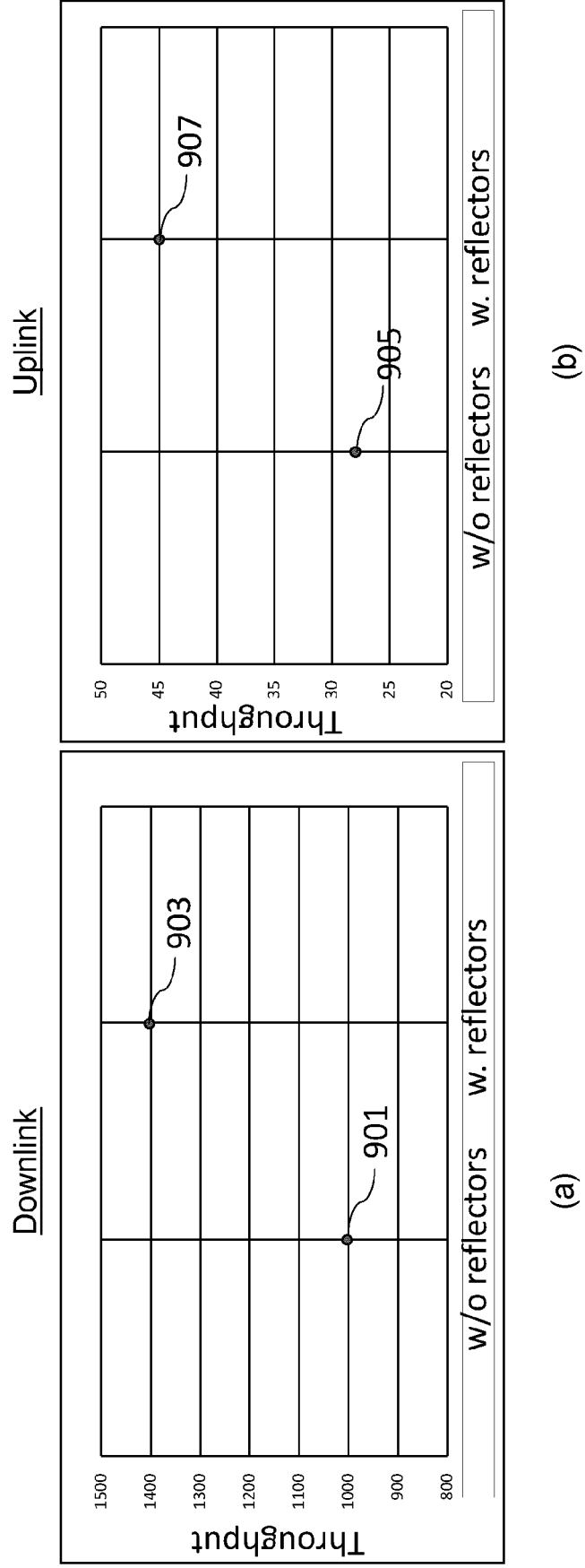


Figure 9



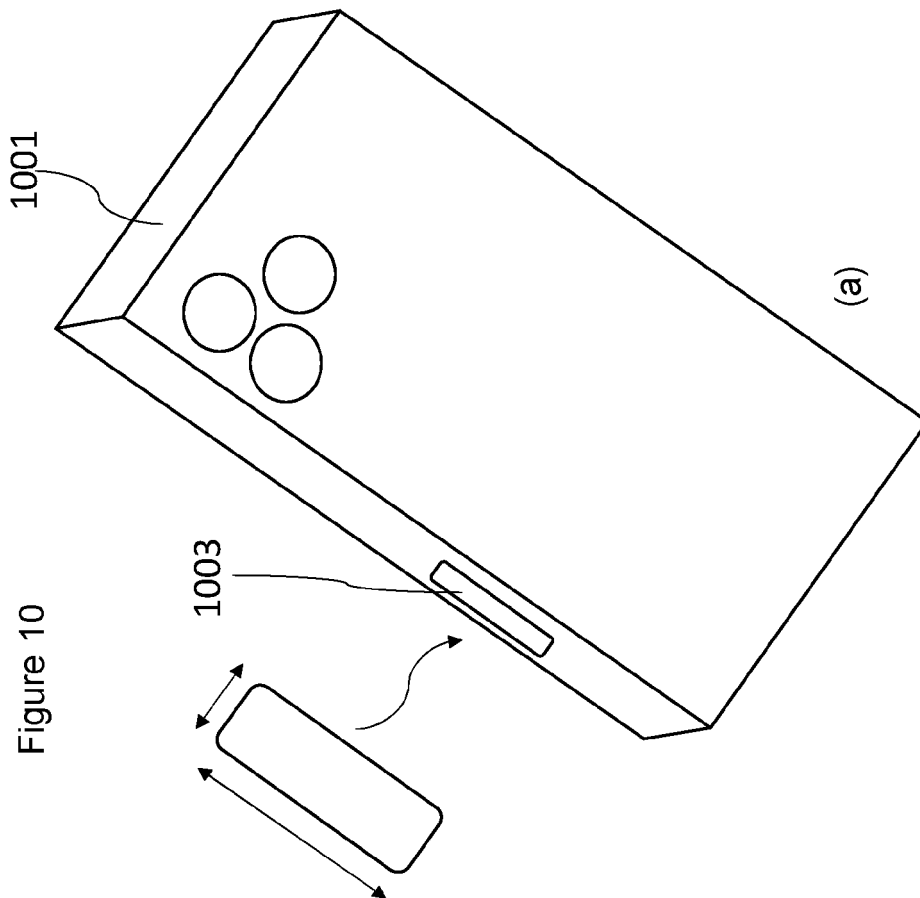
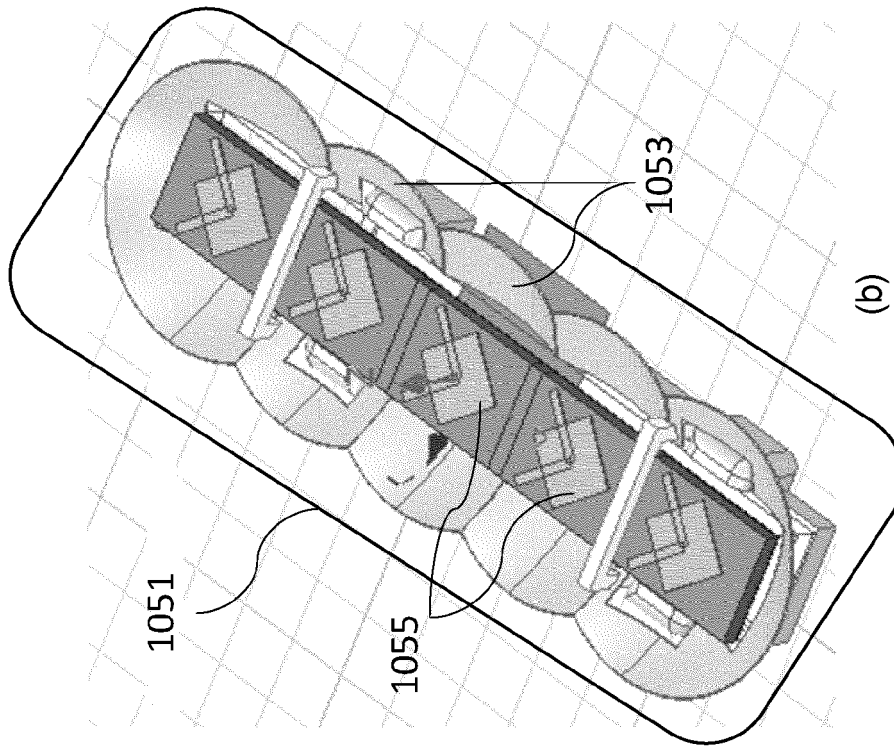
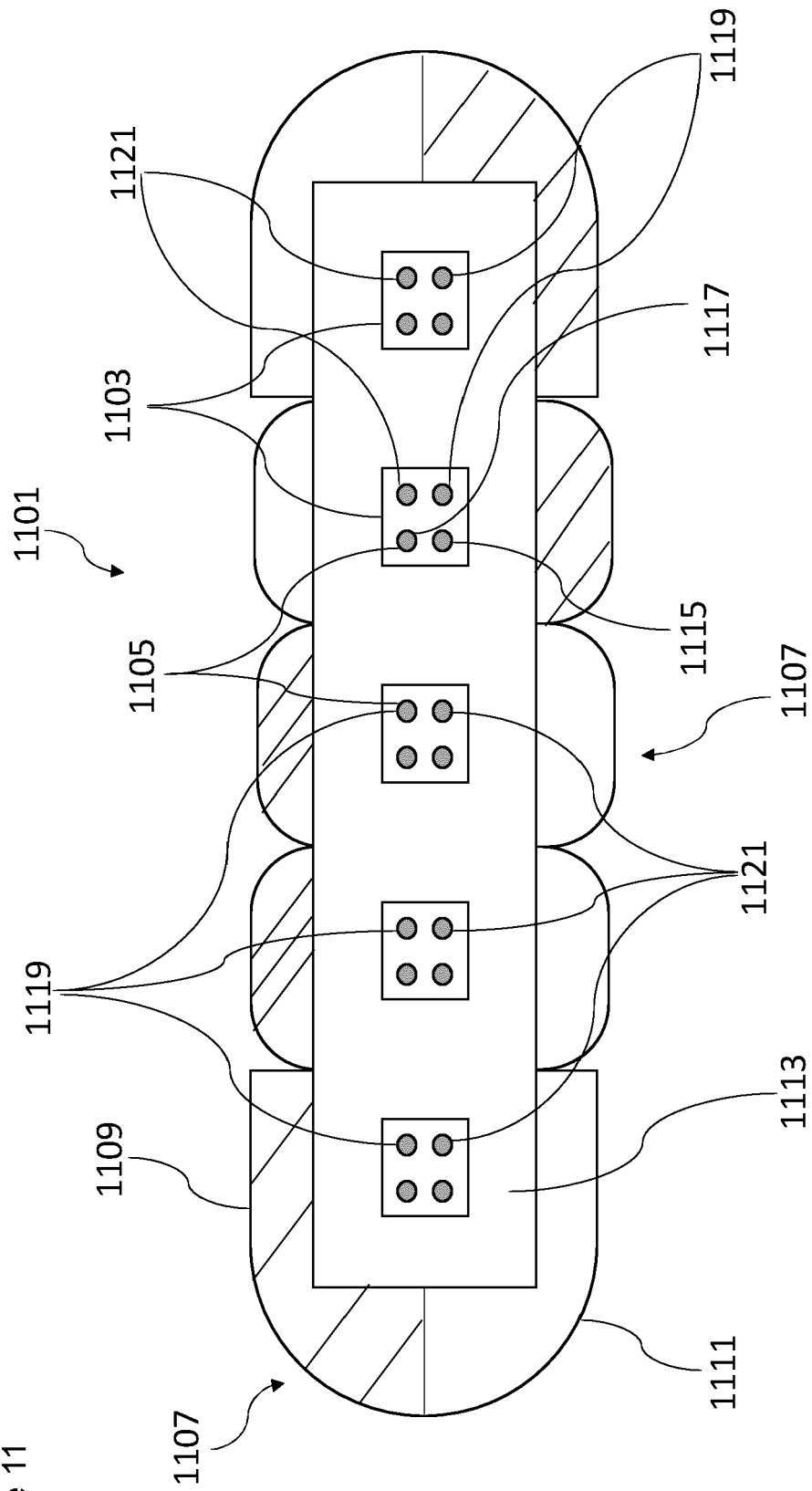


Figure 10

Figure 11





EUROPEAN SEARCH REPORT

Application Number

EP 22 18 9659

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			

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Place of search

The Hague

Date of completion of the search

13 January 2023

Examiner

Culhaoglu, Ali

CATEGORY OF CITED DOCUMENTS

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L : document cited for other reasons

& : member of the same patent family, corresponding document

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

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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