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(54) **ELECTRONICALLY STEERED BEAM ANTENNA OF ESPAR TYPE**

(57) The invention refers to the ESPAR antenna with an electronically steerable main beam direction, which is known and is used as a base antenna enhanced by an additional dielectric structure which modifies its radiation pattern in the elevation plane. The essence of the invention is the determination of the following properties of the dielectric ring: the radius of the ring in the transverse (with respect to the axis of the structure) cross-section R , the ring longitudinal cross-section radius R_0 , the distance of the ring from the basis plane of the base an-

tenna H and the relative permittivity of the ring material. As a result, the desired modification of the radiation pattern is achieved. The essence of the invention is the relative permittivity of the ring material in the range of 2 to 20, ring radius R in the range of $0.5 \lambda_0$ to $1 \lambda_0$, longitudinal cross-section ring radius R_0 in the range of $0.05 \lambda_0$ to $0.2 \lambda_0$ and the distance from the ring to the antenna basis H in the range of $-0.3 \lambda_0$ to $0.3 \lambda_0$. λ_0 is the length of the electromagnetic wave in free space.

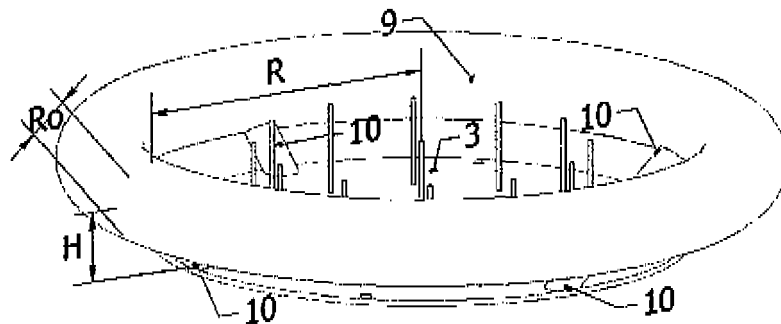


Fig. 7

Description

[0001] The invention refers to the ESPAR antenna with an electronically steerable main beam direction in the horizontal plane and an additional dielectric structure which modifies radiation pattern in the elevation plane.

[0002] The invention has application in wireless communication systems where it introduces a beam direction switching capability and the possibility of adapting the beam's shape to operation environment conditions.

[0003] Reconfigurable antennas that are capable of detecting the direction of incoming signals and pointing their main beam towards the transmitting device are known. Such capability is called beamforming and is typically achieved using phased arrays. This approach requires the utilization of expensive phase shifters and the design of a complex feeding network resulting in reduced energy efficiency. These features make the device unsuitable for use in simple IoT (Internet-of-Things) devices and WSN (Wireless Sensor Network).

[0004] A solution for the requirements and needs of this type of system is ESPAR (Electronically Steerable Parasitic Array Radiator) antenna. This antenna type achieves beamforming functionality utilizing parasitic/passive elements, i.e. those to which the excitation signal is not applied. A typical structure of the ESPAR antenna, e.g. shown in the patent description US6606057, consists of a single active element, which is excited by a radio signal, and several passive elements surrounding it, connected only to a one-port device with electronically controlled impedance. In recent years, constructions that do not have a ground plane, e.g. based on dipole elements, and those that have a ground plane, e.g. based on monopole elements placed above it, have been studied. The latter is particularly valuable from the perspective of possible applications since said ground plane allows a control circuit to be placed on its underside, thus reducing its influence on the antenna performance.

[0005] As a consequence of introducing a ground plane, antenna's main beam direction in the elevation plane is tilted away from the ground plane (typically it is about 60° from the direction perpendicular to the ground plane). Such an outcome may be undesirable, e.g. in the case when the communication devices are placed in the horizontal plane of the antenna. Constructions allowing for a horizontal direction of radiation were studied, e.g. R. Schlub and D. V. Thiel, "Switched parasitic antenna on a finite ground plane with conductive sleeve," in IEEE Transactions on Antennas and Propagation, vol. 52, no. 5, pp. 1343-1347, May 2004, doi: 10.1109/TAP.2004.827504, introduces a metal sleeve attached to the edge of the ground plane. On the other hand, in the construction known from the patent description US660605782, a dielectric ring placed on the ground plane surrounding the passive elements was used, which, apart from obtaining the horizontal direction of the radiation, is also intended to increase the antenna gain. In both cases, in order to achieve the goal, it is necessary to modify the basic design of the antenna (without additional elements modifying the radiation pattern) in terms of modifying the ground plane structure or adjusting the impedance of one-port devices connected to passive elements.

[0006] In the known ESPAR antenna constructions, the elements responsible for switching the beam direction in the horizontal plane also allow for relatively easy shaping of radiation characteristics parameters in the horizontal cross-section (e.g. half-power beam width). On the other hand, without additional elements optimization of the shape in the elevation cross-section is challenging. Usually, the main beam in this cross-section is tilted at a constant angle related to the antenna constriction. In the case of a monopole-based antenna, it is approx. 60° . Similarly, it is difficult to modify the half-power beam width in the elevation cross-section. While the default radiation pattern may not be optimal depending on the spatial arrangement of the communicating devices. In any practical use case of wireless communication, it is desirable to maximize power radiated towards these devices. It leads to improvement in the quality of connection and resistance to interfering signals coming from other directions.

[0007] As mentioned above, the maximum radiation in elevation of a typical, monopole-based ESPAR antenna is about 60° . In consequence, in the case where antenna (1) is placed on the ceiling, the best performance is achieved in the configuration shown in Fig. 1, i.e. when the wireless devices (2) are positioned at a height close to h_2 - at the angle of maximum radiation. However, in the case shown in Fig. 2, when wireless devices (2) are located at a similar height (e.g. at the height h_1 , or also on the ceiling), the desirable modification would be increasing the beam angle ($>60^\circ$) and in the analogical case shown in Fig. 3, desirable would be decreasing mentioned angle ($<60^\circ$). On the other hand, in the situation depicted in Fig. 4, where the wireless devices (2) are spread across different heights, the beam broadening would allow for unifying the communication conditions for all wireless devices (2). Therefore, there are different requirements for the radiation pattern when the wireless devices (2) are at a similar height (e.g. antenna on an autonomous vehicle) and different when their placement height is distant (e.g. antenna on the ceiling of a warehouse). When it is not possible to determine a single direction of incoming signals (in elevation) then the best option would be uniformly cover all elevation angles.

[0008] There are already known structures directing the main beam in the direction of the antenna ground plane, but there is no universal solution allowing to achieve other goals depending on a specific application: directing the beam in order to achieve the maximum radiation in a direction other than the horizontal one or increasing the half-power beam width in order to cover the maximum angular range for uniform energy radiation in elevation. For the solution to be easily applicable and adaptable to different scenarios, it is also important that it does not require modification of the base

antenna structure, i.e. that it allows the same antenna to be easily adapted to different situations.

[0009] That problem is solved by the presented invention which provides a solution for easy radiation pattern adjusting to specific system needs. The goal was achieved by introducing a dielectric ring into the antenna structure, which changes the shape of the radiation pattern in the elevation plane. The invention makes it possible to change the shape of the elevation cross-section of the radiation pattern, not only the horizontal one as in the known ESPAR antennas, and thus allows the use of the same base antenna in different spatial configurations of the wireless devices (situations shown in Figs. 1-4) solely by simply adjusting the parameters of the dielectric ring. Thus, the application of the invention will allow for improving the transmission quality, thereby increasing the resistance to interference, and the accuracy of the direction of arrival estimating algorithms.

[0010] The invention is based on the construction of a known ESPAR-type electronically beam-steered antenna, in which the radiation pattern is modified using a dielectric ring, hereinafter interchangeably called the ring. It allows for changing the radiation pattern in the elevation plane.

[0011] In this document following terms are used: the term base antenna, which states for known ESPAR antenna without the ring. The proposed invention is an antenna that consists of a base antenna and a dielectric ring that modifies the radiation pattern. The use of the base ESPAR antenna enables the control of the radiation direction in the horizontal plane, while the characteristic feature of the antenna according to the invention is the modification of the shape of the radiation pattern in the elevation plane thanks to the accordingly set properties of the dielectric ring.

[0012] The ring is a geometric body limited by the surface of the toroid, i.e. can be created by the rotation of any flat, closed curve around an axis lying in the plane of this curve, but not intersecting it. According to the invention, the rotation axis passes through the center of the basis of the base antenna and is perpendicular to it, so the ring is placed parallel to the basis of the antenna.

[0013] According to the invention, it is preferred that the rotated closed curve is a circle, and the radius of such a circle is referred to as the ring longitudinal cross-section radius R_o . Another possible shape is a regular polygon. In both cases, it is possible to indicate the radius of the circle, commonly known as R_o - the radius of the longitudinal cross-section of the ring. An octagon can be an example of a regular polygon, in which case the radius of the circumscribed circle is hereinafter referred to as the radius of the longitudinal ring cross-section R_o .

[0014] The term longitudinal cross-section means a cross-section in the plane that is perpendicular to the basis of the base antenna and contains its center. A transversal cross-section means this plane is parallel to the antenna basis.

[0015] The distance from the center of the circle (or the circle described on the regular polygon) to the axis of rotation, hereinafter referred to as the radius of the ring R , while the distance from the center of the circle (or the circle described on the regular polygon) to the basis of the antenna is hereinafter referred to as the distance of the ring from the basis plane of the base antenna H . The ring can be located both in the plane of the basis of the base antenna ($H = 0$) and above ($H > 0$) or below ($H < 0$) but always parallel to basis plane of the base antenna.

[0016] There are invention embodiments where the ring touches the basis of the base antenna - then it is possible to mount it directly to the basis of the base antenna. In other cases (the ring does not touch the basis of the base antenna), it is necessary to introduce additional positioning elements (e.g. in the form of pillars), which will provide a correct distance from the basis of the base antenna H . In the case of using positioning elements - it is important to ensure that the material they are made of has a low relative permittivity in the range of 1.01 - 3, it can be the same material that the ring is made of or another (especially when the relative permittivity of the ring material is high - greater than 3).

[0017] The scope and essence of the invention is the determination of the following properties of the dielectric ring: the radius of the ring in the transverse cross-section R , the ring longitudinal cross-section radius R_o , the distance of the ring from the basis plane of the base antenna H and the relative permittivity of the ring material. As a result, the desired modification of the radiation pattern is achieved. The relative permittivity of the ring material ranges from 2 to 20, ring radius R ranges from $0.5 \lambda_0$ to $1 \lambda_0$, longitudinal cross-section ring radius R_o ranges from $0.05 \lambda_0$ to $0.2 \lambda_0$ and the distance from the ring to the antenna basis H ranges from $-0.3 \lambda_0$ to $0.3 \lambda_0$. λ_0 is the length of the electromagnetic wave in free space.

[0018] Summarizing, there are following invention-s features, especially for the ring:

1. Permittivity of the dielectric ring material

2. R , R_o , H - in the respective ranges

3. The ring is placed in parallel to the basis of the base antenna - the rotation axis of the closed curve is perpendicular to the basis

4. The rotation axis of the closed curve that creates the ring passes through the center of the base antenna basis.

[0019] In a preferred embodiment, the ring is mounted on the positioning elements that assure the right orientation

and distance of the ring in relation to the base antenna, preferably in the form of at least three pillars. The material of which the positioning element is made has a relative permittivity in the range of 1.01 to 3. The positioning element can be made of the same material as the ring or a different material with the same permittivity or a different material with a different permittivity, preferably the ring is made of a material with a higher permittivity than the positioning elements.

[0020] The advantage of the invention is in its versatility, as the introduction of the ring does not require modification of the base antenna design. Therefore, it is possible to use one base antenna and adapt its characteristics to different scenarios only by changing the ring parameters, i.e. the radius of the longitudinal cross-section of the ring R_0 , the ring radius R , the distance of the ring from the basis plane of the base antenna H and the relative permittivity - in ranges stated above.

[0021] The invention is disclosed in details in examples - embodiments of the invention below and in the accompanying drawings, in which:

Fig. 1-4 - prior art - illustrate the problems related to the known ESPAR antennas and the goal for the invention

Fig. 5 - prior art - is an axonometric view of the known ESPAR antenna - part - element of the invention

Fig. 6 - prior art - in a longitudinal cross-section view of the known ESPAR antenna- part of the invention

Fig. 7 is an axonometric view of the invention i.e. base antenna with dielectric ring - a general embodiment of the invention

Fig. 8 in a longitudinal cross-section view of the first embodiment of the invention

Fig. 9 shows a normalized radiation pattern in the elevation cross-section of the first embodiment of the invention

Fig. 10 in a longitudinal cross-section view of the second embodiment of the invention

Fig. 11 shows a normalized radiation pattern in the elevation cross-section of the second embodiment of the invention

The general embodiment of the invention

[0022] In the invention, a known structure of the ESPAR-type base antenna with switched beam (3) is used. The ESPAR base antenna is shown in Fig. 5, while Fig. 6 shows its longitudinal cross-section view. The following features of the invention have been developed.

[0023] The basis 4 of the base antenna 3 is realized in the form of a round printed circuit board with a radius R_g ranging from $0.5 \lambda_0$ to $0.7 \lambda_0$ (λ_0 - free space wavelength), the top layer is the antenna's ground plane, while on the bottom one, a beam steering circuit is realized. Active element 5 in the form of a monopole antenna is placed in the center of the basis 4 of the base antenna 3 with a height H_a ranging from $0.2 \lambda_0$ to $0.3 \lambda_0$. The antenna is excited using a coaxial connector 7 (e.g. SMA - SubMiniature version A) - the inner conductor is connected to the active element 5, while the outer conductor is connected to the antenna's ground plane (top layer of the basis 4). The active element 5 is surrounded by 2 to 24 passive elements 6 with a height H_p in the range from $0.2 \lambda_0$ to $0.3 \lambda_0$, evenly distributed on a circle with a radius R_p being in the range from $0.25 \lambda_0$ to $0.5 \lambda_0$, also in the form of monopole antennas, however, these are connected to the one-port devices with electronically controlled impedance 8. Setting the impedance close to an electrical short-circuit makes the element act as the reflector (reflects an electromagnetic wave) while setting an impedance similar to an electric open-circuit makes the element act as the director (passes through an electromagnetic wave). When all passive elements are directors, the antenna has an omnidirectional radiation pattern and setting at least one as a reflector causes it to take on directional properties. Optimum directional properties are obtained in the case when 40 - 60% of the elements are set to the reflector. The cyclical change of the elements' functions (reflector or director) allow sweeping the direction of radiation in the horizontal plane in the 360° range, the resolution of discrete directions depends on the number of passive elements (e.g. for $12:360^\circ/12 = 30^\circ$).

[0024] A characteristic and essential feature of the invention is the dielectric ring 9 in the form of a toroid. In this example, it has a circular longitudinal cross-section through the ring, i.e. the figure forming the ring is a circle. A general embodiment of the invention is shown in Fig. 7. According to the invention, it has been found that: the relative permittivity of the material of which ring 9 is made ranges from 2 to 20, the radius of the ring R is in the range of $0.5 \lambda_0$ to $1 \lambda_0$, the ring longitudinal cross-section radius R_0 is in the range $0.05 \lambda_0$ to $0.2 \lambda_0$, and the ring distance from the antenna basis H is in the range $0.3 \lambda_0$ to $0.3 \lambda_0$.

[0025] In this preferred embodiment - example, the ring 9 is mounted on the antenna base by means of positioning elements 10, preferably in the form of pillars, e.g. three to four elements. The specific form of the positioning elements

10 is of secondary importance as they are made of a dielectric material with a low relative permittivity ranging from 0.01 to 3, e.g. ABS - acrylonitrile butadiene styrene terpolymer - with a relative permittivity of about 2.6, therefore their influence on the radiation pattern is negligible.

[0026] The basis of inventions' activity, thus invention's principle of operation, utilizes propagation properties of the dielectric material from which the ring is made. It has greater permittivity than air, and therefore its presence affects electromagnetic wave propagation and, consequently, changes the radiation pattern of the antenna. On the one hand, there also are reflections at the medium boundary (air-dielectric) related to the impedance difference, on the other hand, the velocity of the wave propagating through the dielectric decreases.

[0027] A closed curve the rotation of which creates the ring - the figures the rotation of which creates the ring and defines its longitudinal cross-section does not have to be a circle, but a regular polygon, e.g. a hexagon or an octagon. When the regular polygon is used it can be characterized by the circumscribed circle radius R_o .

[0028] Depending on the fabrication method, it may turn out that it is much easier to fabricate a ring with an octagonal longitudinal cross-section (e.g. 3D printing). In the case of converting a circle into a polygon, the same effect in terms of the influence on the radiation pattern can be achieved by adjusting R_o so that the surface of the polygon and the circle are the same.

[0029] Therefore, by adjusting the parameters of the ring 9 (ring radius R , ring longitudinal cross-section radius R_o , ring distance from the antenna basis H , relative permittivity), various effects can be achieved in terms of the antenna radiation pattern shape modification in the elevation plane, such as the direction (increase or decrease of maximum radiation angle) of the main beam, increasing the half-power beam width to ensure even distribution over the selected angular range or focusing it to increase the gain. The specific combinations of ring parameters along with the obtained effects are shown in the preferred embodiments below.

[0030] The invention's essence - feature and advantages - lies in an easy change of the parameters of the entire antenna by replacing the ring with one that provides a different effect, but the parameters of the ring - R , R_o , H and relative permittivity - must be within predetermined ranges. Thus, the use of the invention does not require modification of the base antenna structure.

[0031] The invention is applicable - used in wireless systems where it provides the capability of adjusting the radiation pattern of the ESPAR antenna to a specific arrangement of wireless devices. In consequence, it is enough to have a once-designed base antenna and, depending on the needs, select adequate ring parameters, however, in the predefined range of R , R_o and H and the relative permittivity.

[0032] The example application concerns the scenario in which the invention is mounted on the ceiling of a warehouse and is communicating with devices located on the ground. Then the invention can be used to increase the signal level in the area directly below the antenna compared to the unmodified base antenna. On the other hand, if these devices are mounted at the same height as the invention, then an accordingly chosen ring will allow the concentration of the radiation close to the horizontal plane. In a scenario where the invention will be mounted on an inspection robot receiving data from various types of sensors located in different places and at different heights, another ring will increase half-power beam width to ensure reliable communication with each of the sensors.

[0033] The invention has a simpler construction, lower price and lower power consumption compared to the conventional phased arrays used to implement beamforming. As a result, the invention can be used in wireless sensor networks, where the use of the directional radiation pattern allows for a reduction of the required transmitting powers, resulting in extended battery life or a reduction of the minimum number of nodes by increasing their communication range. In addition, in conjunction with the direction of arrival estimation, it is possible to determine the position of wireless devices, and the possibility of modifying the antenna beam shape in the elevation plane improves positioning accuracy. The invention can also be applied in vehicle-to-vehicle communication systems to improve link quality in a demanding, highly reflective environment (e.g. city center) in which usually such systems are used. Modification of the beam direction in the elevation plane allows for more stable communication with road infrastructure elements located at a specific height in relation to the vehicle. As a result, it will reduce the level of signals received from undesirable directions, thereby improving the security of communication by increasing immunity to interfering signals.

The example 1- details

[0034] A preferred embodiment of the invention is an antenna, the longitudinal cross-section of which is shown in Fig. 8. The antenna operates at a frequency of 2.45 GHz. The active element 5 is made in the form of a metal rod with a length $H_a = 26.4$ mm ($0.22 \lambda_0$), placed in the center of the basis 4 with a radius $R_g = 76.2$ mm ($0.62 \lambda_0$) and excited by the SMA connector 7. The basis 4 is made of a PCB (printed circuit board), using an FR4 substrate, the top layer of which is the antenna's ground plane. The active element 5 is surrounded by 12 passive elements 6 also in the form of a metal rod with a length $H_p = 25.7$ mm ($0.21 \lambda_0$). Passive elements 6 are evenly spaced on a circle with a radius $R_p = 46.8$ mm ($0.38 \lambda_0$). Passive elements 6 are connected to microwave switches (realization of one-port devices with electronically controlled impedance 8) allowing them to be open or short-circuited to the ground plane. Five successive

passive elements are open acting as directors, while the remaining seven are shorted to ground acting as reflectors.

[0035] The key element of the antenna is a dielectric ring 9 made of a non-conductive material with a relative permittivity equal to 10 (in this case PREPERM® 3D ABS1000 filament was used), while its other parameters are: ring radius $R = 89.2 \text{ mm}$ ($0.73 \lambda_0$), ring longitudinal cross-section radius $R_o = 12.4 \text{ mm}$ ($0.1 \lambda_0$) and the distance of the ring from the antenna basis $H = 20.6 \text{ mm}$ ($0.17 \lambda_0$). Therefore, the ring 9 does not have direct contact with the base antenna 3. The ring 9 and the base antenna 3 are connected by positioning elements 10, in the form of four dielectric pillars equally spaced around the perimeter of the basis 4 and made of a material with low relative permittivity (in this case ABS - acrylonitrile butadiene styrene terpolymer with a relative permittivity of about 2.6).

[0036] Such configuration provides the effect of tilting the beam towards the basis/ground plane, thus increasing radiation in the horizontal plane. A comparison of the radiation patterns in the elevation plane of the antenna according to the invention (with the ring) and the base antenna (without the ring) is shown in Fig. 9. The effect achieved in the first preferred embodiment is a beam tilting but not a beam widening, and is therefore not included in Table 1.

[0037] Fig. 9 shows that the maximum of radiation in the elevation plane of the first embodiment antenna is at an angle greater than that of the base antenna (without the ring), so the main beam has been tilted down towards the basis of the antenna.

Example 2 - details

[0038] Another example - preferred embodiment of the invention is an antenna, the longitudinal cross-section of which is shown in Fig. 10. The antenna operates at a frequency of 2.45 GHz. The active element 5 is made in the form of a metal cylinder with a length $H_a = 26.4 \text{ mm}$ ($0.22 \lambda_0$), placed in the center of the basis 4 with a radius $R_g = 76.2 \text{ mm}$ ($0.62 \lambda_0$) and excited by the SMA connector 7. The basis 4 is made of a PCB (printed circuit board), using an FR4 substrate, the top layer of which is the antenna's ground plane. The active element (5) is surrounded by 12 passive elements 6 also in the form of a metal cylinder with a length $H_p = 25.7 \text{ mm}$ ($0.21 \lambda_0$). Passive elements 6 are evenly spaced on a circle with a radius $R_p = 46.8 \text{ mm}$ ($0.38 \lambda_0$). Passive elements 6 are connected to microwave switches (realization of one-port devices with electronically controlled impedance 8) allowing them to be open or short-circuited to the ground plane. Five successive passive elements are open acting as directors, while the remaining seven are shorted to ground acting as reflectors.

[0039] Again, the key element of the antenna is a dielectric ring (9) this time made of a material with a relative permittivity equal to 7.5 (in this case PREPERM® 3D ABS750 filament was used), while its other parameters are: ring radius $R = 94 \text{ mm}$ ($0.77 \lambda_0$), ring longitudinal cross-section radius $R_o = 16 \text{ mm}$ ($0.13 \lambda_0$) and the distance of the ring from the antenna basis $H = -5.6 \text{ mm}$ ($-0.05 \lambda_0$). Therefore, the ring 9 does not have direct contact with the base antenna 3. The ring 9 and the base antenna 3 are connected by positioning elements 10, in the form of four dielectric pillars equally spaced around the perimeter of the basis 4 and made of a material with low relative permittivity (in this case ABS - acrylonitrile butadiene styrene terpolymer with a relative permittivity of about 2.6).

[0040] Such configuration provides the effect of increasing half-power beam width in the elevation plane, thus ensuring wider angular coverage. A comparison of the radiation patterns in the elevation plane of the antenna according to the invention (with the ring) and the base antenna (without the ring) is shown in Fig. 11.

[0041] Fig. 11 shows that the half-power beam width in the elevation plane of the second embodiment antenna is greater than that of the base antenna (without the ring).

[0042] The values of the relative permittivity of the rings' dielectrics in the above embodiments are exemplary values, and in general, can have any values in the range of 2 - 20. Appropriately changing the dimensions of the ring, it is possible to adjust its operation to a specific permittivity value and obtain a similar effect. The table below shows the half-power beam widths of exemplary embodiments of the antenna at 2.45 GHz using a dielectric of relative permittivity of 2 and 20, together with the value from the second embodiment i.e., 7.5. This validates the proposed range of the ring's relative permittivity.

Relative permittivity	R	R_o	H	Half-power beam width difference in relation to the base antenna - without the ring
2	$0,82 \lambda_0$	$0,32 \lambda_0$	$-0,12 \lambda_0$	+64°
7,5 (Example 2)	$0,77 \lambda_0$	$0,13 \lambda_0$	$-0,05 \lambda_0$	+84°
20	$0,74 \lambda_0$	$0,08 \lambda_0$	$-0,02 \lambda_0$	+86°

List of symbols from figures:

[0043]

- 5 1 - Reconfigurable ESPAR antenna - presents issues present in the prior art solutions - is intended to generally apply to various reconfigurable ESPAR type antennas
- 2 - Wireless devices
- 3 - Base ESPAR antenna
- 4 - Antenna basis/ground plane
- 10 5 - Active element in the form of a monopole antenna
- 6 - Passive elements in the form of monopole antennas
- 7 - Coaxial connector
- 8 - One-port devices with electronically controlled impedance
- 9 - Dielectric ring modifying the radiation pattern
- 15 10 - Dielectric ring's positioning elements

Claims

- 20 1. Antenna ESPAR type with an electronically steered beam comprising a basis (4) of the base ESPAR antenna (3) that makes the antenna's ground plane, an active element (5) in the form of a monopole antenna, a passive elements (6) in the form of monopole antennas, a coaxial connector (7), one-port devices with electronically controlled impedance (8), **characterized in that** the element for modifying radiation pattern in the elevation plane is used in the way that to the construction of the base antenna (3) an dielectric ring (9) is added made of material that has a relative
- 25 permittivity ranging from 2 to 20, while the radius of the ring (9) in the transverse with respect to the axis of the structure cross-section through the ring (R) ranges from $0.5 \lambda_0$ to 1 wavelength in the free space λ_0 and the radius of the ring (9) in the longitudinal cross-section (R_0) is in the range of $0.05 \lambda_0$ to $0.2 \lambda_0$ and additionally the ring (9) is mounted at a distance H from the basis (4) of the base antenna (3) in the range of $-0.3 \lambda_0$ to $0.3 \lambda_0$ and is parallel to it.
- 30 2. The antenna according to the claim 1, wherein, the ring (9) is mounted to the base antenna using a positioning elements (10), preferably in the form of at least three pillars made of a dielectric material whose relative permittivity ranges from 1.01 to 3.
- 35 3. The antenna according to the claim 2, wherein, the positioning elements (10) are made of a material having a relative permittivity in the range of 1.01 to 3 and the material of which the ring (9) is made has the same or greater relative permittivity.
- 40 4. The antenna according to the claims 1-3, wherein, the basis (4) of the base antenna (3) is made in the form of a round printed circuit board (4) with a radius R_g ranging from $0.5 \lambda_0$ to $0.7 \lambda_0$ wavelengths in the free space λ_0 , the top layer of which is the antenna's ground plane, while at the bottom one, all electronic components are mounted.
- 45 5. The antenna according to the claims 1-4, wherein, the active element (5) with a height H_a ranging from $0.2 \lambda_0$ to $0.3 \lambda_0$ in the form of a monopole antenna is placed in the center of the basis (4) and the active element is connected to the coaxial connector (7) and is surrounded by 2 up to 24 passive elements (6) with a height H_p in the range from $0.2 \lambda_0$ to $0.3 \lambda_0$ in the form of monopole antennas connected to the one-port devices with electronically controlled impedance (8) and evenly distributed on a circle with a radius R_p in the range of $0.25 \lambda_0$ to $0.5 \lambda_0$.
- 50 6. The antenna according to the claims 1-5 wherein, the ring's (9) longitudinal cross-section section has a circle shape.
- 7. The antenna according to the claims 1-5 wherein, the ring's (9) longitudinal cross-section section has a regular polygon shape.
- 8. The antenna according to the claims 6 or 7 wherein, the half-power beam width in the elevation plane is increased.
- 55 9. The antenna according to the claims 6 or 7 wherein, the main beam direction in the elevation plane is tilted.
- 10. The antenna according to the claim 9 wherein, the main beam direction in the elevation plane is tilted down towards the basis (4) of the base antenna (3).

11. The antenna according to the claim 2 wherein, the ring (9) is made of the same material as the positioning elements (10).

12. The antenna of claim 2 wherein, the ring (9) is made of a different material than the positioning elements (10).

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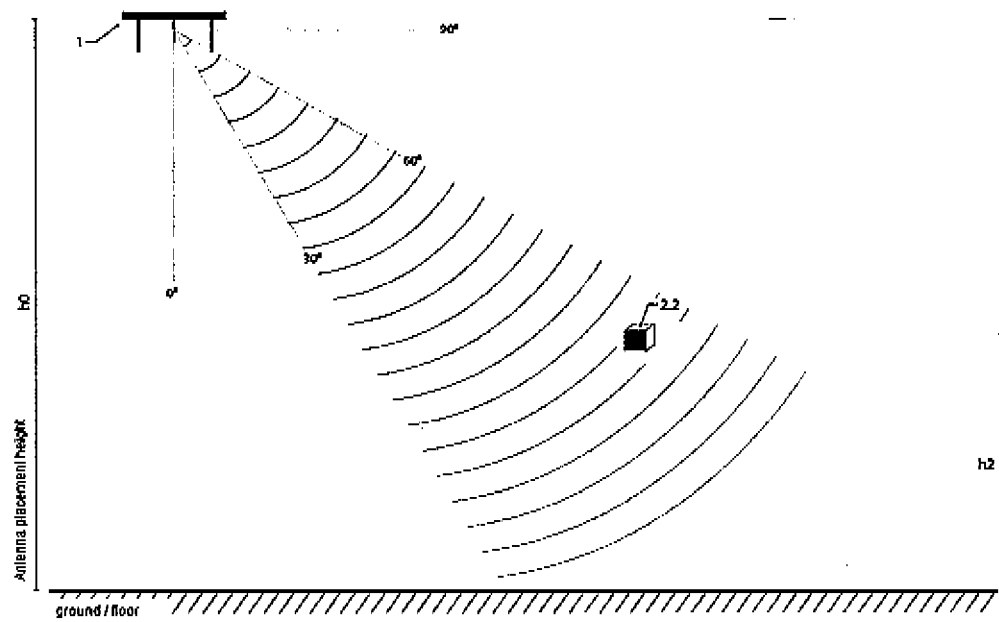


Fig.1

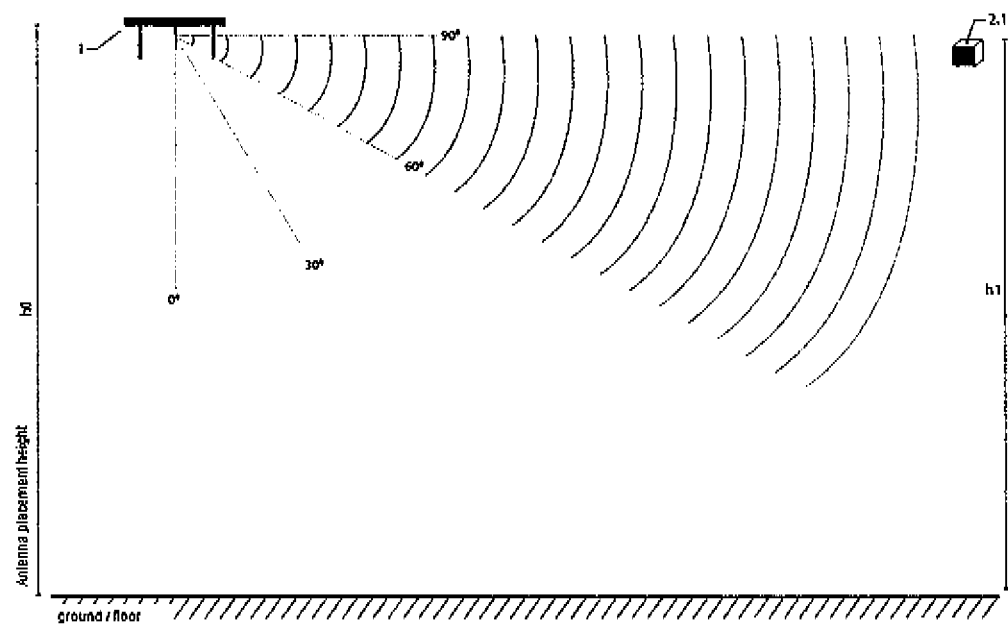


Fig. 2

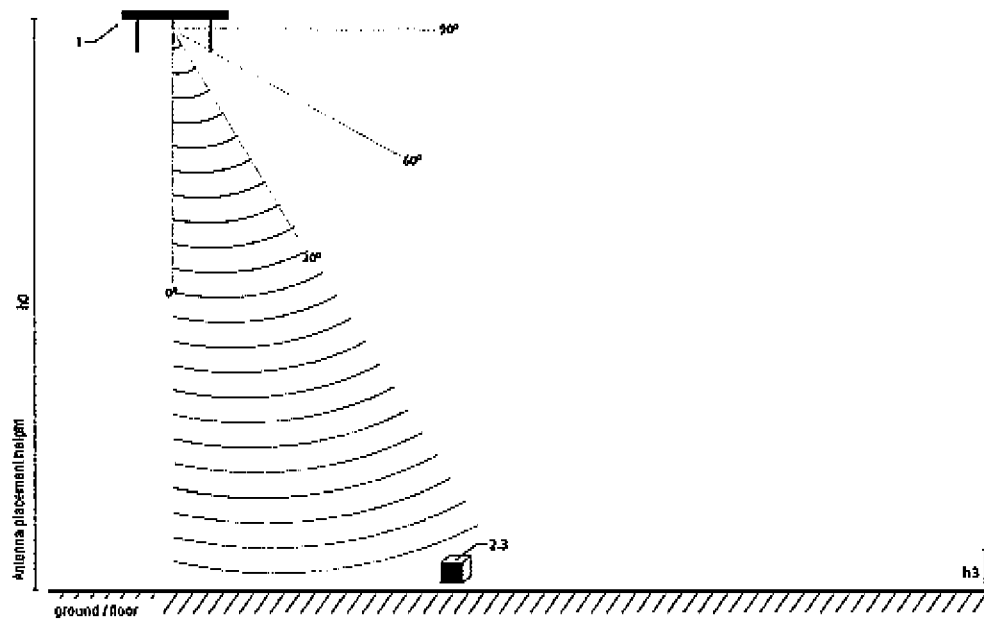


Fig. 3

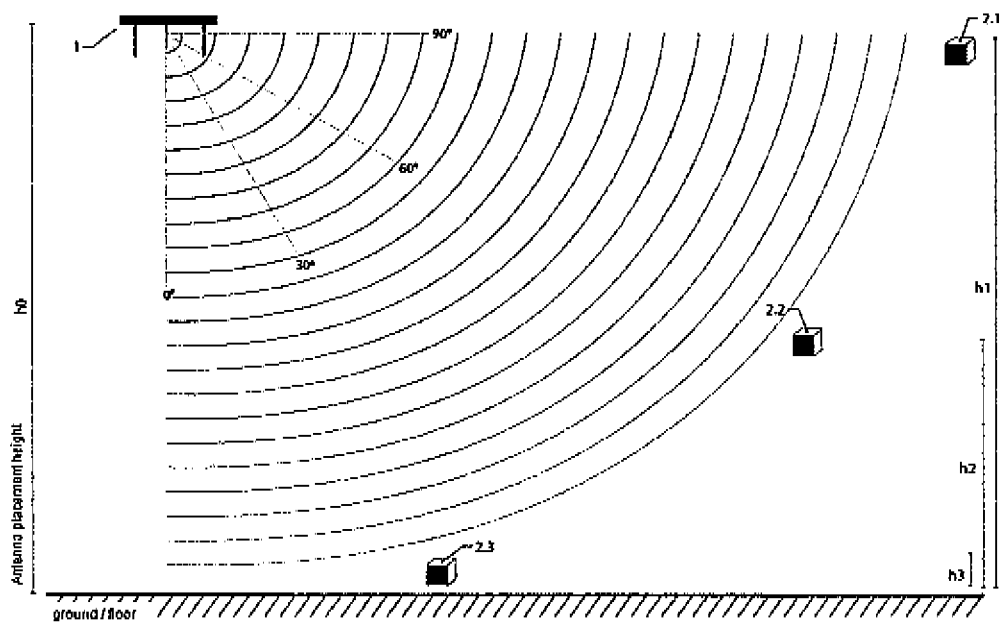


Fig. 4

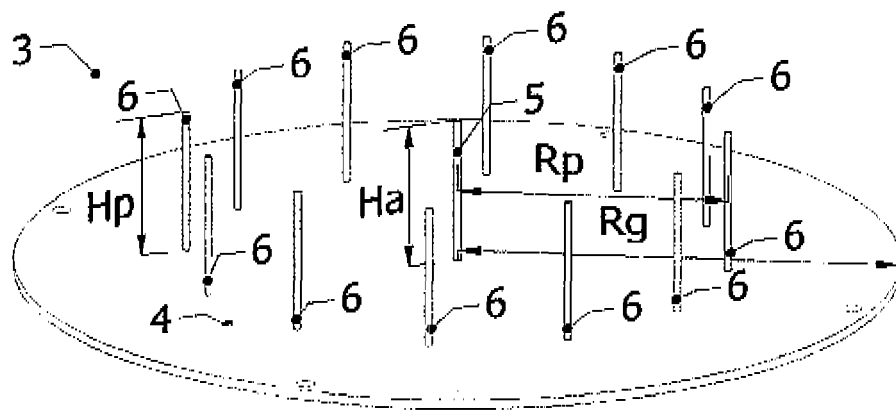


Fig. 5

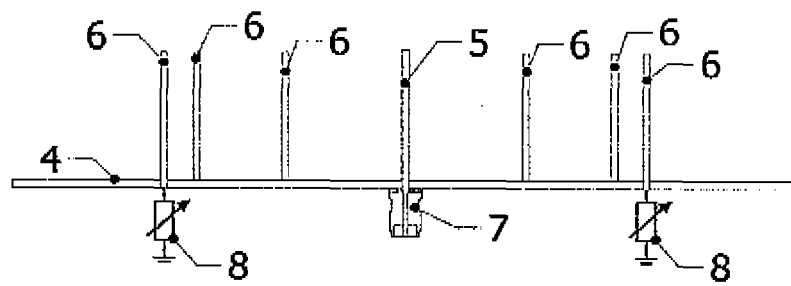


Fig. 6

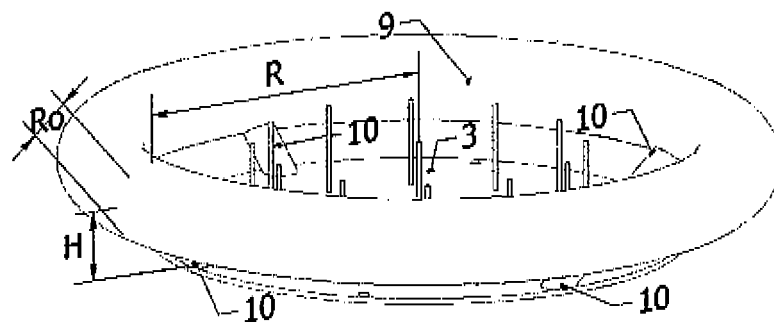


Fig. 7

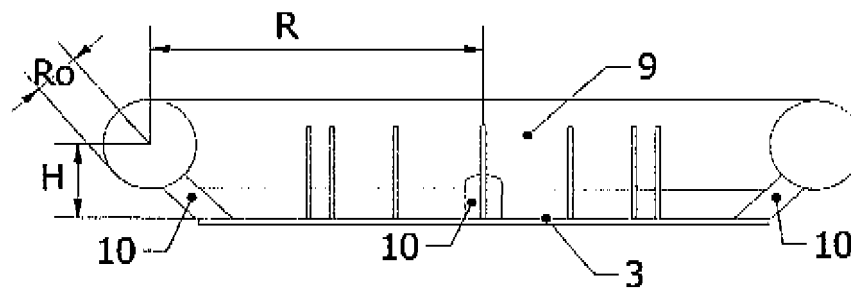


Fig. 8

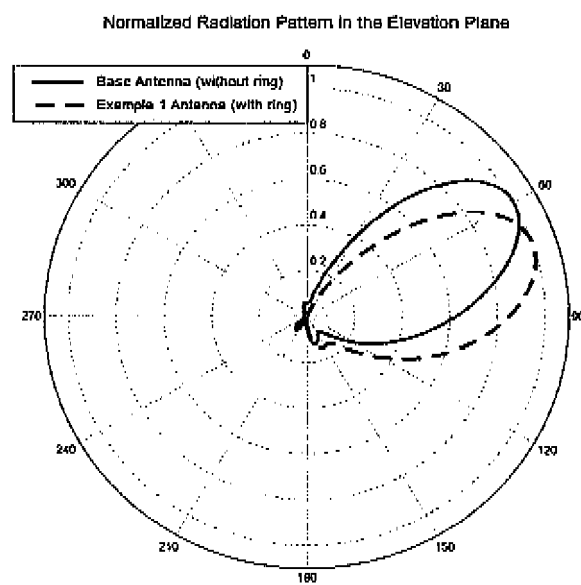


Fig. 9

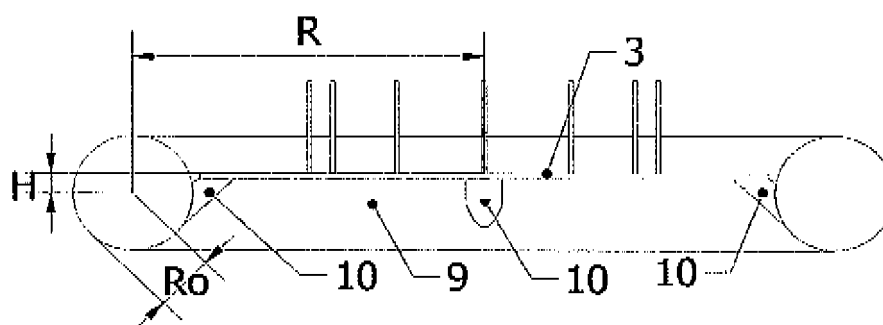


Fig. 10

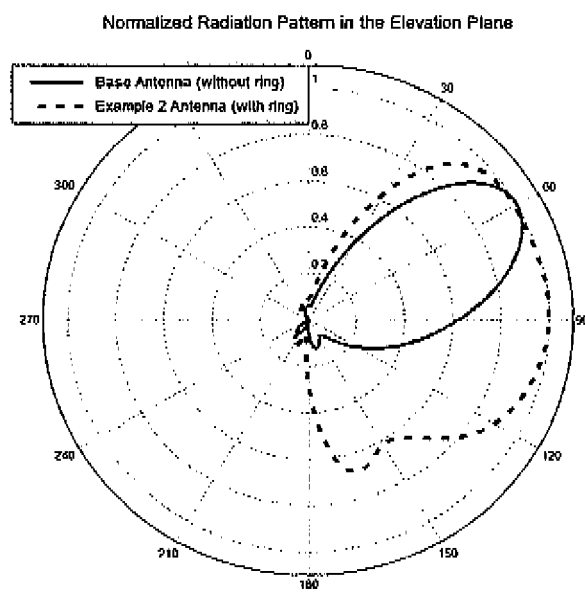


Fig. 11



EUROPEAN SEARCH REPORT

Application Number

EP 22 46 0055

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2002/158798 A1 (CHIANG BING [US] ET AL) 31 October 2002 (2002-10-31) * paragraphs [0038] - [0044]; figures 5, - * -----	1-12	INV. H01Q19/32 H01Q3/44 H01Q9/32 H01Q19/06
A	US 2016/302081 A1 (LIU AN-SHYI [TW] ET AL) 13 October 2016 (2016-10-13) * paragraphs [0048] - [0055]; figure 7 * -----	1-12	H01Q1/24 H01Q1/22
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			H01Q

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EPO FORM 1503 03.82 (P04C01)

Place of search	Date of completion of the search	Examiner
The Hague	13 March 2023	Georgiadis, A
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		

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ON EUROPEAN PATENT APPLICATION NO.**

EP 22 46 0055

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
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13-03-2023

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		US 2016302081 A1	13-10-2016
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- **R. SCHLUB ; D. V. THIEL.** Switched parasitic antenna on a finite ground plane with conductive sleeve. *IEEE Transactions on Antennas and Propagation*, May 2004, vol. 52 (5), 1343-1347 [0005]