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(54) **Improved broadband multi-dipole antenna with frequency-independent radiation characteristics**

(57) An antenna for transmitting or receiving electromagnetic waves comprises several electric dipoles positioned over a conducting ground plane (4). The dipoles are arranged in pairs of oppositely located dipoles, and they are arranged in such a way that the geometrical centres of each dipole pair are at least approximately

coinciding. The dipoles are supported at certain heights over the ground plane, the height being the same for each dipole pair, by means of a support structure (5) arranged between the dipole and the ground plane, wherein this support structure is at least partly made of electrically conducting material.

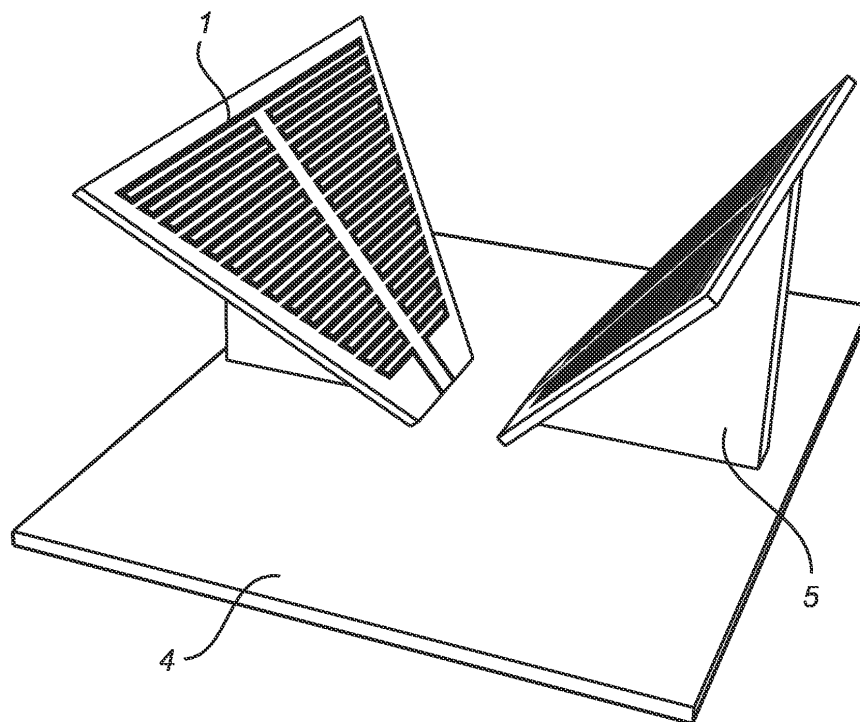


Figure 13

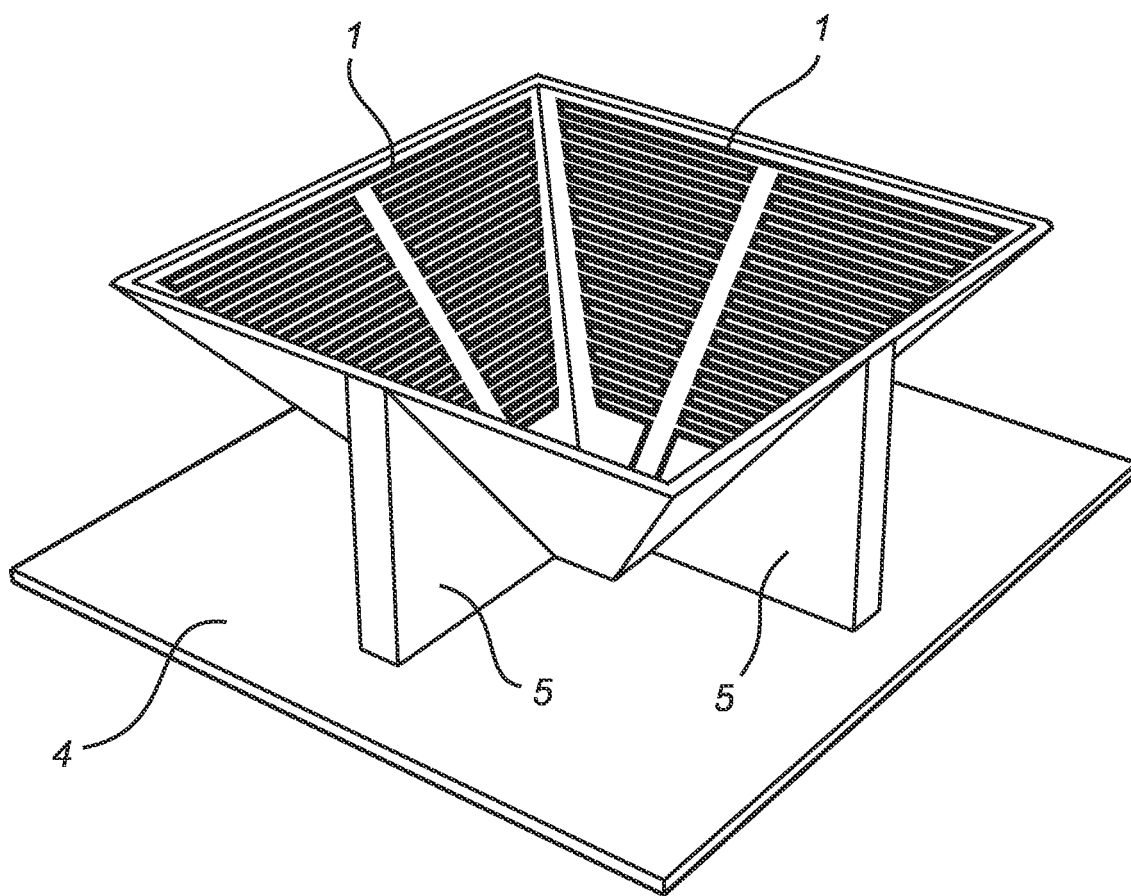


Figure 14

Description

Field of the invention

[0001] The present invention relates to a broadband multi-dipole antenna, and in particular an antenna that has low input reflection coefficient, low cross polarization, rotationally symmetric beam and constant beam width and phase centre location over several octaves bandwidth.

Background

[0002] Reflector antennas find a lot of applications such as in e.g. radio-link point-to-point and point-to-multipoint systems, radars and radio telescopes. Modern reflector antennas are often fed by different types of corrugated horn antennas. They have the advantage compared to other feed antennas that they can provide a rotationally symmetric radiation pattern with low cross polarization over a large frequency band. It is also possible with appropriate choice of dimensions to obtain a beam width that does not vary with frequency. Still, the bandwidth is normally limited to about an octave. Corrugated horns are also expensive to manufacture, in particular at low frequency where their physical size and weight become large.

[0003] Some reflector antennas are mass produced, in particular when they are small and up to about a meter in diameter, such as e.g. for application to satellite TV reception or as communication links between base stations in a mobile communication network. Even within radio astronomy there are proposals for radio telescopes that consist of several cheap mass produced antennas, such as the Allen telescope array (ATA) and the square kilometer array (SKA). ATA is already in the process of being realized in terms of mass produced large reflector antennas, and there exist similar realistic proposals for SKA. The requirement for bandwidth is incredible in both ATA and SKA, covering several octaves. In some proposed future mobile and wireless communication systems there are also requirements for antennas with large bandwidth. Such systems are often referred to as ultra wide band (UWB) systems and the broadband antenna technology as UWB antennas. As a result of the above there will be a need for new types of broadband antennas in the future, in particular antennas that can be used to feed reflectors in an efficient way.

[0004] There is also other commercial interests in both broadband and multiband antenna technologies, e.g. for satellite communication (satcom). The ground terminal of a satcom system is very often a reflector antenna, and it is a desire to combine several satcom frequency bands in one antenna, e.g. two or more of the so-called L-, S-, C-, X, Ku- and Ka-bands. In order to do this broadband or multiband feeds are of interest.

[0005] For satcom applications it is also of interest to use an antenna that can provide information about the

position of the satellite relative to the pointing direction of the antenna, in such a way that the antenna can be moved to point exactly at the satellite. This is referred to as tracking, and such antennas have tracking capabilities. One way to obtain such pointing information is by using a feed with several ports that can be combined to provide so-called tracking (or difference) patterns in both horizontal and vertical planes in addition to the common (and in this connection so-called "sum") pattern over which the communication signals are transferred. The levels and phases of the signals received via the two tracking patterns, relative to the amplitude and phase of the signal received via the sum pattern, gives information about the position of the satellite relative to the pointing direction of the antenna. Therefore, there is also a need for multiport reflector feeds for tracking purposes.

[0006] Multiport antennas are also needed in future proposed communication systems for use in environments with fading, i.e. having large signal level variations between the transmit antenna port and the receive antenna port due to interference between many reflected and scattered propagation paths from the transmitting to the receiving side. The problems with the interference minima in the channel can be reduced by setting up more channels between the transmitting and receiving sides using multiport antennas. Such communication systems designed for an optimum spatial distribution of the information between the different channels are commonly referred to as MIMO systems (multiple input multiple output). Multiport antennas for such systems should have uncoupled ports (to give uncorrelated channels) and high radiation efficiency, whereas there ideally is no requirement to the antenna gain and directivity. However, it may be desirable with an extra directive beam, because there may in reality often be a line-of-sight component present in the environment. Therefore, there is a need for adaptive or reconfigurable multiport antennas that has efficient uncoupled ports, and in addition can provide an additional directive beam. Such antennas can with advantage be wideband to cover more communication systems, and compact to make them cheap on the market. Consequently, antennas designed as multiport feeds with tracking capability for satcom could also be used as multiport antennas for MIMO systems with an extra directive beam.

[0007] There have recently been developed broadband feeds for reflectors that are much more broadband, lighter and cheaper to manufacture than corrugated horns. They have been obtained by locating four logperiodic antennas together in a pyramidal geometry, see Greg Engargiola "Non-planar log-periodic antenna feed for integration with a cryogenic microwave amplifier", Proceedings of IEEE Antennas and Propagation Society international symposium, page 140-143, 2002. The beam width is constant and the reflection coefficient at the input port is low over several octaves bandwidth. However, for known log-periodic antennas of this kind the phase centre moves with frequency. This causes problems with reduced directivity due to defocusing at

most frequencies. Also, the known log-periodic pyramidal feed represents a rather complex mechanical solution.

From WO 05/015685 and WO 05/015686 by the same inventor, it is known how to alleviate the above-mentioned drawbacks of previously known antennas. In particular, the antenna of WO 05/015685 and WO 05/015686 is a relatively small and simple antenna, with at least one, and preferably all, of the following properties: constant beam width and directivity, low cross polarization as well as crosspolar sidelobes, low input reflection coefficient and constant phase centre location over a very large frequency band of several octaves. Typical numerical values are between 8 and 12 dBi directivity, lower than -12 dB crosspolar sidelobes, and lower than -6 dB reflection coefficient at the antenna port. At the same time the antenna is preferably cheap to manufacture and has a light weight.

[0008] The antenna of WO 05/015685 and WO 05/015686 is now in the scientific literature known as the Eleven antenna, see e.g. R. Olsson, P.-S. Kildal, S. Weinreb, "The Eleven antenna: a compact low-profile decade bandwidth dual polarized feed for reflector antennas", IEEE Transactions on Antennas and Propagation, vol. 54, no. 2, pt. 1, pp. 368-375, Feb. 2006. The reason for this is that the basic linearly polarized radiating element is a set of two parallel dipoles spaced half wavelength apart, i.e. in Eleven configuration. To achieve large bandwidth such parallel dipoles are scaled log-periodically and connected together. For dual or circular polarization an orthogonal set of log-periodically scaled dipoles is located orthogonal to the first, with its geometrical center coinciding with that of the first set of dipoles.

[0009] However, it is difficult to use the antennas of WO 05/015685 and WO 05/015686 over large frequency ranges due to problems with mechanical tolerances when small and large mechanical parts are combined, and in particular it is difficult to design for use at high frequencies above typically 10 GHz.

Summary of the invention

[0010] Therefore, it is the object of the present invention to alleviate the above-discussed problems of the prior art. It is a further object of the present invention to reduce the problem of mechanical tolerances. This is done by supporting the radiating dipoles of the general type discussed in WO 05/015685 and WO 05/015686, or their feed lines, or both, to the ground plane by means of a mechanical structure in such a way that the tolerances are improved. In particular, the support structure is fully or partly made of metal or other conducting material, but we will still for simplicity call it a conducting support structure. A special characteristic with the invention is that this support structure may comprise several separate parts, and that these may be located in such a way that they do not significantly deteriorate the desired theoretical radiation characteristics of the antenna, and

they can even be designed to improve the radiation characteristics.

[0011] According to a first aspect of the invention, there is provided an antenna for transmitting or receiving electromagnetic waves comprising several electric dipoles positioned over a conducting ground plane, **characterized in that** the dipoles are arranged in pairs of oppositely located dipoles, that they are arranged in such a way that the geometrical centres of each dipole pair are at least approximately coinciding, and that the dipoles are supported at certain heights over the ground plane, the height being the same for each dipole pair, by means of a support structure arranged between the dipole and the ground plane, wherein this support structure is at least partly made of electrically conducting material.

[0012] The invention can be used to feed a single, dual or multi-reflector antenna in a very efficient way. However, the application is not limited to this. It can be used whenever a small, lightweight broadband antenna is needed, and in particular when there is a requirement that the beam width, directivity, polarisation or phase centre or any combination of these measures should not vary with frequency. In addition, the antenna of the invention can be designed with multiple ports, which makes it possible in addition to the directive beam to achieve either tracking beams for satcom terminals or multiple uncoupled and efficient beams for use in MIMO systems.

[0013] The basic component, from which the desired radiation characteristics of the antenna is constructed, is a pair of parallel dipoles, preferably located 0.5 wavelengths apart and about 0.15 wavelengths over a ground plane. This is known to give a rotationally symmetric directive radiation pattern according to e.g. the book Radiotelescopes by Christiansen and Högbom, Cambridge University Press, 1985. Such a dipole pair is also known to have its phase centre in the ground plane. However, the bandwidth is limited to the 10-20% bandwidth of a single dipole.

[0014] The broadband behaviour is obtained by locating several such dipole pairs of different sizes in such a way that their geometrical centres coincide according to the invention in WO 05/015685 and WO 05/015686. This means that the dipole pair operating at the lowest frequency is located outermost, and that the smaller higher frequency dipole pairs are located inside the outermost with the highest frequency pair in the innermost position. In addition there may be a set of similar, but orthogonally oriented, dipole pairs with the same geometrical centre to provide dual linear or circular polarization. All these characteristics can be combined with the present invention.

[0015] The present invention also provides an advantageous solution to feed the dipole pairs appropriately from one or a few feed points. This can be done in many ways, as described in WO 05/015685 and WO 05/015686, and all of these can be combined with the present invention.

[0016] The term wire is used in the description below.

This term must not be taken literally, as it can also mean a conducting tube or strip as described in the patent claims.

[0017] A standard way to feed a dipole is to connect a two-wire feed line to a feed gap close to the centre of the dipole. By this method several neighbouring and parallel dipoles can be connected together with very short feed lines. Such feeding is known from US patent 3,696,437, said document hereby incorporated by reference. In this feeding, the two wires of the feed line must cross each other between two neighbouring and parallel dipoles in order to function as intended. This means that the right wire that is connected to the right arm of the first dipole must be connected to the left arm of the second dipole, and thereafter to the right arm of the third dipole, and so on, and visa versa for the wire connected to the left arm of the first dipole. The two wires thereby have to cross each other without touching each other. This makes it difficult and cumbersome to realize the antenna mechanically with high precision, in particular at high frequency when the dimensions are small and the dipoles and wires preferably are made as metal patterns on one side of a thin dielectric substrate. Tho of the feeding techniques described in WO 05/015685 and WO 05/015686 do not suffer from this disadvantage of crossing lines, as described in the two next paragraphs, respectively. All the feeding techniques described in WO 05/015685 and WO 05/015686 can be combined with the present invention, and said documents are hereby incorporated by reference.

[0018] In addition, the present invention opens up for new feeding techniques in which the metal support structure of the invention is an integral part of the feed line, to be explained in connection with the figure descriptions below, and in the patent claims.

[0019] The dipoles in WO 05/015685 and WO 05/015686 can be made as folded dipoles, i.e. each dipole is made as two parallel wires connected together at their two outer ends. Such a folded dipole has, seen at a feed gap at the centre of one of the wires, an input impedance closer to that of the two-wire feed line than normal single-wire arms. It has previously been shown by the present inventor, in e.g. R. Olsson, P.-S. Kildal, S. Weinreb, "The Eleven antenna: a compact low-profile decade bandwidth dual polarized feed for reflector antennas", IEEE Transactions on Antennas and Propagation, vol. 54, no. 2, pt. 1, pp. 368-375, Feb. 2006, that it is advantageous in to connect such parallel folded dipoles together by making a gap also at the centre of the second wire, and continue the two-wire line from this gap to the feed gap of the next neighbouring dipole. Thereby, neighbouring dipoles and their feed lines form two opposing serpentine-shaped wires. This feed method opens an extra possibility to tune the reflections at the input, by making each dipole arm consist of a two-wire inner part and a single-wire outer part, and adjusting the location of the transition from two-wire to single-wire line. The folded dipole feeding is described in more detail in

WO 05/015685 and WO 05/015686, and can also be used in combination with the present invention. In particular, it is possible to make the metal support structure of the present invention as a ridge located directly under the two-wire feed line all the way from the center to the end of the feed, and to design the top of the ridge in such a way that it becomes part of the two wire transmission line. It is even possible to let the two wires form two separate transmission lines, each of them using the top of the ridge as a common ground. Thereby, it will be possible to design transmission lines with lower losses. E.g., if the two-wire line is realized by two thin strips there will be metal losses due to the sharp adjacent edges of the two strips, whereas if they are located over a grounded edge with a flat top, they appear more like two parallel microstrip lines which have lower metal losses.

[0020] It is also possible to feed dipoles from a single-wire line supporting a wave between the ground-plane and the line. This can be done by connecting together endpoints of neighbouring dipoles, in such a way that shorter high frequency dipoles act as feed lines for longer low frequency dipoles. Thereby, neighbouring dipoles and their feed lines form a single serpentine-shaped line. This is later described in connection with Figure 8, where it is seen that the input feeding point of the antenna is in the centre. It is also in this case advantageous with a conducting support structure under the central part of the dipoles.

[0021] As already mentioned the present invention is not limited to the feeding techniques described above. Other techniques, e.g. those described in connection with the descriptions of Figures 15, 16, 17, 18 and 19 in WO 05/015685 can also be combined with the invention. They all have crossing wires but makes the crossing in a well controlled manner suitable for mass production with high accuracy.

[0022] The mechanical support under the center of the dipoles also opens up for new ways of feeding them. A promising feeding techniques is to allow one microstrip line, instead of two as explained before, to run along the mechanical support ridge. This line is then connected to one of the arms of the first dipole. The other dipole arm is connected to the top of the metal support ridge (ground plane). These connections and the continuation of the microstrip line to the next dipole can be done in many ways, both for folded and unfolded dipoles, to be explained in the figures to follow. However, the feed lines that can be combined with the invention is not limited to those described in these figures.

[0023] The conducting support structure according to the invention is above described as a solid conducting ridge that can be used as a ground plane for the feed line. However, the conducting support structure may also be a set of posts, connected vertically or nearly vertical to the original ground plane. Then, there will be typically one post per dipole set, but it can be more or less. The posts may also be located under the feed lines between the dipoles rather than under the dipoles themselves.

These posts can also provide a ground plane for the feed lines, like the supporting ridge. The posts will actually (if they are close to quarter wavelength long under each dipole) invert the voltage on the feed line to the next dipole. Thereby, we can get the required opposite feeding of the following dipole without the need for using a folded dipole or crossing the feed lines. Thus, posts can be designed in such a way that the transmission line appears to have voltage inverting shorted stubs, one for each dipole, giving the correct phase conditions for log-periodic feeding.

[0024] In the above descriptions the ground plane is explained as if it is a planar ground, with the conducting support structure placed on top of it. However, the ground plane can also have other shapes. It can have a pyramidal shape, so that the surface on top of the conducting support structure becomes more flat. It can also be provided with grooves or a periodic pattern in order to improve the performance as a ground plane. The invention makes use of a dipole pair as the basic building component. This does not necessarily mean that two such dipoles are connected together mechanically to one unit, e.g. by locating them on the same thin dielectric substrate, in such a way that if one is removed the other is removed as well. On the contrary, the dipole pair is only a basic electromagnetic building component when we construct the radiation pattern from electric current sources, i.e., we need two equal dipoles that radiate at the same frequency and are spaced about 0.5 wavelengths apart to get the desired rotationally symmetric radiation pattern. Actually, the dipoles on one side of the geometrical centre will normally be mechanically connected by their feed lines, so that removing one of the dipoles of a pair will mean that we at the same time remove one of the dipoles of all the pairs. The connected dipoles may also be located on the same supporting material, such as a dielectric substrate. However, even if we normally may do so this is not at all necessary. The dipoles to be used together with the invention are not limited to such realization.

[0025] The dipoles in the description are normally thought of as being straight and about half a wavelength long. However, they may also be V-shaped or slightly curved or serpentine, as long as the radiation pattern gets a rotationally symmetric beam at the frequency of radiation of the considered dipole pair. In particular, it has been found advantageous to make the dipoles curved in such a way that they have a center of curvature in the geometrical center of the antenna. Thereby, it will be more space between the innermost dipoles, and this may open up for using this space for locating a conventional horn antenna or open-ended waveguide in order to include a waveguide-fed higher frequency band in the antenna. This center-located horn antenna may have one or more corrugations, also called choke rings, around its aperture to improve performance. Such dualband feed antenna is covered by the subclaims of the invention.

[0026] The dipoles and feed lines can be realized as

wires, tubes, or thin metal strips. They can also be etched out from a metal layer on a dielectric substrate. They can also be located on both sides of one or more thin dielectric layers, e.g. the dipoles on one side and the feed lines on the other side, or part of the dipoles and feed lines on one side and the rest on the other side.

[0027] The different feed lines must be correctly excited in such a way that the radiating currents on the two dipoles of the same dipole pair are excited with the same phase, amplitude and direction.

[0028] US patent 5,274,390 describes a phased antenna array including log-periodic antennas above a ground plane. However, it is clear from our description above that the invention is not a phased array antenna, but rather that each dipole chain is excited so that the dipoles of each dipole pair radiate with the same phase.

[0029] The present application describes a broadband multi-dipole antenna with conducting support for the dipoles, that has several advantages over the prior art, such as simultaneous low input reflection coefficient, low cross polarization, low crosspolar sidelobes, rotationally symmetric beam and almost constant directivity, beam width and phase centre location over several octaves bandwidth. Further, the dipoles are fed from one or a few centrally located feed points, and they may with advantage have log-periodic dimensions.

[0030] The antenna is very well suited for feeding single, dual or multi-reflector antennas.

[0031] The centrally located feed area may contain a balun or a 180 deg hybrid which provides a transition from a coaxial line to the two opposite directed two-wire lines feeding opposite located dipole chains. The balun may be active, meaning that it is combined with a receiver or transmitter circuit. In the case of a dual polarized antenna there need to be two such baluns or 180 deg hybrids located in the central area. The baluns or 180 deg hybrids can also be located behind the ground plane.

[0032] The support structure of the present invention also allows the use of a single-wire microstrip line to feed the dipoles, as explained above. In this case there is no need for a balun or 180 deg hybrid in the center, which is a big advantage. The two single-wire lines feeding opposing dipole sets can be connected together with the same phase to provide correct excitation of the two sets relative to each other. Thereby, it is much simpler to connect the antenna to receivers and transmitters. In particular, it becomes simpler to integrate low noise amplifiers with the antenna, mounted in front of or behind the ground plane in the center region of the antenna.

[0033] For scientific applications the receivers will in many cases be cooled to provide as low receiver noise temperature as possible. It can also be advantageous to cool the whole feed. This is possible with the Eleven antenna, because of its small size. Then, a solid metal support structure in the form of a ridge or posts will provide a good heat conductor close to the feed lines, which will make them have lower temperature than the otherwise would have. Thereby, the noise originating from the loss-

es in the feed lines will be smaller.

[0034] The Eleven antenna can also be used as a multi-port antenna as explained previously. For the single-wire feed line there is a possibility of 2 ports per polarization, i.e. a 2x2 port antenna. This can provide one difference pattern per polarization for tracking. For the two-wire fed case, each wire can be fed from a separate port. This opens up the possibility of 4 ports per polarization, i.e. a 2x4 port antenna. Thereby difference patterns in two orthogonal planes per polarization can be realized.

[0035] Preferably, the support structure is part of the same metal piece as the ground plane that thereby becomes a profiled ground plane. It is also preferred that the support structure comprises several parts that are fixed to the ground plane. Each support structure may also preferably comprises a metal ridge with a flat or almost flat top. According to another preferred embodiment, each support structure comprises several posts with a flat or almost flat top. It is also preferred that each support structure has an increasing height from the geometrical center of the dipole pairs and outwards, and/or that each support structure has an increasing width from the geometrical center of the dipole pairs and outwards. Each support structure may comprises both ridges and several posts, having a flat or almost flat top. Further, at least a part of each support structure may advantageously be connected to the ground plane inside one or more grooves, dents or depressions in the ground plane.

[0036] Preferably, all dipole pairs are oriented in one direction in order to transmit or receive waves of one linear polarization. It is also preferred that approximately half the dipole pairs are oriented in one direction and the rest in an orthogonal direction, in order to transmit or receive waves of dual linear polarization or circular polarization.

[0037] Preferably, the metal lines connecting neighbouring dipoles do not cross each other.

[0038] The conducting body acting as a ground plane is preferably non-flat.

[0039] The dipoles may advantageously be V-shaped or curved. The dipoles are preferably made of conducting wires, tubes or strips and/or made by conducting strips on a dielectric substrate.

[0040] The dipoles are preferably excited by connecting together the endpoints of neighbouring parallel dipoles so that they form serpentine-shaped lines from one or more feed points. Alternatively, at least one dipole comprises two oppositely directed conducting arms with a feed gap between them may be provided, and preferably several dipoles, and most preferably essentially all dipoles. In the latter case, each dipole arm preferably comprises two or more conducting lines that are connected together at one or more points or over an extended part of the arm. Further, the feed gaps of neighbouring dipoles of different dipole pairs are preferably excited by two-conductor feed lines starting from one or more feed points.

[0041] According to a preferred embodiment, each di-

pole consists of two opposite arms, and each dipole arm comprises two conducting lines that are connected at the outer end whereas the inner end at a feed gap is connected with the inner end of the closest line of a neighbouring inner or outer dipole arm, so that one set of dipoles with feed lines are formed by two opposing serpentine-shaped lines.

[0042] The dimensions of each dipole pair may be essentially as follows: dipole length approximately 0.5 wavelengths, dipole height over ground between 0.05 and 0.50 wavelengths, and dipole spacing approximately 0.5 wavelengths, where the wavelengths is for that frequency of which the given dipole pair is the dominating contributor to the radiation pattern. The dimensions of the different dipole pairs preferably varies in a log-periodic manner in order to make a very broadband overall performance.

[0043] The radiation patterns preferably have an almost constant beam width over a very wide frequency band that may be several octaves.

[0044] The antenna may be used to illuminate a single or dual reflector antenna system.

[0045] Further, at least one balun is preferably arranged in the central region between a pair of dipoles, and preferably between the smallest dipoles. Still further, at least one 180 deg hybrid may be arranged in the central region between a pair of dipoles, and preferably between the smallest dipoles. The balun or 180 deg hybrid may be realized as an active circuit including transistor amplifiers. The balun or 180 deg hybrid may also be located behind the ground plane in the central region with transmission lines providing the connection through the ground plane.

[0046] Preferably, at least one dipole comprises two oppositely directed conducting arms with a feed gap between them, and wherein the feed gaps of neighbouring dipoles of different dipole pairs are excited by a two-conductor feed line starting from one or more feed points, the two separate conductors of the two-conductor feed line being arranged in at least two different, non-intersecting planes.

[0047] The two-conductor feed line may comprise a first conductor in a first plane, and a second conductor at least partly arranged in a second plane, said first and second planes being different and non-intersecting to each other. At least part of the dipole arms may in this case be arranged in said first plane. The dipoles are further preferably made by conducting strips on a dielectric substrate, and wherein the first and second planes are arranged on different sides of said substrate.

[0048] Preferably, essentially all dipoles are arranged on one side of a substrate, and a first conductor of a two-conductor feed line is arranged on this side of the substrate, whereas a second conductor of said two-conductor feed line is arranged at least partly on an opposite side of the substrate, and being connected to the dipoles through the substrate. The second conductor preferably connects dipoles within at least some of the dipole pairs

to each other, said dipole pairs thereby being excited by electromagnetic coupling to neighbouring dipoles.

[0049] For at least some of the dipoles, and preferably essentially all the dipoles, it is preferred that the dipoles' arms are arranged on opposite sides of a substrate, and wherein a separate conductor of a two-conductor feed line is arranged on each side for exciting the dipole arms arranged on said sides. Alternatively, essentially all dipole arms may be arranged on one side of a substrate, and the conductors of a feed line are wound in parallel on a dielectric rod so that different windings of the lines are connected to different dipole arms.

[0050] Preferably, at least some of the dipole pairs have dipoles being connected to separate feed lines. It is also preferred that at least some neighbouring dipole pairs are connected to separate feed lines.

[0051] There may be located another antenna of different type between the dipoles of the innermost dipole pair or pairs. There may also be located a radiating circular waveguide or horn antenna between the dipoles of the innermost dipole pair or pairs.

[0052] The ground plane preferably comprises grooves or holes. Further, the ground plane is preferably connected to a metal wall surrounding the whole antenna.

[0053] The outermost dipole or transmission line preferably has metal contact with the ground plane via the ground plane wall or a metal post.

[0054] The central parts of all the feed lines are preferably connected to up to eight individual coaxial antenna ports located on the back side of the ground plane.

[0055] Further, the feed lines may be connected to a centrally located quad-ridged feed line that goes through a hole in the ground plane and has its coaxial ports on the back side of it.

[0056] The feed lines may be connected to a centrally located dually-polarized Vivaldi antenna that goes through a hole in the ground plane and has its coaxial ports on the back side of it.

[0057] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

Drawings

[0058] For exemplifying purposes, the invention will be described in closer detail in the following with reference to embodiments thereof illustrated in the attached drawings, wherein:

Figure 1 shows the top view of a dipole pair according to an embodiment of the invention, functioning as a basic component of the invention.

Figure 2 shows the top view of a dipole pair with fed gaps, according to an embodiment of the invention, functioning as a basic component of the invention.

Figures 3 and 4 show top views of a dipole pair realized as so-called folded dipoles with fed gaps, ac-

cording to an embodiment of the invention, functioning as a basic component of the invention.

Figure 5 shows a top view of multiple dipole pairs arranged for providing linear polarization, according to an embodiment of the invention.

Figure 6 shows a cross section of multiple dipole pairs located above a ground plane and arranged for providing linear polarization, according to an embodiment of the invention.

Figure 7 shows a top view of multiple dipole pairs arranged for providing dual linear or circular polarization, according to an embodiment of the invention. Figure 8 shows a top view of the left part of multiple dipole pairs with included feed connections between dipole ends, according to an embodiment of the invention.

Figures 9 and 10 show a top view of the left part of multiple dipole pairs realized as folded dipoles with included a feed line between the feed gaps of the dipoles, according to an embodiment of the invention. Figures 9 and 10 show a conducting support structure that has constant width along the set of dipoles, but it may also have a width that increases from the shortest to the longest dipole as shown in the previous figures.

Figures 11 and 12 show alternative embodiments of the dipole pair. Figure 11 shows circularly curved dipoles where the center of curvature is at or close to the geometric center on the antenna.

Figures 13 and 14 illustrates in perspective two embodiments of the antenna realized by folded dipoles according to the invention, with a single and dual polarisation, respectively.

Figure 15 shows an embodiment of the present invention with a dual polarized version of the Eleven antenna around an open-ended circular waveguide with one choke ring around it.

Figure 16 shows one half of one quarter of another embodiment of the Eleven antenna, based on using folded dipoles.

Figures 17 shows an example of conducting support structure for supporting dipoles on a ground plane in accordance with an embodiment of the present invention. In this exemplary embodiment, the support structure is in the form of a metal ridge of linearly increasing height and width.

Figures 18 shows an alternative embodiment of a conducting support structure, in the form of a metal ridge of linearly increasing height and constant width.

Figures 19 shows another example of a conducting support structure in accordance with the present invention, in the form of a set of posts of linearly increasing height and constant width.

Figures 20 shows still another example of a conducting support structure in accordance with the present invention, in the form of a set of posts of linearly increasing height and linearly increasing width.

Figures 21-23 illustrate further exemplary embodi-

ments of support structures in accordance with the present invention, these examples basically being combinations of the above conducting supports.

Figure 24 shows the cross section of an example of a conducting support structure of one of the types in Figures 17-23, with a two-wire feed line located at the top, supported by a solid or foam type dielectric substrate.

Figure 25 shows the cross section of an example of a conducting support structure of one of the types in Figures 17-23, with a single-wire feed line located at the top, supported by a solid or foam type dielectric substrate.

Figure 26 shows the cross section of an example of a conducting support structure of one of the types in Figures 17 to 23, with a single-wire feed line located at the top, supported by a foam type dielectric substrate.

Figures 27 to 33 show the top view of different new layouts of dipoles, and two-wire or single-wire feed lines in accordance with the present invention, made possible by an underlying conducting support structure, according to the invention. Only one quadrant of a dual-polarized realization of the Eleven antenna is shown.

Figure 34 shows a cross section of a dipole with two dipole arms on a conducting support structure above a ground plane with foam layer, according to one embodiment of the present invention.

Figures 35-39 show a top view of different ways of connecting to the Eleven antenna in the center.

Detailed description of the figures

[0059] The invention will now be described in more detail with reference to preferred embodiments. However, it should be understood that different features in the specific embodiments are, unless otherwise stated, exchangeable between the embodiments. Further, all embodiments relate to locating the radiating dipole parts of a multi-dipole antenna in such a way that the radiation pattern gets rotational symmetry with low cross polarization and a frequency independent beam width over a large bandwidth.

[0060] The dipole pair in Figure 1 is the basic component of the invention. The dipole pair is arranged at a predetermined separation distance above a ground plane 4 by means of a conducting support structure 5. The support structures 5 may be integrated with or connected to the ground, and have a flat or almost flat top. Further, the support structure 5 preferably has a tapering form when seen from the side, so that the height increased from the geometrical center of the dipole pairs and outwards. Further, the support structure 5 may have a tapering form when seen from above, so that the width increased from the geometrical center of the dipole pairs and outwards. However, the support structure may also have other shapes and designs, as is discussed in more

detail in the following.

[0061] If the two dipoles 1 are about 0.5 wavelengths long and located with a spacing of about 0.5 wavelengths about 0.2 wavelengths above a ground plane, the radiation pattern of the dipole pair unit has rotational symmetry with low cross polarization, provided the currents on the two dipoles have the same direction, amplitude and phase. The height over ground plane can be chosen within the interval 0 and 0.3 wavelengths, whereas the length and spacing typically must be within ± 0.2 wavelengths.

[0062] A dipole antenna preferably has a feed gap 2 in the center so that two dipole arms 3 are formed, as shown in Figure 2. The dipole pair 1 in Figure 2 is also located by means of a conducting support structure 5 over a ground plane 4. The dipoles can also be realized as folded dipoles as shown in Figures 3 and 4, said dipoles also arranged on support structures 5. Each folded dipole in Figure 3 is realized as one single wire that is folded twice, once to the left and then to the right, so that the left fold makes up the left dipole arm 3 and the right fold makes up the right one 3. The folded dipoles in Figure 4 have completely separated arms with no wire connection between them, so that it appears to have two feed gaps 2. The feeding of the dipole versions in Figures 1, 2, 3 and 4 will be described in connection with Figures 8, 9 and 10.

[0063] Several dipole pairs 1 can be arranged on conducting support structures 5 over a ground plane 4 as shown in Figure 5 to provide broadband linearly polarized radiation. The feeding of the dipoles can be done in many different ways, as will be described later. The main point is that they have to be fed in such a way that the currents on the dipoles of each dipole pair have the same direction, amplitude and phase.

[0064] The dipoles 1 of the invention are located above a ground plane 4 on conducting support structures, and preferably with a height increasing in a direction away from the geometrical center of the dipole pairs, as shown in Figure 6. The ground plane is in the figure shown to be flat and plane, whereas in some applications it may be desirable and possible to make it slightly conical, pyramidal, doubly curved or any other shape deviating from a plane.

[0065] An antenna according to the invention can also be used for dual linear or circular polarization. In such cases the dipole pairs may be arranged as shown in Figure 7. Figure 7 shows a top view of multiple dipole pairs arranged for providing dual, linear or circular polarizations, and located by means of conducting support structures 5 over a ground plane 4. There exists for each dipole pair an orthogonal dipole pair having the same dimensions. The feeding of the dipoles are within each quadrant of the geometry the same as for one half of the linearly polarized version in Figure 6.

[0066] The dipoles in Figures 5, 6 and 7 are shown without a feed gap, but they can equally well have a feed gap. They are also shown without feed lines and sup-

porting material. In reality, they will have feed lines, e.g. as shown in Figures 8, 9, 10, 11, 12, 13 or 14. In reality there will also often be an additional supporting material between the dipoles and the ground plane, such as a dielectric substrate or a foam material. This can also take the form of one or more thin dielectric sheet on which the dipoles are located.

[0067] Figure 8 shows how the dipoles of the left half of the antenna in Figure 6 can be connected with conducting joints 5 between their ends according to the invention. In this embodiment, the dipoles and joints can be realized by the same wire, propagating a feed voltage between the wire and the ground plane from the feed point 6 to all the dipoles. In the embodiment illustrated in Figure 8, the support structure 5 is arranged with a constant width along the set of dipoles, instead of a tapering width as illustrated in the previous examples. This embodiment with a uniform width is particularly advantageous if the feed line 7 has the same dimensions between all dipoles.

[0068] In Figure 9 the dipoles are arranged on a similar type of support structure as in Fig. 8. The dipoles in Fig. 9 are realized as so-called folded dipoles of the kind shown in Figure 4, i.e. each dipole is made of two parallel wires connected at their both ends. A folded dipole can be fed by a two-wire line connected to the feed gap 2 in one of these wires. In the invention, there is also a gap in the second wire of each dipole as shown in figure 4, at which a new two-wire line 7 is connected and continuing to the feed gap of the next neighbouring dipole. Thereby, two opposing serpentine lines running from the feed point 6 are created, exciting all dipoles by a propagating wave.

[0069] Figure 10 shows also a realization in terms of folded dipoles, similar to the one discussed in relation to Figure 9. However, the two-wire lines making up the dipoles arms are shortened at their ends, so that the radiating dipole length is longer than the length of its folded two-wire part.

[0070] Figures 11 and 12 show alternative embodiments of the dipole pair, located by means of conducting supports structure 5 over a ground plane 4. Figure 11 shows circularly curved dipoles where the center of curvature is at or close to the geometric center on the antenna. Figures 13 and 14 illustrate in perspective two embodiments of an antenna realized by folded dipoles. In fig 13, the dipoles are provided on two antenna plates arranged on a ground plate. The antenna plates are arranged in a slanted disposition relative to each other, so that the functional antenna elements of the antenna plates are facing each other. The antenna of fig 13 is a single polarisation antenna.

The antenna of fig 14 resembles the antenna of fig 13, but it has four rather than two antenna plates arranged in a slanted disposition relative to each other, so that the functional antenna elements of the antenna plates are in pairs facing each other. The antenna of fig 14 is a dual polarisation antenna. As in the previous examples, the

dipoles are located by means of conducting support structures 5 over a ground plane 4.

[0071] The embodiments in Figures 13 and 14 show two respectively four antenna plates facing each other. However, the invention is not limited to such realizations. In particular, such antenna plates on which the dipoles are etched, milled or otherwise located may be lying beside each other in the same plane, or there may be one plane antenna plate containing all dipoles rather than two or four plates.

[0072] In Figures 6 to 10 the antennas according to the invention makes use of dipoles of 7 different dimensions. This number is arbitrarily chosen, as the antenna can consist of any number of dipole pairs of different dimensions, smaller, larger or much larger than 7. Also, the spacing between neighbouring dipoles is arbitrarily chosen. It can be smaller or larger dependent on the results of the optimization of the design.

[0073] The drawings in the figures show multi-dipole antennas where the dimensions of the different dipole pairs appear to vary approximately log-periodically. This means that the dimensions of all dipole pair are scaled relative to the dimensions of the closer inner pair of each of them by the same constant factor. This is done in order to provide an environment for each dipole pair that looks the same independent of whether it has large dimensions for operation at some of the lowest frequencies or small dimensions for operation at some of the highest frequencies. This log-periodic scaling is not necessary, although it is expected to give the best and most continuous broadband performance. In particular, this log-periodic choice of dimensions may not be needed if multiband instead of broadband performance is asked for.

[0074] It is according to the invention possible to provide the antenna with several feed points, even within one quadrant of the antenna. With a quadrant we mean in this case the geometry in Figures 8, 9, 10 or 11. Such a quadrant makes up half a linearly polarized version of the complete antenna as shown in Figure 3, and it makes up one quarter of a complete dual linear or circularly polarized antenna as shown in Figure 7. If a quadrant has several feed points, it means that quadrants of different sizes are located besides each other so that they form a new complete and much more broadband antenna, but that the bandwidth is divided between the separate feed points.

[0075] Feeding of the dipoles could be provided in various ways, as is indicated in the foregoing discussion. Other further advantageous feeding systems are also feasible, as complements or alternatives to the already disclosed feeding systems.

[0076] Figure 15 shows an embodiment of a dual polarized version of the Eleven antenna around an open-ended circular waveguide with one choke ring around it, where the dipoles of the Eleven antenna are located by means of conducting support structure 5 over a ground plane 4. The centrally located choke horns provides an extra higher frequency band in the same antenna. The

support structures 5 are in this embodiment realized as oval or circular posts.

[0077] Figure 16 shows one half of one quarter of an embodiment of the Eleven antenna, based on using folded dipoles 1, located by means of conducting support structures 5 over a ground plane 4.

[0078] Figure 17 shows an example of a conducting support structure for use in accordance with any one of the dipole arrangement discussed above, and e.g. as one of the four antenna parts in a dual polarization realization of the Eleven antenna. This support structure 5 is in the form of a metal ridge of linearly increasing height and width. Figure 18 shows an alternative example of a conducting support structure, in the form of a metal ridge of linearly increasing height and constant width. It is emphasized that the ridge is shown as a solid piece of material, but it does not need to be so. Figure 19 shows another example of a conducting support structure, in the form of a set of posts of linearly increasing height and constant width. Further, Figure 20 shows an example of a conducting support structure in the form of a set of posts of linearly increasing height and linearly increasing width.

[0079] Figures 21-23 illustrates further alternative embodiments of the support structure, essentially being combinations of the above conducting supports.

[0080] The support structure in Fig. 21 comprises a central wedge shaped portion, similar to the support structures illustrated in Fig. 18, tapering in one direction, but it is also possible to use the one illustrated in Fig. 17, tapering in two directions. Further, there is provided posts arranged separated from said central portion, and preferably arranged displaced in relation to each other in the length direction. The posts are in this embodiment of a uniform width and thickness, but it can also have other shapes.

[0081] Fig. 22 illustrates a support structure similar to the one discussed above in relation to Fig. 21. However, in this case, posts are only arranged on one side of the central portion, and the posts are further of varying width and thickness, so that the width and thickness increases in proportion to the height.

[0082] Fig. 23 illustrates still a further alternative embodiment, resembling the ones discussed above in relation to Figs. 21 and 22. In this support structure, posts of varying width, thickness and height, similar to the ones in Fig. 22, are arranged on both sides, and the central wedge-shaped portion is omitted. Thus, the embodiment of Fig. 23 may alternatively be described as a wedge-like support structure, as illustrated in Fig. 17, but with the provision of separation gaps both in the length direction and transversely in the width direction.

[0083] Figure 24 shows the cross section of an example of a conducting support structure of one of the types in Figures 17-23, with a two-wire feed line 7 located at the flat top, supported by a solid or foam type dielectric substrate 8. The substrate 8 can also be wider than the conducting support structure, and provide dielectric sup-

port even for the dipoles. The dipoles and two-wire lines may be etched out from a metal sheet fixed to the dielectric substrate, or they may be made from a separate sheet of metal.

[0084] Figure 25 shows the cross section of an example of a conducting support structure of one of the types in Figures 17-23, with a single-wire feed line 9 located at the flat top, supported by a solid or foam type dielectric substrate 8.

[0085] Figure 26 shows the cross section of an example of a conducting support structure of one of the types in Figures 17 to 23, with a single-wire feed line 9 located at the flat top, supported by a foam type dielectric substrate 8. The single-wire feed line is etched on a more solid dielectric substrate 10 that is above the single-wire line, providing a stable mechanical support for the feed line and the dipoles. The advantage of this upside-down microstrip structure is that the propagation constant and losses of the feed line is determined by the foam and not the solid substrate, and thereby lower losses are achieved. This upside-down structure can also be applied to the two-wire line structure in Figure 24.

[0086] Figures 27 to 33 show the top view of different new layouts of dipoles, and two-wire or single-wire feed lines, made possible by an underlying conducting support structure, according to the invention. Only one quadrant of a dual-polarized realization of the Eleven antenna is shown.

[0087] Figure 28 shows dipoles fed from a two-wire line. The 180 deg phase shift of the excitation of one dipole compared to that of the previous one is in this case obtained with a conducting support structure in the form of posts, as discussed above, and in particular of the type shown in Figures 19 or 20. The opening between two posts corresponds to a shorted transmission line that will give 180 deg phase shift when the posts are approximately a quarter wavelength long.

[0088] Figure 27 shows dipoles fed from a single-wire line. The 180 deg phase shift of the excitation of one dipole compared to that of the previous one is in this case obtained with a conducting support structure in the form of posts, as discussed above, and in particular of the type shown in Figures 19 or 20. The opening between two posts corresponds to a shorted transmission line that will give 180 deg phase shift when the posts are approximately a quarter wavelength long. One set of dipole arms is seen to be connected to the single-wire feed line, whereas the opposite arm has conducting contact with the top of the conducting support posts. This metal connection is illustrated by a dark dot 11, representing a screw into the top of underlying post, or a metal pin fastened in the post and soldered to dipole arm.

[0089] Figures 29 and 30 show dipoles fed from a single-wire line. The 180 deg phase shift of the excitation of one dipole compared to that of the previous one is in this case obtained with a conducting support structure in the form of a ridge, as discussed above, and in particular of the type shown in Figures 17 or 18, and by connecting

the left and right arm 3 of the dipoles to the underlying ridge every second time along the feed line 9. The dark dot 11 is also in this case representing the metal connection to the conducting support structure, being e.g. a metal screw into the top of the ridge, or a metal pin fastened in the ridge and soldered to dipole arm.

[0090] Figures 31 to 33 show folded dipoles that appear to be fed by a two-wire line, but in reality they have single-wire feeding. The reason is that one of the wires of the two-wire line is connected to the underlying conducting support structure that has the form of a ridge, as discussed above, and in particular of the type shown in Figures 17 or 18. The 180 deg phase shift of the excitation of one dipole compared to that of the previous one is in this case obtained by the not-grounded folded arm the dipoles. The dark dots 11 are also in this case representing the metal connection to the conducting support structure, being e.g. a metal screw into the top of the ridge, or a metal pin fastened in the ridge and soldered to dipole arm. The folded arms that are connected to the ridge may or may not be folded, although they are shown as if they are folded. The connection to the conducting supporting structure makes them anyway work the same way independent of whether they are folded or not.

[0091] Figure 34 shows a cross section of a dipole with two dipole arms 3 on a conducting support structure 5 above a ground plane 4 with foam layer 8. The dipoles and feed line 9 are fixed upside-down on a solid dielectric substrate 10, and one dipole arm has metal contact with the support structure by means of a screw through the substrate, dipole arm and into the support structure. This screw will also provide a strong mechanical support for the dipoles and feed lines to the conducting support structure.

[0092] The conducting support structure is above defined as a separate structure connected to the ground plane. However, it may also be made from the same material piece as the ground plane, by e.g. milling. Thereby, the ground plane with conducting support structure can instead be called a profiled ground plane.

[0093] Figures 35-39 show different ways of connecting to the two-wire 7 or single-wire feed line in the center of a dual- or circularly-polarized Eleven antenna. There two dipoles 3 in each quarter, but this is only for the purpose of the illustration. Corresponding embodiments exist for linear polarization.

[0094] Figure 35 show an embodiment with eight ports 12. Each ports can be connected to the center line of a coaxial line, e.g. by soldering, and continue through a little hole in the ground plane to a transmitter or receiver on the back side.

[0095] Figure 36 shows an embodiment with four ports 12. This is the feed configuration studied in R. Olsson, P.-S. Kildal, S. Weinreb, "The Eleven antenna: a compact low-profile decade bandwidth dual polarized feed for reflector antennas", IEEE Transactions on Antennas and Propagation, vol. 54, no. 2, pt. 1, pp. 368-375, Feb. 2006. The feed lines of opposing dipoles are connected togeth-

er in the center, the feed lines of one polarization on top of the other, and one coaxial line is connected to each of the four ports. Vertically opposing ports feed horizontally opposing vertical dipoles, and visa versa.

[0096] Figure 37 shows an embodiment with four ports, obtained by connecting every second of the original eight ports to the ground and the remaining ports to coaxial lines that go through holes in the ground plane. The ground-plane connection can make the feed line 7 work as a balun and will cause correct excitation of the dipoles.

[0097] Figure 38 shows an embodiment of another four-port case. Here, neighbouring ports of different dipoles are connected together to form four ports instead of the original eight, and to each of these ports there are connected coaxial lines that can be led through the ground plane to the back side. Thereby, the antenna will be fed by a linear 45 deg rotated polarization when two opposing coaxial lines are fed 180 deg out of phase. This is no limitation. The advantage is that we have no crossing feed lines as in Figure 36.

[0098] Figure 39 shows a further development of the embodiment in Figure 38. Here, the neighbouring ports are connected to each of four ridges 14 located in the 45 deg planes with respect to the dipoles. These metal ridges continue through the ground plane in a big hole 15. The advantage is that it is well known how to feed such ridges even at very high frequencies, as this is the way used to feed so-called Vivaldi antennas and quad-ridged horn antennas.

[0099] The above-discussed embodiments of antennas according to the invention have many features in common. For example, all, or at least most, of said embodiments encompass the following features:

- The antennas comprise dipoles arranged in pairs, which is evident from e.g. Figures 6, 7, 11 and 12, whereas e.g. Figures 8, 9, 10, 13 and 14 show only one half of a linearly polarized antenna according to the invention, or one quarter of a circularly polarized realization of the antenna.
- The antenna dipoles are arranged on one side of a ground plane, and in such a way that the main lobe of the output radiation pattern is directed in a direction perpendicular to said ground plane.
- The antenna dipole are held at a certain height above the ground plane by means of a conductive support structure.
- The lengths of the dipoles (antenna elements) increase along the feed line away from a centrally located feed point. The length of succeeding dipoles preferably differ in length from the dipole positioned immediately before by a frequency-independent factor. The factor is preferably in the range 1.1 - 1.2.
- The spacings between the dipoles increases along

the feed line away the centrally located feed point as well, by a constant frequency-independent factor. The factor is preferably in the range 1.1 - 1.2.

- The two (linearly polarized version) or four (dual polarized version) parts of the antenna are fed by separate feed lines that are connected to common feed point or feed points in the central region between the antenna parts.
- The antenna elements/dipoles are essentially formed as straight conducting wires or strips.
- The antenna elements are formed on supporting dielectric substrates, such as PCBs, and preferably by means of etching techniques, as is per se known in the art.
- The antennas could be used for a wide range of different output wavelengths, and is particularly useful for wavelengths in the range 1-15 GHz, and most particularly for the ultra wideband range (2-10 GHz).

[0100] Specific embodiments of the invention have now been described. However, several alternatives are possible, as would be apparent for someone skilled in the art. For example, different arrangement designs of the dipoles are possible, different combination of antenna planes are possible, various feeding arrangements are feasible, etc. Such and other obvious modifications must be considered to be within the scope of the present invention, as it is defined by the appended claims. It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims.

Claims

1. An antenna for transmitting or receiving electromagnetic waves comprising several electric dipoles positioned over a conducting ground plane, **characterized in that** the dipoles are arranged in pairs of oppositely located dipoles, that they are arranged in such a way that the geometrical centres of each dipole pair are at least approximately coinciding, and that the dipoles are supported at certain heights over the ground plane, the height being the same for each dipole pair, by means of a support structure arranged between the dipole and the ground plane, wherein this support structure is at least partly made of electrically conducting material.
2. An antenna according to claim 1, wherein the support structure is part of the same metal piece as the ground plane that thereby becomes a profiled ground

plane, or comprises several parts that are fixed to the ground plane. An antenna according to any one of the preceding claims, wherein each support structure comprises a metal ridge with a flat or almost flat top, and/or several posts with a flat or almost flat top, and/or has an increasing height from the geometrical center of the dipole pairs and outwards, and/or has an increasing width from the geometrical center of the dipole pairs and outwards.

3. An antenna according to claim 1, wherein each support structure comprises both ridges and several posts, having a flat or almost flat top.
4. An antenna according to any of the preceding claims, wherein at least a part of each support structure is connected to the ground plane inside one or more grooves, dents or depressions in the ground plane.
5. An antenna according to any one of the preceding claims, wherein each dipole consists of two opposite arms, and each dipole arm comprises two conducting lines that are connected at the outer end whereas the inner end at a feed gap is connected with the inner end of the closest line of a neighbouring inner or outer dipole arm, so that one set of dipoles with feed lines are formed by two opposing serpentine-shaped lines.
6. An antenna according to any one of the preceding claims, wherein at least one dipole comprises two oppositely directed conducting arms with a feed gap between them, and wherein the feed gaps of neighbouring dipoles of different dipole pairs are excited by a two-conductor feed line starting from one or more feed points, the two separate conductors of the two-conductor feed line being arranged in at least two different, non-intersecting planes.
7. An antenna according to any one of the preceding claims, wherein there is located another antenna of different type between the dipoles of the innermost dipole pair or pairs.
8. An antenna according to any one of the preceding claims, wherein there is located a radiating circular waveguide or horn antenna between the dipoles of the innermost dipole pair or pairs.
9. An antenna according to any one of the preceding claims wherein the ground plane comprises grooves or holes.
10. An antenna according to any one of the preceding claims wherein the ground plane is connected to a metal wall surrounding the whole antenna.
11. An antenna according to any one of the preceding

claims wherein the outermost dipole or transmission line has metal contact with the ground plane via the ground plane wall or a metal post.

12. An antenna according to any one of the preceding claims where the central parts of all the feed lines are connected to up to eight individual coaxial antenna ports located on the back side of the ground plane. 5
- 10
13. An antenna according to any one of the preceding claims where the feed lines are connected to a centrally located quad-ridged feed line that goes through a hole in the ground plane and has its coaxial ports on the back side of it. 15
- 20
14. An antenna according to any one of the preceding claims where the feed lines are connected to a centrally located dually-polarized Vivaldi antenna that goes through a hole in the ground plane and has its coaxial ports on the back side of it. 25
- 30
- 35
- 40
- 45
- 50
- 55

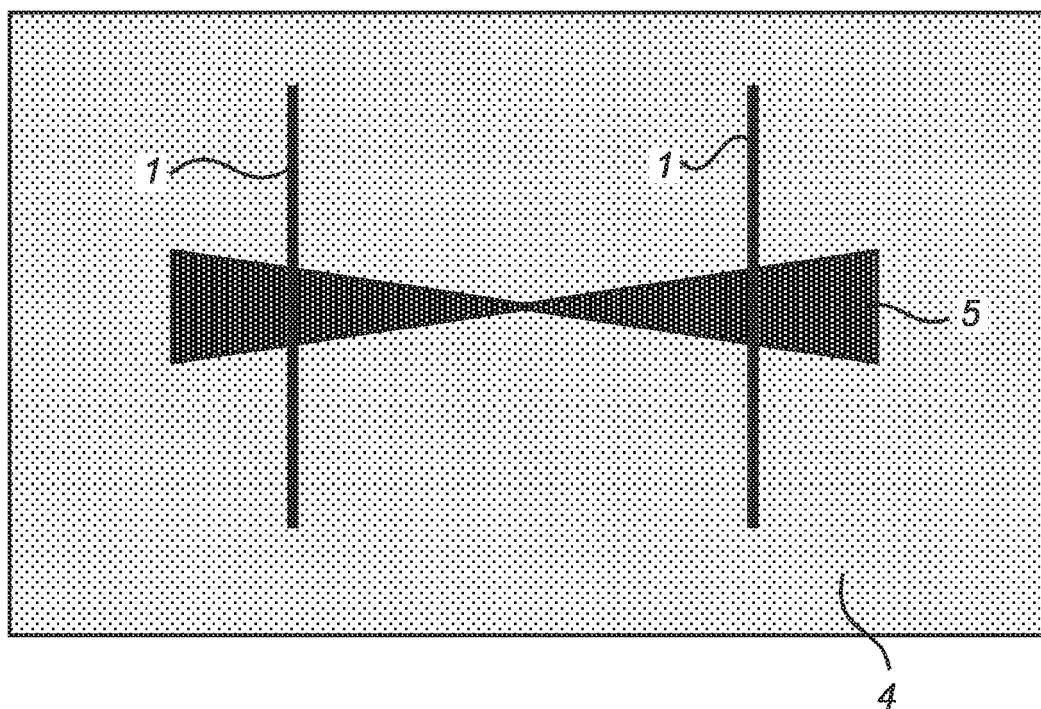


Figure 1

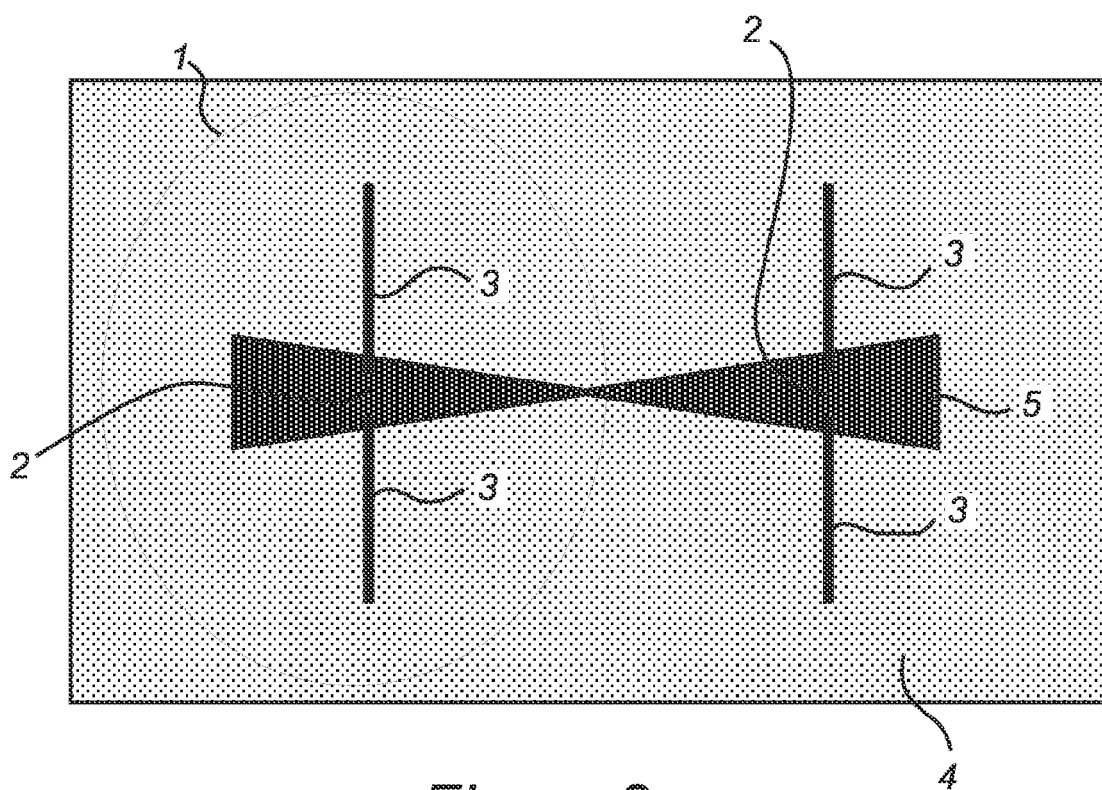


Figure 2

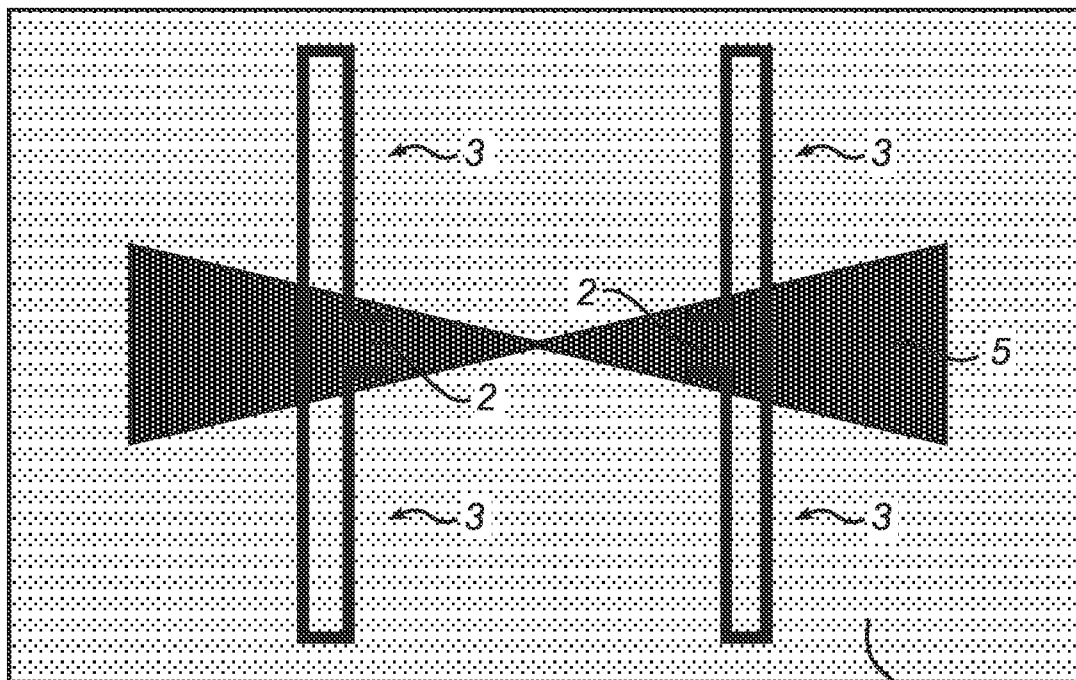


Figure 3

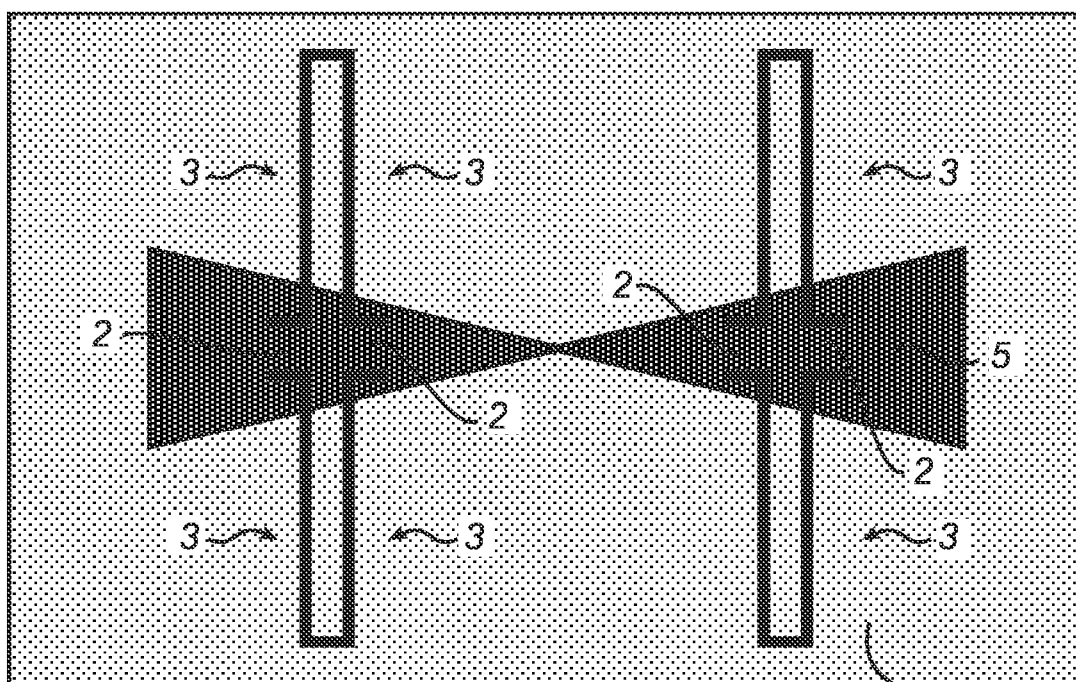


Figure 4

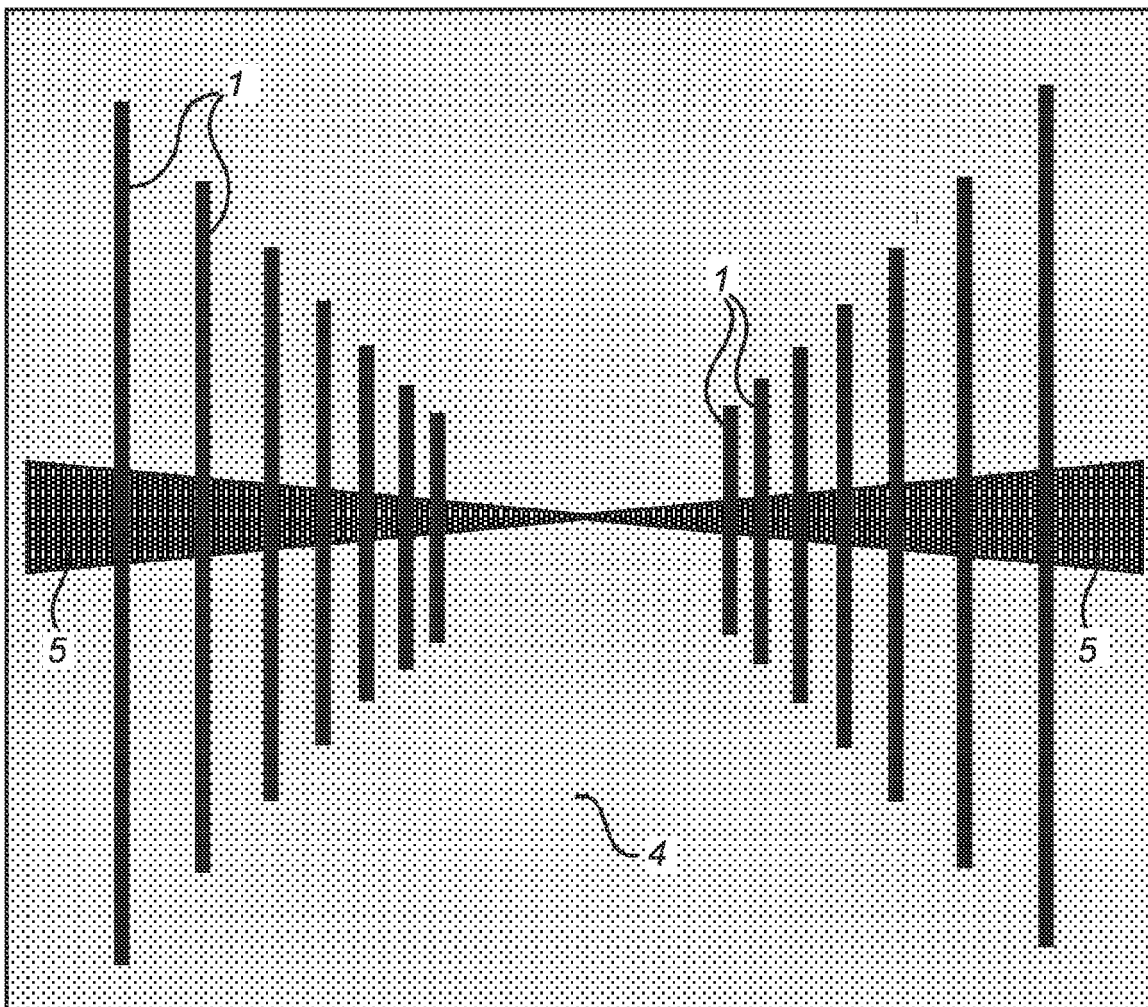


Figure 5

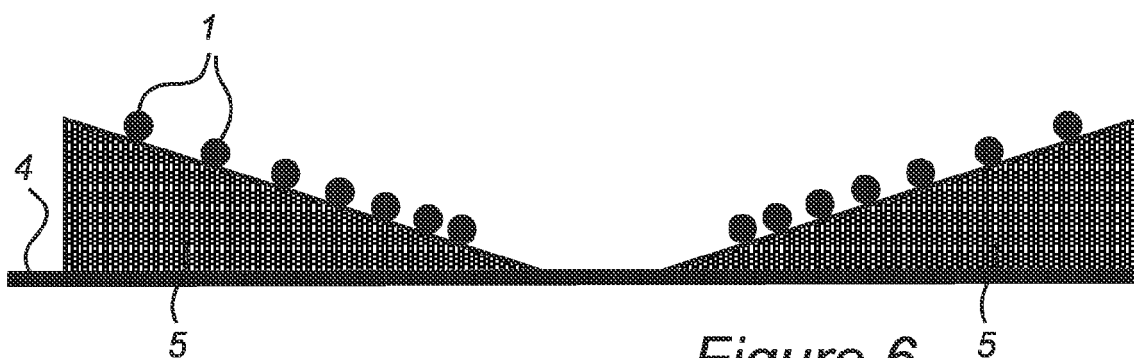


Figure 6

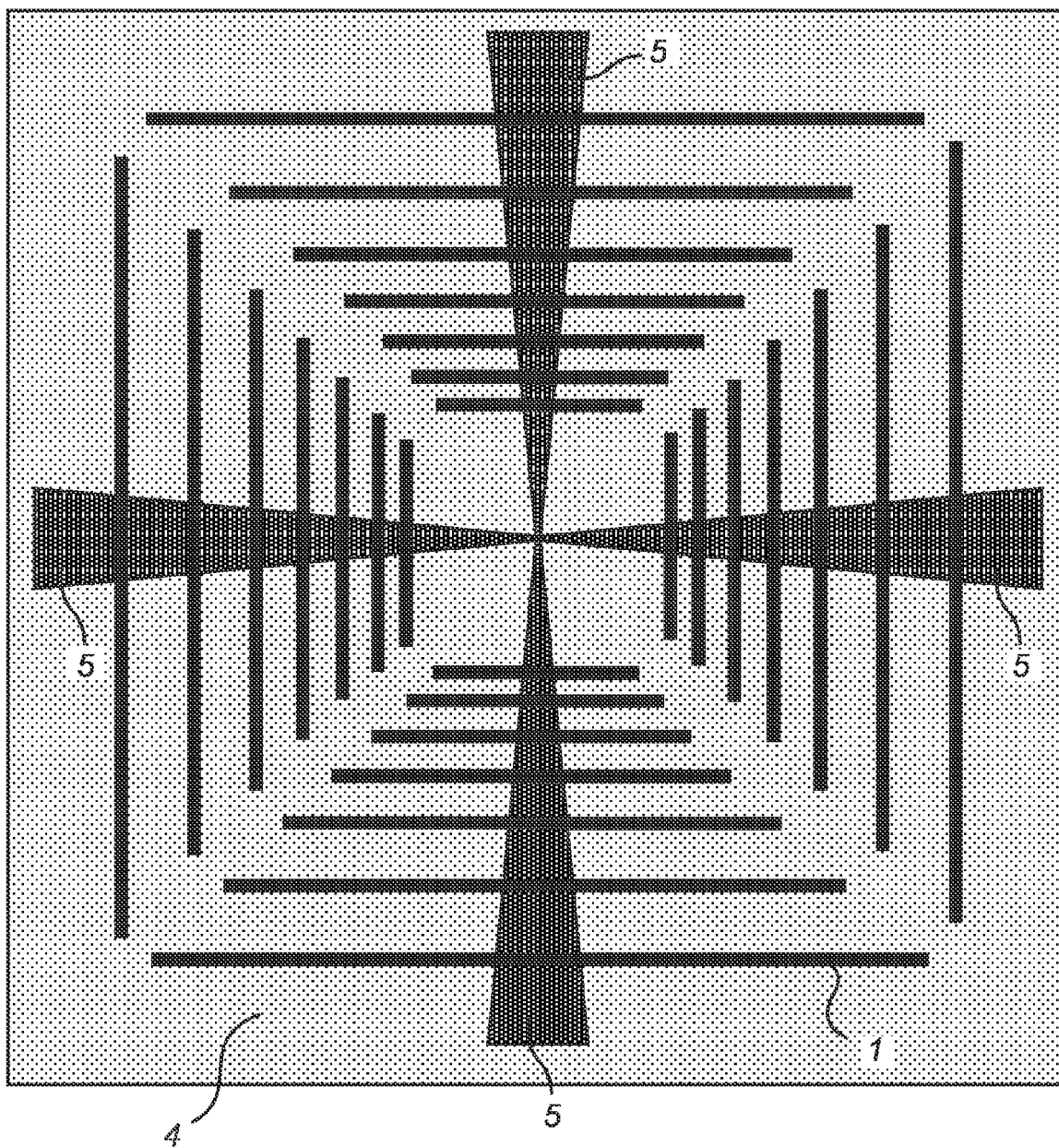


Figure 7

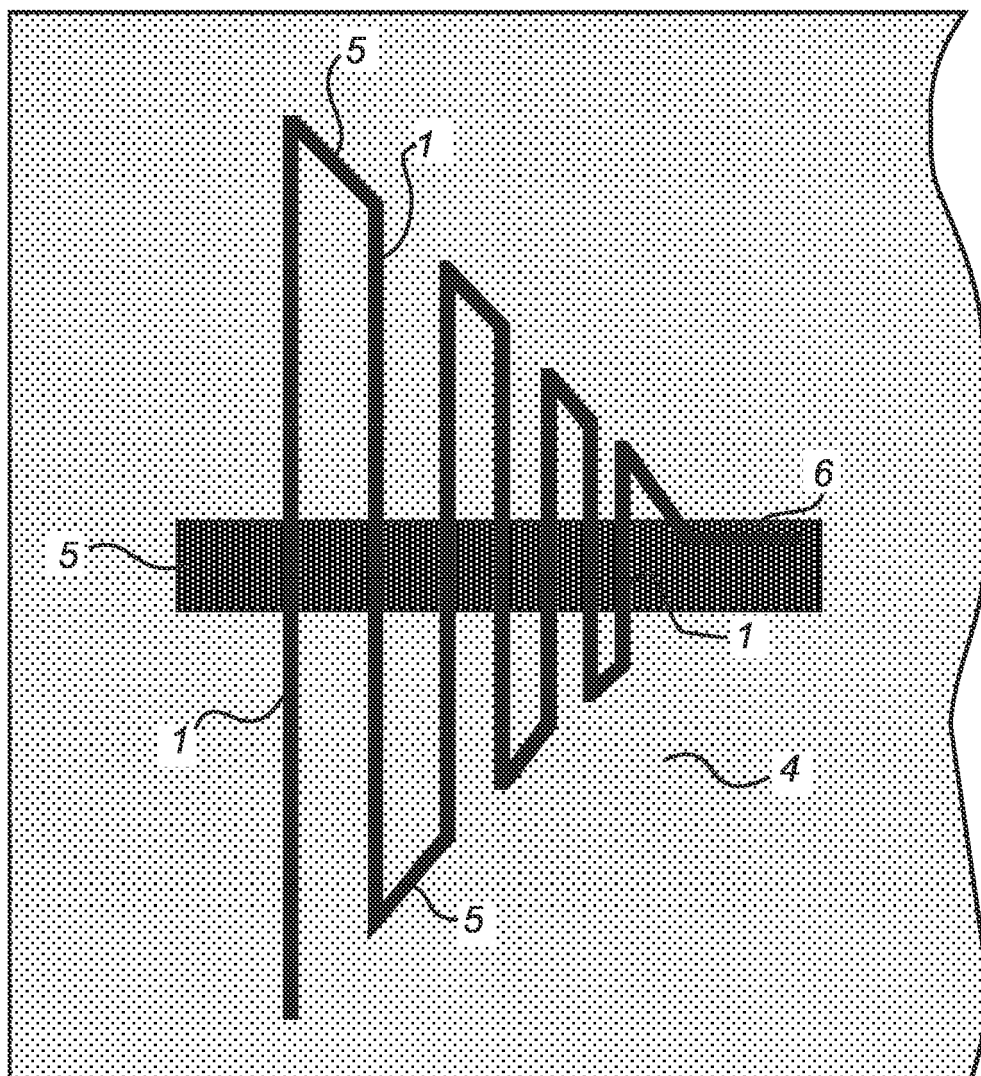


Figure 8

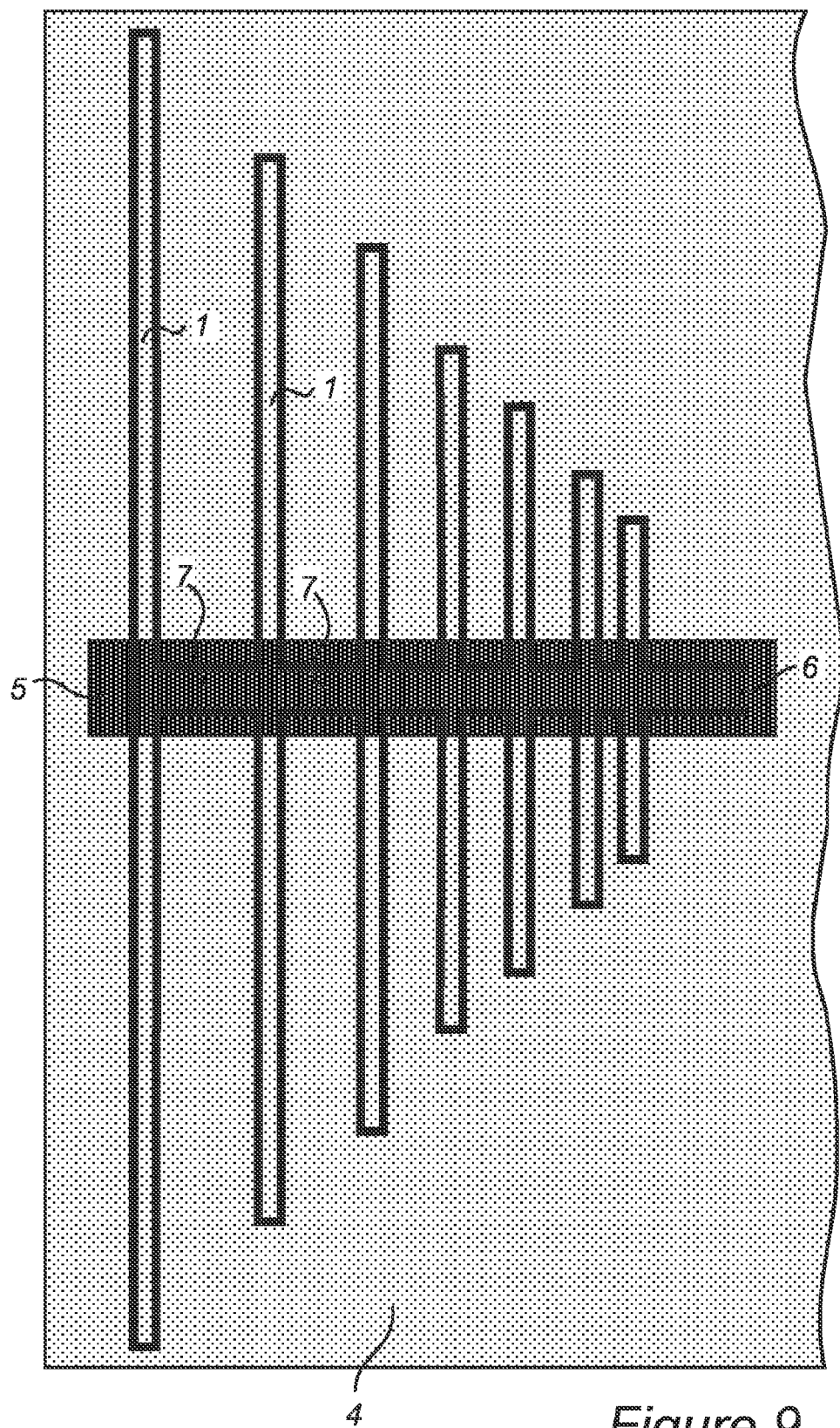


Figure 9

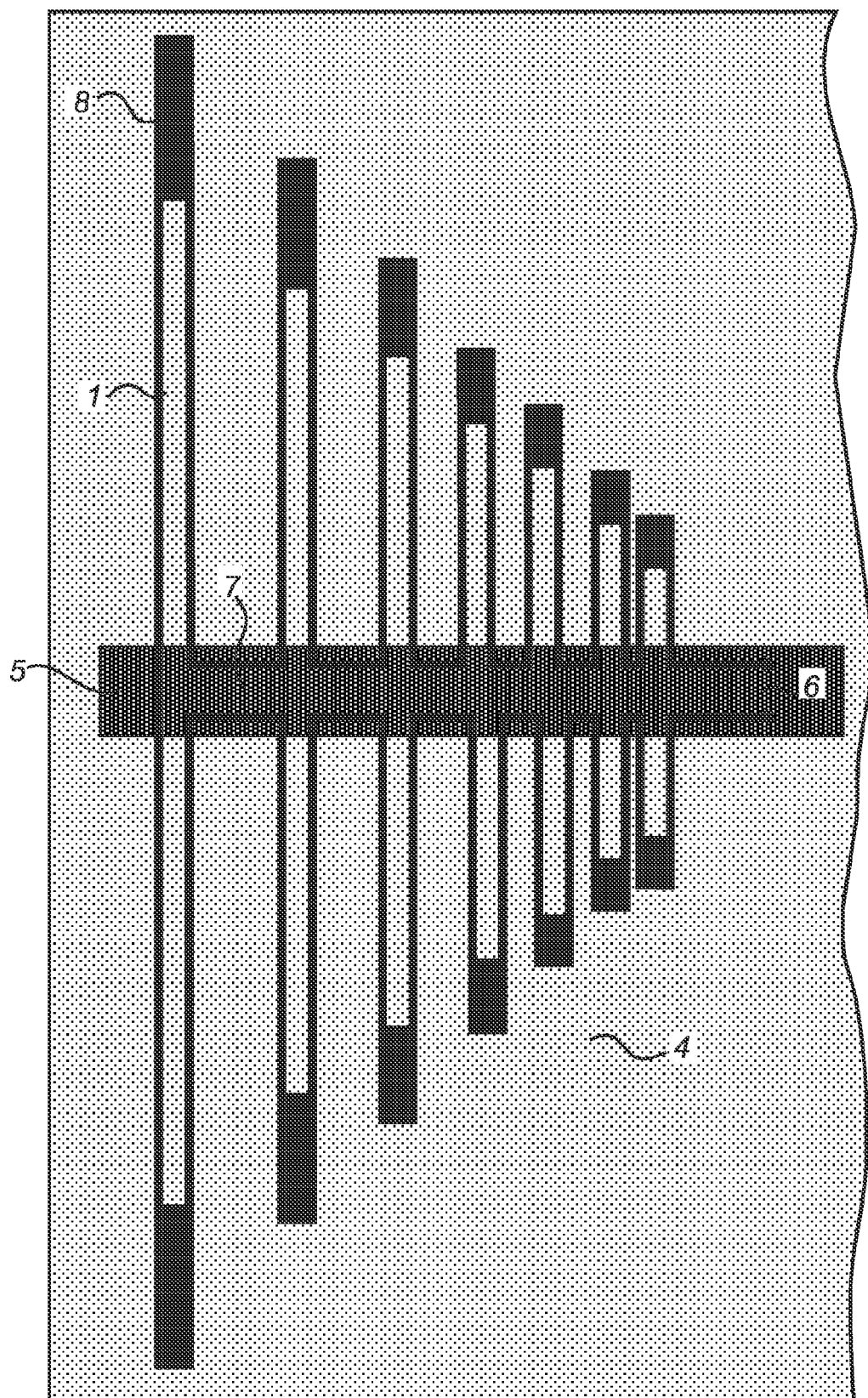


Figure 10

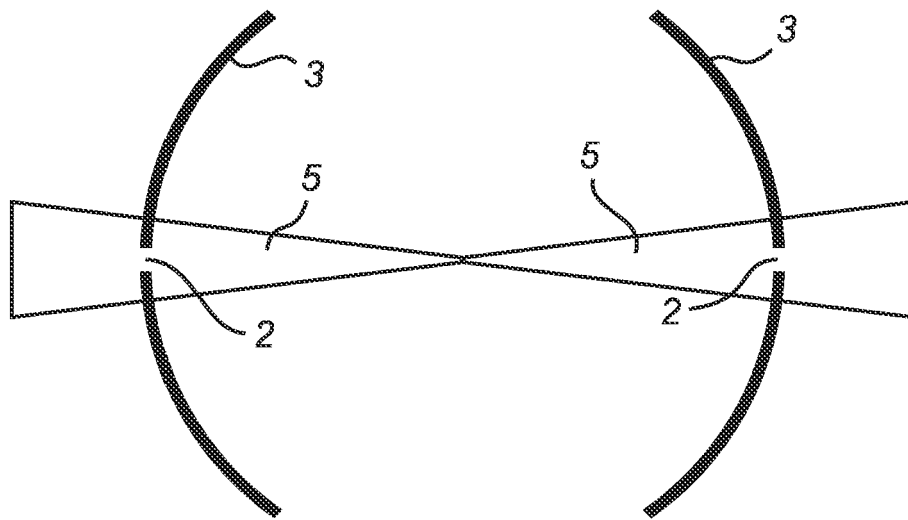


Figure 11

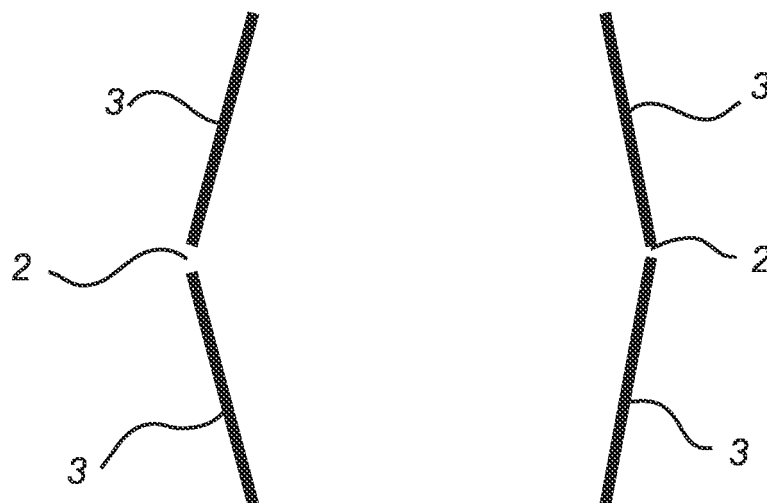


Figure 12

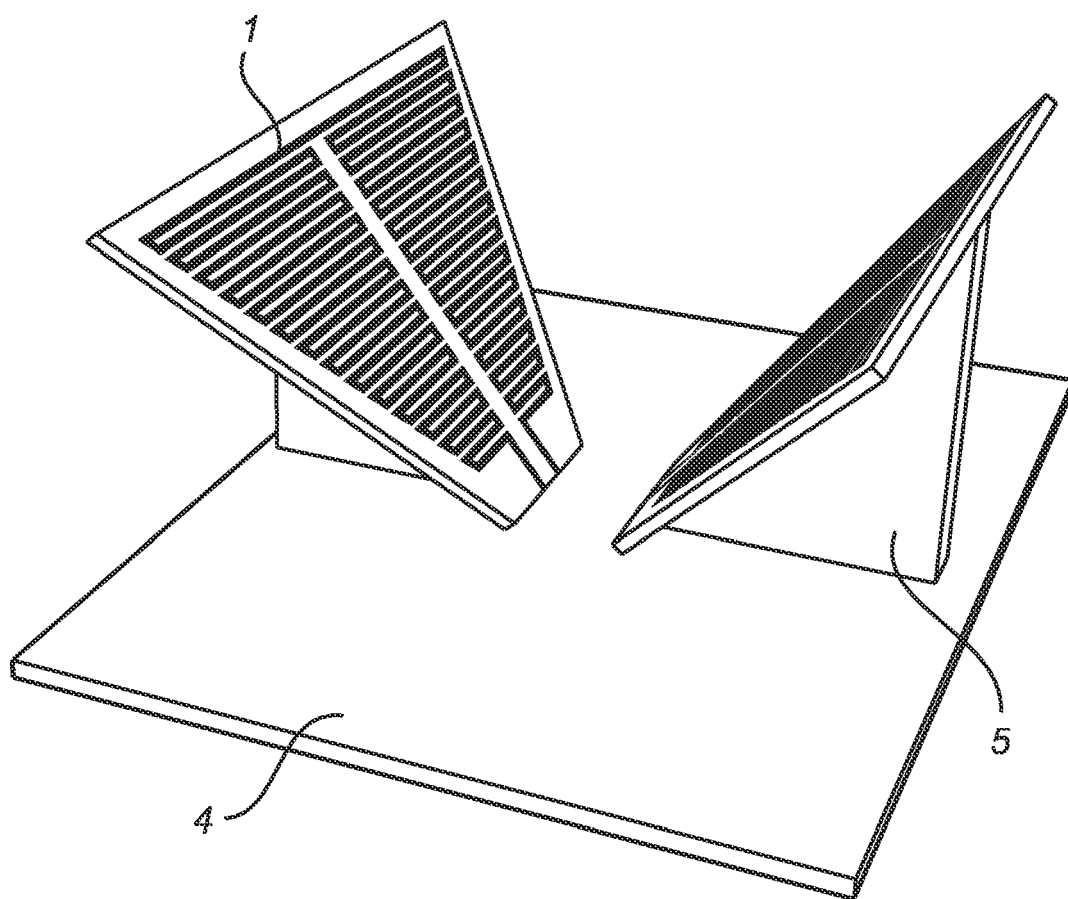


Figure 13

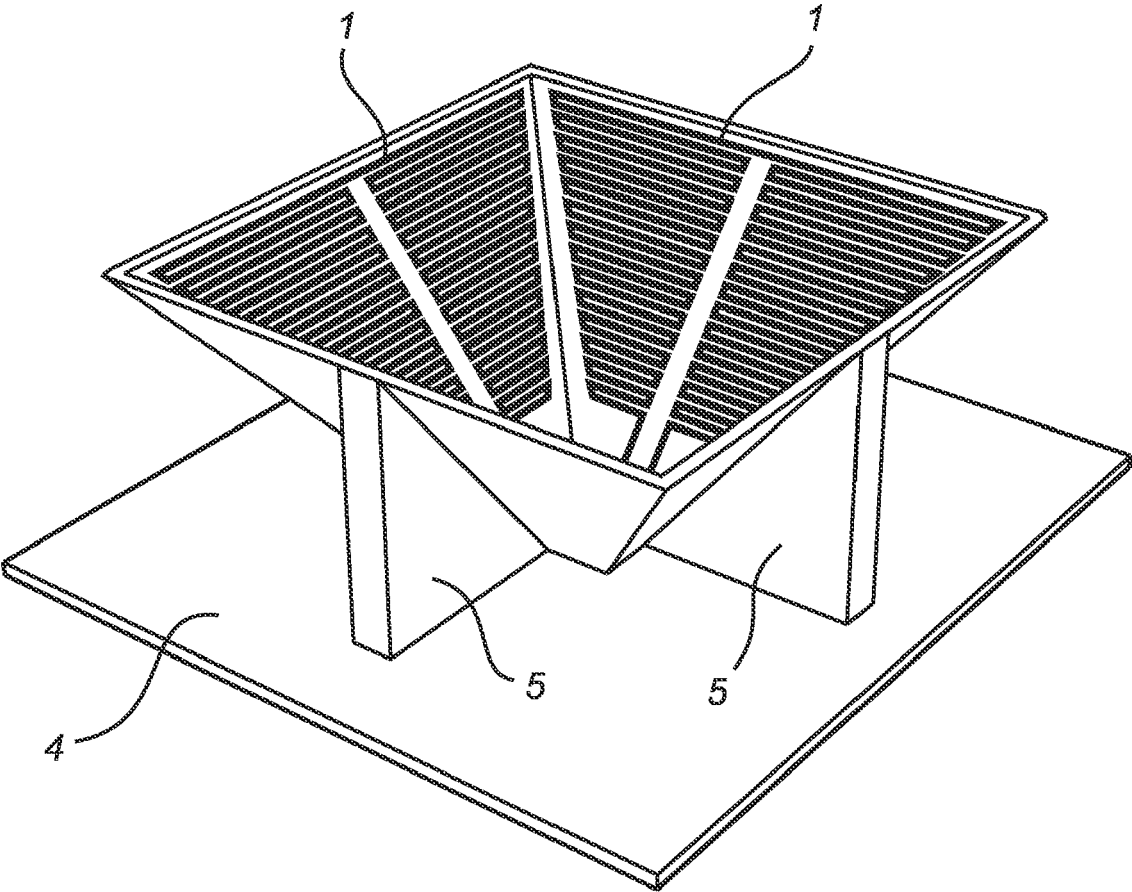


Figure 14

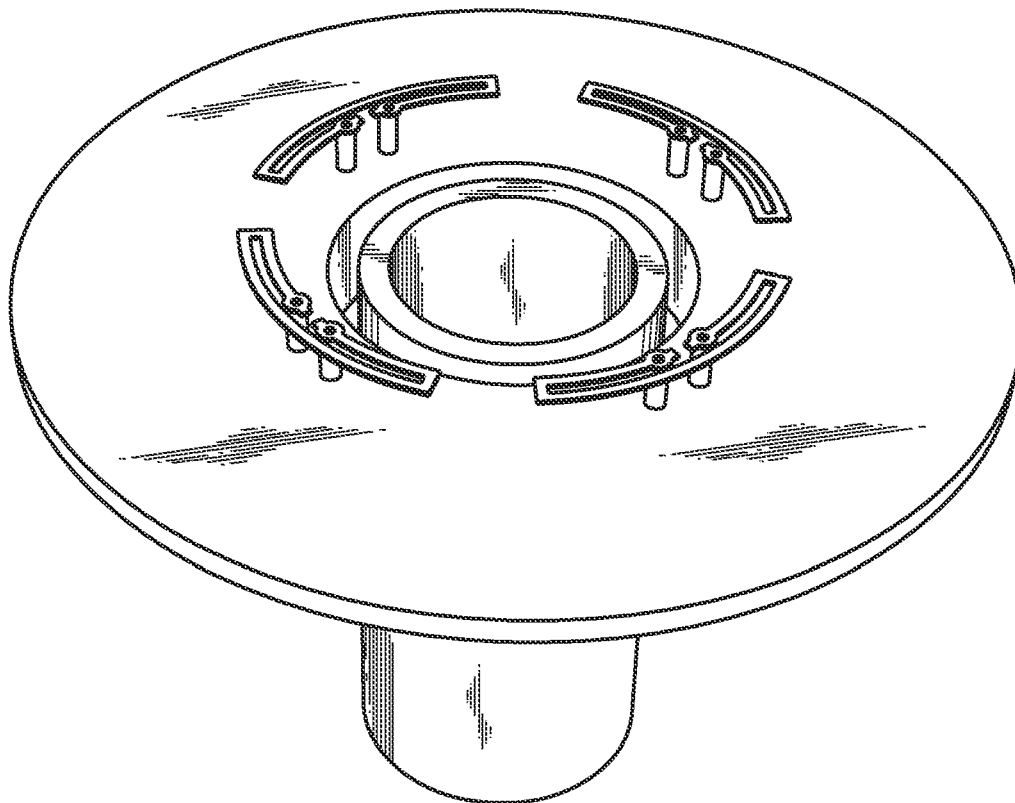


Figure 15

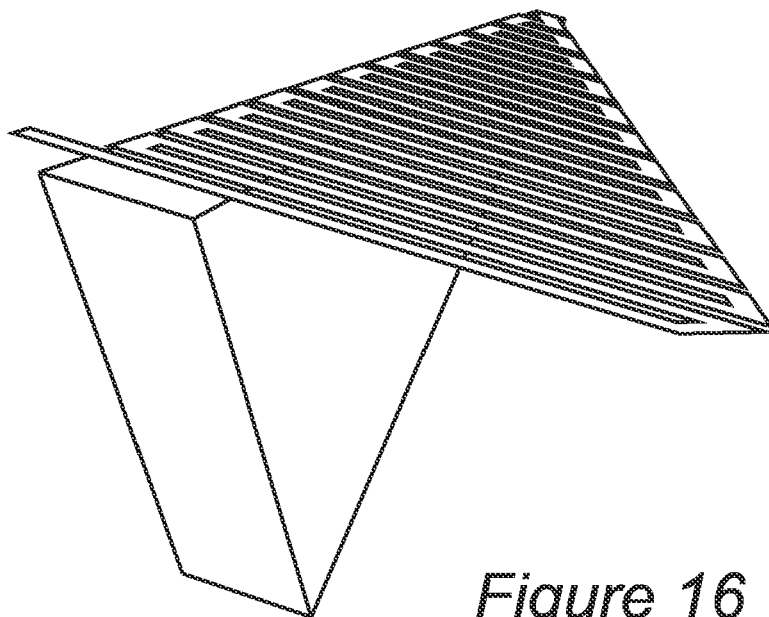


Figure 16

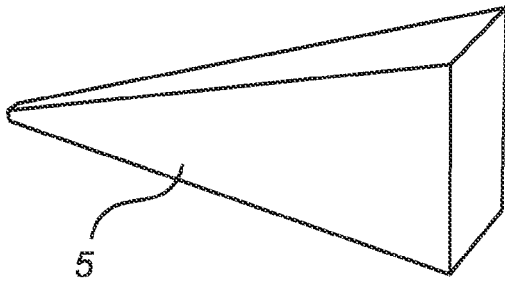


Figure 17

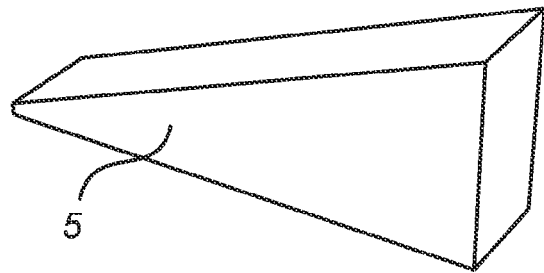


Figure 18

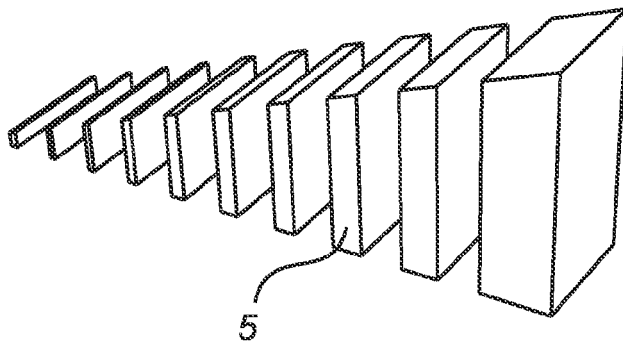


Figure 19

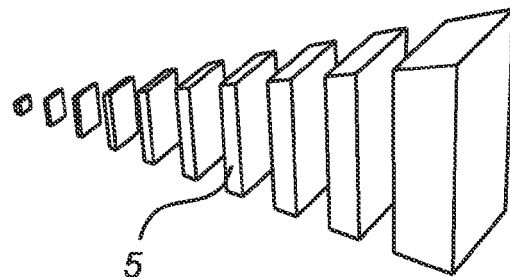


Figure 20

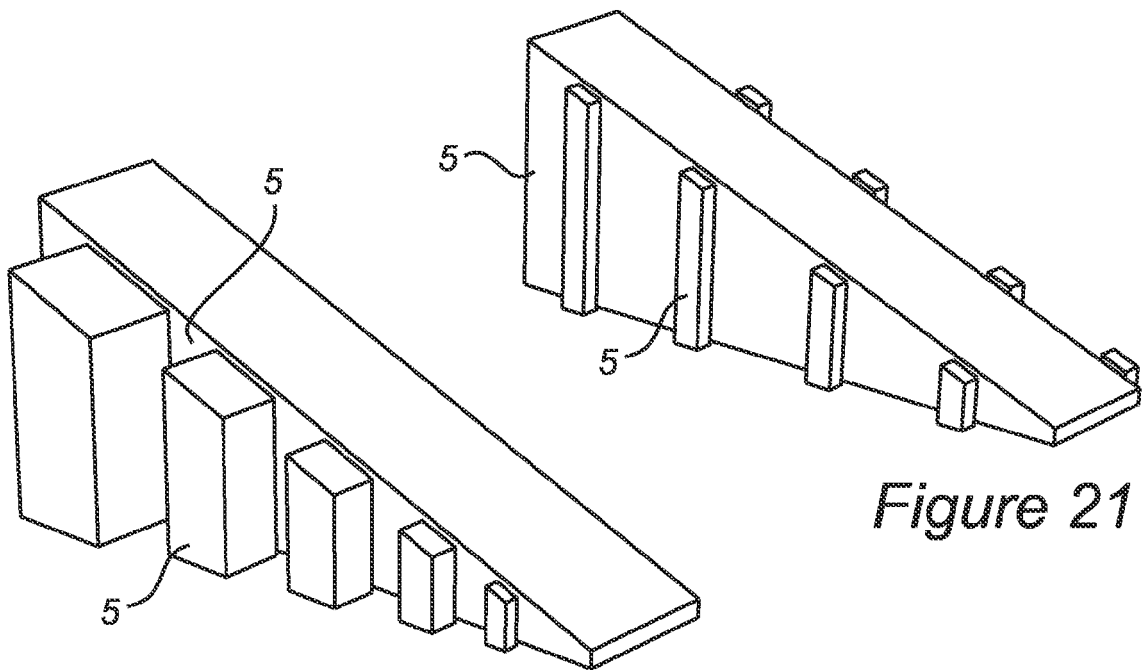


Figure 21

Figure 22

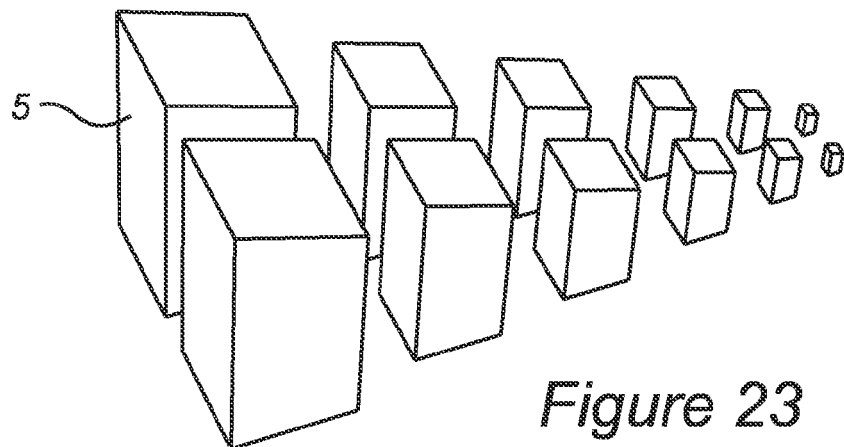


Figure 23

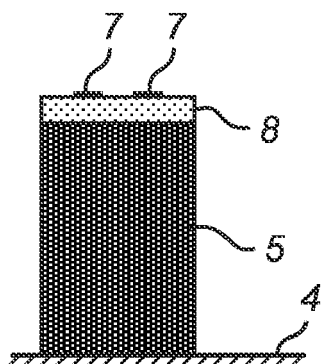


Fig. 24

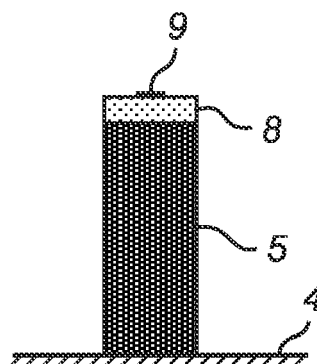


Fig. 25

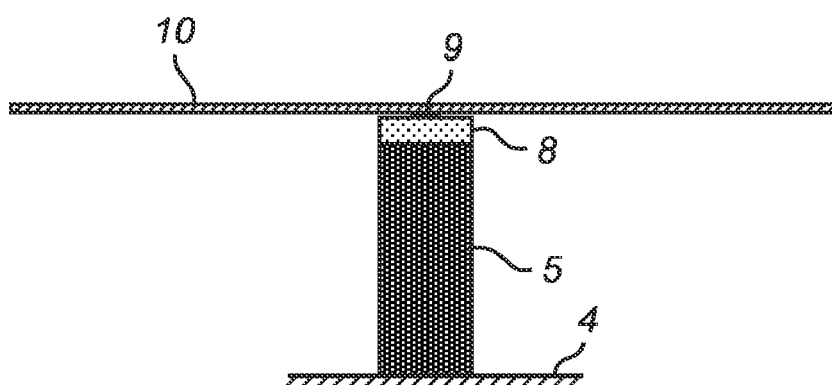


Fig. 26

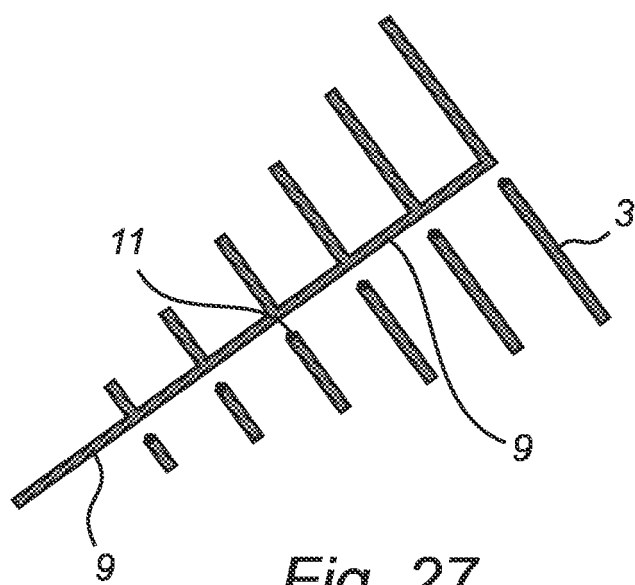


Fig. 27

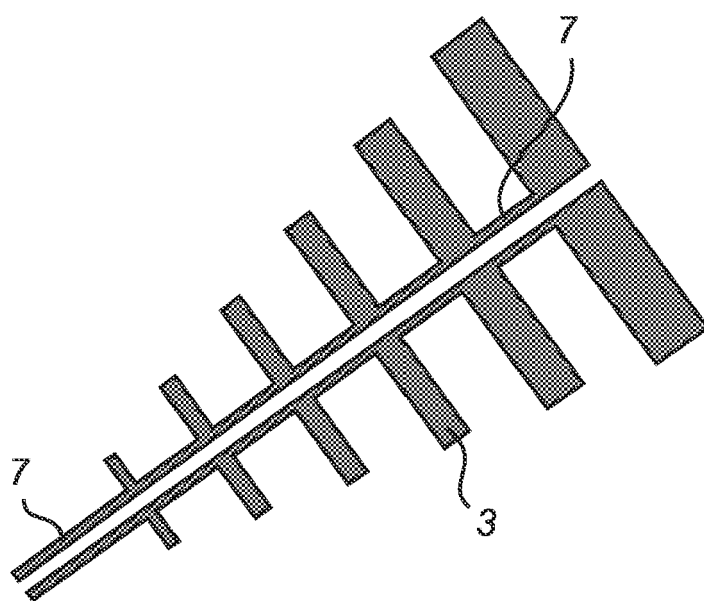


Fig. 28

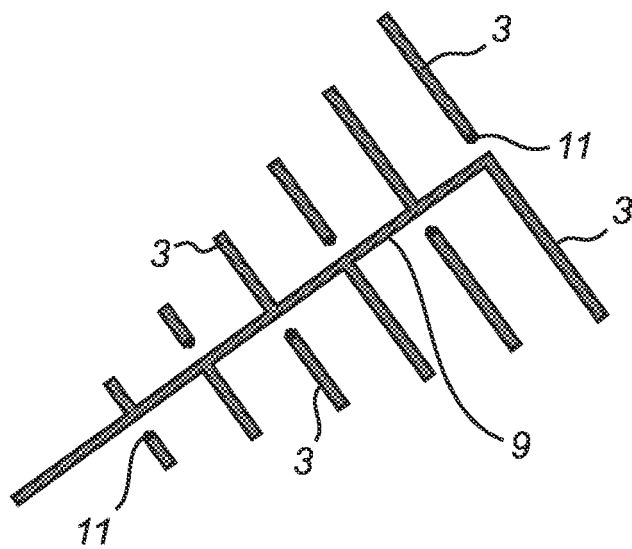


Fig. 29

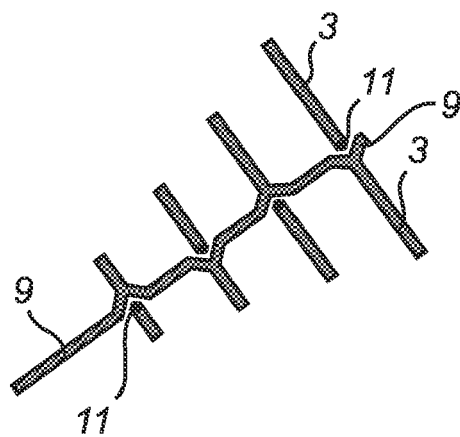


Fig. 30

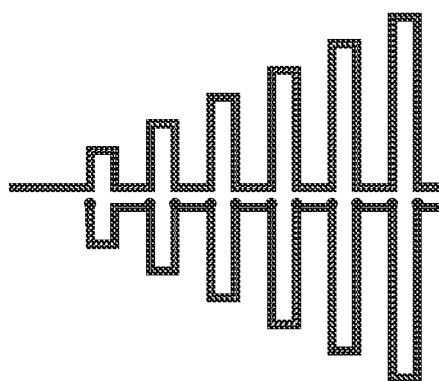


Fig. 31

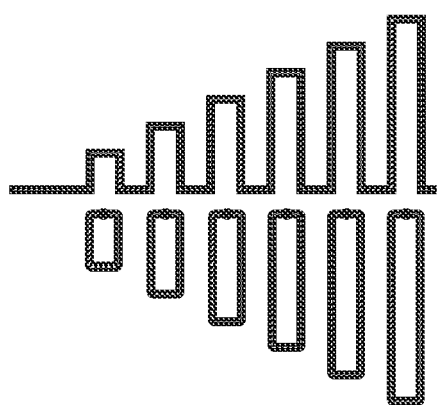


Fig. 32

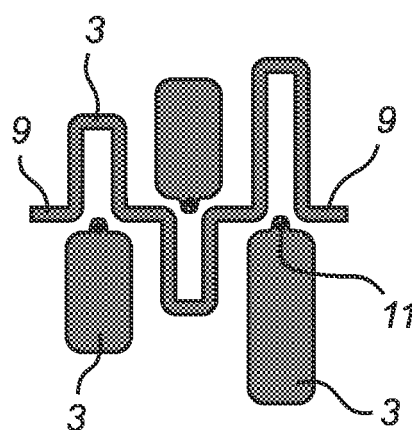


Fig. 33

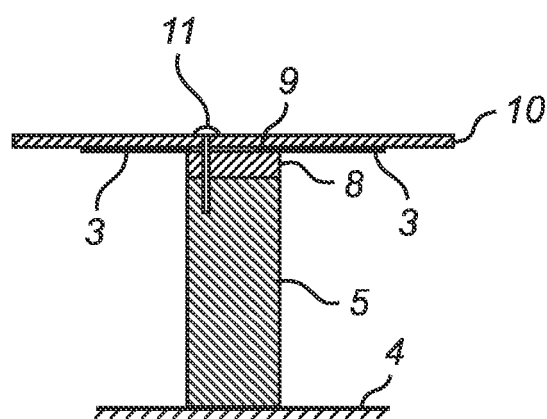


Fig. 34

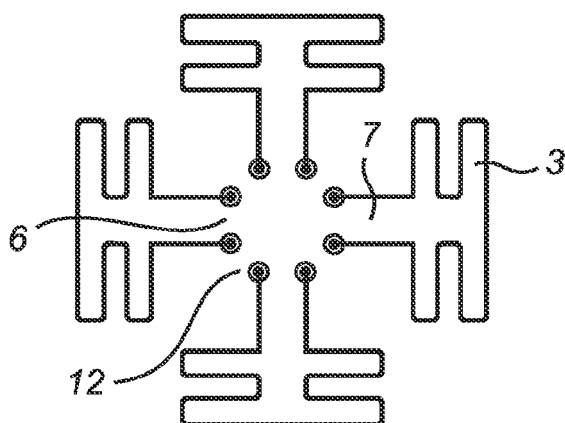


Fig. 35

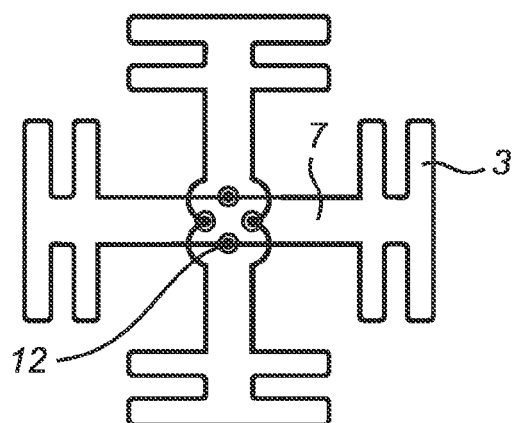


Fig. 36

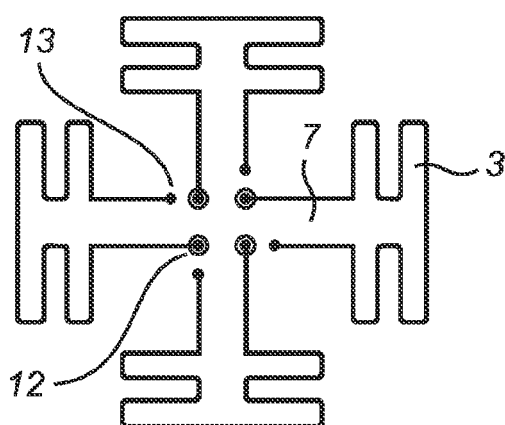


Fig. 37

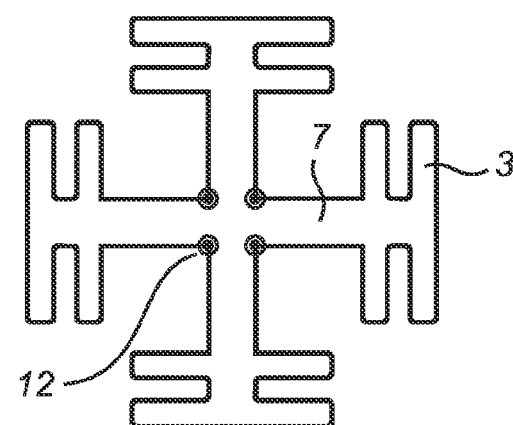


Fig. 38

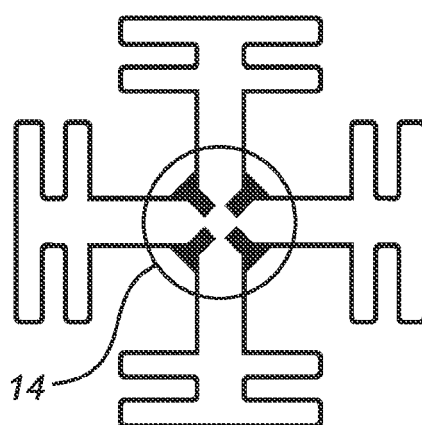


Fig. 39



EUROPEAN SEARCH REPORT

Application Number
EP 08 15 6390

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	FR 2 841 391 A (JACQUELOT TECHNOLOGIES [FR]) 26 December 2003 (2003-12-26) * page 4, line 5 - page 6, line 32; figures 1-3 *	1-4,7-14	INV. H01Q11/10 H01Q19/10 H01Q21/24
X	WO 2006/096402 A (EMS TECHNOLOGIES INC [US]; SIMILE ARIN MATTHEW [US]) 14 September 2006 (2006-09-14) * page 11, line 4 - page 13, line 17; figures 3-6 *	1	
Y		5,6	
Y,D	WO 2005/015685 A (KILDAL ANTENNA CONSULTING AB [SE]; KILDAL PER-SIMON [SE]) 17 February 2005 (2005-02-17) * the whole document *	5,6	
A	US 5 041 840 A (CIPOLLA FRANK [US] ET AL) 20 August 1991 (1991-08-20) * abstract; figure 2 *	8,14	
A	WO 99/35711 A (THOMSON MULTIMEDIA SA [FR]; LOUZIR ALI [FR]) 15 July 1999 (1999-07-15) * claims 3-5; figures 2,5 *	8,14	TECHNICAL FIELDS SEARCHED (IPC) H01Q
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 13 November 2008	Examiner La Casta Muñoa, S
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

 4
EPO FORM 1503 03.82 (P04C01)

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

EP 08 15 6390

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The members are as contained in the European Patent Office EDP file on
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13-11-2008

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
FR 2841391	A	26-12-2003	AU 2003255660 A1	06-01-2004
			CN 1663075 A	31-08-2005
			EP 1516393 A1	23-03-2005
			WO 2004001902 A1	31-12-2003

WO 2006096402	A	14-09-2006	US 2006202900 A1	14-09-2006

WO 2005015685	A	17-02-2005	BR PI0413382 A	17-10-2006
			CN 1864303 A	15-11-2006
			EP 1652269 A1	03-05-2006
			JP 2007502049 T	01-02-2007
			KR 20060066717 A	16-06-2006
			WO 2005015686 A1	17-02-2005
			US 2008204343 A1	28-08-2008

US 5041840	A	20-08-1991	NONE	

WO 9935711	A	15-07-1999	CN 1285966 A	28-02-2001
			EP 1044482 A1	18-10-2000
			FR 2773271 A1	02-07-1999
			ID 27106 A	01-03-2001
			JP 2002501315 T	15-01-2002
			US 6362788 B1	26-03-2002

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 05015685 A [0007] [0008] [0009] [0010] [0014] [0015] [0017] [0019] [0021]
- WO 05015686 A [0007] [0008] [0009] [0010] [0014] [0015] [0017] [0019]
- US 3696437 A [0017]
- US 5274390 A [0028]

Non-patent literature cited in the description

- **Greg Engargiola.** Non-planar log-periodic antenna feed for integration with a cryogenic microwave amplifier. *Proceedings of IEEE Antennas and Propagation Society international symposium*, 2002, 140-143 [0007]
- **R. Olsson ; P.-S. Kildal ; S. Weinreb.** The Eleven antenna: a compact low-profile decade bandwidth dual polarized feed for reflector antennas. *IEEE Transactions on Antennas and Propagation*, February 2006, vol. 54 (2), 368-375 [0008] [0019] [0095]