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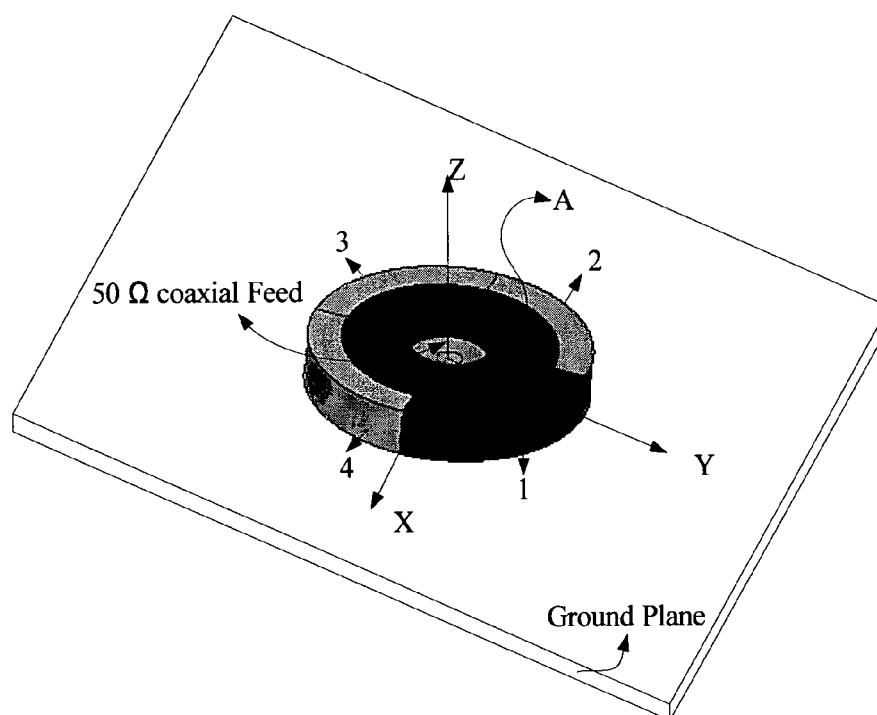
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(54) Title: COMPACT ANTENNA



(57) Abstract: An antenna comprising a radiator that has a radiating portion (1) for allowing radiation to be transmitted and/or received and a non-radiating portion (2,3,4) for preventing radiation transmission and/or reception, and means for changing the position and/or shape of the radiating portion (1).

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Compact Antenna

The present invention relates to a compact antenna, and in particular a compact antenna containing anisotropic permeable, dielectric and conductive materials whose properties can be preferably altered by electric or magnetic means. The compact antenna in which the invention is embodied is particularly suited for use in mobile telecommunications devices, and provides such devices with the capability to transmit and receive beams in any desired direction.

Background of the Invention

The history of using materials with high dielectric constants in antenna goes back to the late 1930s. Richtmyer realised in 1939 that open dielectrics are able to radiate into free space. [RICHTMYER, R.D.: "Dielectric Resonators", J. Appl. Phys., June 1939, (10), pp 391-398]. Bladel V. J. reported in 1975 a theoretical study for the evaluation of the modes of dielectric resonator antennas with high dielectric constant. [BLADEL V. J.: "On the Resonances of a Dielectric Resonator of Very High Permittivity", IEEE Trans. Microwave Theory and Tech., Feb 1975, (MTT-23), no. 2]. However, the first study on a shaped dielectric resonator antenna was reported by Long et al in 1983. [LONG A. S., M.W.M., and SHEN C. L.: "The resonant cylindrical cavity Antenna", IEEE Trans. on Antennas and propagation, May 1983, (AP-31), no. 3]. Since then, dielectric resonator antennas have received much attention mainly due to their many advantages for mobile applications, which include small physical dimensions, high radiation efficiency, large bandwidth, and the little or no matching circuit requirements.

As is well known, there is a desire in the mobile wireless, industry to increase bandwidths and data rates. Multiple input multiple output systems (MIMO) attempt to do this. These require that the base station and the mobile device should have more than two antennas. By judicious signal processing, separate signal paths on the same frequency band may be utilised to increase bandwidth. This requires antennas to detect signals from different directions. This is relatively easy at the base station, but at present is not readily achievable in a small, hand-held mobile device. Another industry desire is to increase the

user density, i.e. the number of user devices in a given area that can transmit and receive signals. One way of increasing the user density is by reusing the space i.e. confining the signals to a restricted area. At present, this is not easily achieved because mobile devices are not spatially aware.

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US 6768454 describes a method of steering the maximum radiation pattern of dielectric resonator antennas by switching between existing beams. The contents of this document are incorporated by reference. The radiation pattern of the antenna of US 6768454 is manipulated by exciting one of a plurality of probes. Another dielectric resonator antenna is described in US 6816118B2, the contents of which are herein incorporated by reference. This has a plurality of dielectric elements separated by conductive walls and deployed in a circular array. This is capable of producing several beams having a boresight i.e. direction of maximum radiation.

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15 A disadvantage of the antennas of US 6768454 B2 and US 6816118B2 is the large size of the backlobe generated, which causes significant power losses and a high specific absorption rate (SAR). This results in lower efficiency, and lower battery life. A solution to this problem is described in US 6900764B2, the contents of which are herein incorporated by reference. This involves including a monopole in the dielectric array.

20 However, this adds to the complexity of the antenna by requiring extra phase shift networks.

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Maxwell's equations of electromagnetism determine that the permeability and permittivity of a medium control the speed of electromagnetic wave propagation in it. In general, when electromagnetic waves propagate in dielectric or magnetic materials, the wave may be reflected, absorbed or transmitted. When propagating radiation meets a boundary between two materials, transmission occurs when the material constants are similar or close. Reflection occurs when the mediums have different relative permittivities. This also occurs in mediums of different permeabilities. The larger the difference in permittivities or permeabilities of the two mediums the higher the reflection

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coefficient. These features of boundaries between different materials are used to advantage in the present invention.

Summary of the Invention

5 According to the present invention, there is provided an antenna comprising a radiator that has a radiating portion for allowing radiation to be transmitted and/or received and a non-radiating portion for preventing radiation transmission and/or reception, and means for changing the position and/or shape of the radiating portion.

10 The antenna may comprise a resonator of dielectric and/or magnetic and/or conductive materials for generating radiation, and the means for changing may be operable to change the relative positions of the resonator and the radiating portion.

In the non-conductive antenna form the radiating portion should have a permittivity
15 and/or permeability that is substantially the same as that of the resonator, whereas the non-radiating portion should have a permittivity and/or permeability that is different from that of the resonator, so that radiation incident on it is reflected into the radiating portion. In practice, the permittivity and/or permeability of the non-radiating portion is higher than that of the resonator.

20 Radiation generated by the resonator is transmitted through the radiating portion of the anisotropic radiator, but reflected by the non-radiating, reflective portion. This results in a directional radiation pattern. By causing relative movement between the resonator and the radiating portion of the anisotropic radiator, the principle radiation direction may be
25 steered through 360 degrees without the use of multiple antennas or the segmented dielectric resonator structure described in US 6768454 B2. Advantageously, the beam formed has a low backlobe and a relatively wide bandwidth.

The radiator may be annular, cylindrical, spherical, or hemispherical. Additionally or
30 alternatively, the anisotropic radiator may comprise a plurality of segments, at least one of which is the radiating portion. The segments may be placed at regular angular

intervals around the resonator. Alternatively, the anisotropic radiator may be non-segmented and have a permittivity and/or permeability that varies from a start to an end point, at least one of the regions of the radiator having similar electric/magnetic properties to the active resonator material, other parts having a higher dielectric constant.

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The radiator may comprise a solid, liquid and/or gel. With a liquid based dielectric, such as water, salt can be added to modify the dielectric properties, allowing the antenna to operate over a wider bandwidth. Moreover the liquid can be composed of a dielectric in which is suspended dielectric particles of higher relative permittivity, and/or ferrites of high relative permeability and/or organic metallic particles enabling a change in conductivity. The radiator may be anisotropic.

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The positioning means may comprise a drive for positioning the radiator, so that the radiating portion is positioned relative to the resonator. The positioning means may be operable to physically move the radiator thereby to move the radiation beam. Preferably, the positioning means are operable to rotate the radiator.

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Where the radiator comprises a liquid and/or gel with dielectric and/or magnetic particles suspended in it, the positioning means may be operable to vary the position of the radiating part, but not the whole radiator. This could be done by for example varying the distribution of particles within the liquid or gel, thereby to cause localised changes in the permittivity and/or permeability. This can be done by applying an electric and/or magnetic field to the radiator to cause particles to congregate in a predetermined area of the radiator. Movement of the field around the radiator causes corresponding positioning of the congregation of particles and so the radiation beam angle that is transmitted.

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In the conductive antenna form, the radiating element may be formed from aggregates of conductive particles that are coated with a dielectric material and suspended in a dielectric liquid. In this form, the radiation pattern is steered by aggregating the conductive particles, by manipulating them electrically, for example, using the dielectrophoretic technique, i.e. the force applied to dielectric particles when subjected to

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a non-uniform electric field. In this case, at the antenna operating frequency, the dielectric particles will electrically short out and a conductive patch of required shape and position will be formed from the suspended conductive particles. Beam forming is achieved by the pattern constructed by the aggregates of conductive particles.

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The antenna in which the invention is embodied is ideal for use in mobile telephones, wireless internet devices, and location or direction finding devices. It could also be used in imaging systems or scanners, in particular microwave or terahertz imaging systems or scanners.

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Brief Description of the Drawings

Various aspects of the invention will now be described by way of example only and with reference to the accompanying drawings, of which:

Figure 1 is a perspective view of a dielectric antenna;

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Figure 2 shows multiple reflections occurring in different dielectric media;

Figure 3 shows the radiation pattern of the antenna of Figure 1, when in a first position;

Figure 4 shows the far field radiation pattern of the antenna of Figure 1, when in a second position;

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Figure 5 shows a measured far-field radiation pattern, in H-plane for 3 angular positions of an outer ring of a liquid based antenna at 1.264GHz;

Figure 6 shows a perspective view of a hemispherical dielectric antenna;

Figure 7 shows an alternative way of exciting the compact antenna through a slot fed by a micro-strip;

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Figure 8 shows a plan view of a liquid-based patch antenna formed from aggregates of conductive particles coated by dielectrics and suspended in liquid, and

Figure 9 displays a 3-dimensional liquid based antenna in a hemispherical container.

Detailed Description of the Drawings

Figure 1 shows a steerable dielectric antenna. This has an inner cylindrical, solid or liquid dielectric resonator, A, with a stimulating electrode at the centre. Enclosing the resonant core is an annulus whose dielectric properties vary around the ring. This annulus can rotate freely around the resonator A, preferably driven by a motor. The gap between the resonator and the annulus is ideally as small as possible, whilst still allowing for free movement therebetween. The annulus is of similar height to the resonant core A and has four segments of dielectric material 1, 2, 3 and 4 at 45 degrees intervals. The segments 2, 3 and 4 may have the same or a progressively increasing dielectric constant. The segments may have fixed properties or be made of anisotropic dielectric materials whose properties can be altered by electric charge such as Barium Strontium Titanate or Barium Zirconium Titanate. Materials that could be used for the annulus include *M110A, M110B, M140, M180. For the resonator, the materials could include M6.8, M8 and *M20. All of these are supplied by Maruwa CO., LTD. Equally, the antenna could be made using liquid dielectrics.

To allow it to act as the radiating portion, the relative permittivity of segment 1 is similar or close to that of A. In contrast, the relative permittivities of segments 2, 3 and 4 are different from A. Because of these relative permittivities, an electromagnetic wave generated by the cylindrical resonator A will be transmitted into region 1 and reflected from regions 2, 3 and 4. This means that a highly directional beam is formed, this beam being projected from segment 1. Rotation of the outer ring causes rotation of the part of the outer ring that functions as the radiation pattern, so that the antenna is fully steerable about 360 degrees.

25

To understand how the structure of Figure 1 works, consideration has to be given to how the electromagnetic fields are transmitted and reflected at the dielectric boundaries. When electromagnetic waves (EM) propagate in dielectric or magnetic materials, the wave may be reflected, absorbed or transmitted. Consider a small section of the ring, in which the curvature is negligible and the direction of the plane wave is normal to the interface, as shown in Figure 2. This has thickness L in medium '2', ' n_i ' a refractive index of

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medium i , $n_i = \sqrt{\epsilon_i}$ where ϵ_i is the relative permittivity of dielectric medium, η_i is the intrinsic impedance of medium i ($i=1,2$ and 3), and (ρ_1, τ_1) ; (ρ_1', τ_1') ; and (ρ_2, τ_2) are the interfacial reflection and transmission coefficients of the different dielectric interfaces.

$$\rho_1 = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = \frac{\frac{\eta_0}{n_2} - \frac{\eta_0}{n_1}}{\frac{\eta_0}{n_2} + \frac{\eta_0}{n_1}} = \frac{n_1 - n_2}{n_1 + n_2}; \tau_i = 1 + \rho_i; \rho_1' = \frac{\eta_1 - \eta_2}{\eta_2 + \eta_1} = \frac{n_2 - n_1}{n_2 + n_1} \text{ and } \rho_2 = \frac{\eta_3 - \eta_2}{\eta_3 + \eta_2} \quad (1)$$

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The E and H fields are conserved across the boundary. This analysis is based on the simplest case where fields are normal to the boundary interface and the dielectric material is assumed to be lossless. Referring to Figure 2, the right and left incident fields at the dielectric interfaces can be represented as follows:

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$$E_i = E_i' \text{ i.e. } E_{i+} + E_{i-} = E_{i+}' + E_{i-}'; \text{ for } i=1,2,3 \quad (2)$$

And the magnetic field,

$$H_i = H_i' \text{ i.e. } \frac{1}{\eta} (E_{i+} - E_{i-}) = \frac{1}{\eta'} (E_{i+}' - E_{i-}'); \text{ for } i=1,2,3 \quad (2.a)$$

Equation 2 may be written in a matrix form, thus:

$$15 \quad \begin{bmatrix} E_{i+} \\ E_{i-} \end{bmatrix} = \frac{1}{\tau} \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \begin{bmatrix} E_{i+}' \\ E_{i-}' \end{bmatrix}; \tau = 1 + \rho \quad (2.b)$$

Furthermore, the wave impedance across the dielectric boundary interfaces should also equate:

$$20 \quad Z_i = Z_i' = \frac{E_i}{H_i} = \frac{E_i'}{H_i'} \Rightarrow \eta \frac{1+\Gamma}{1-\Gamma} = Z = Z' = \eta' \frac{1+\Gamma'}{1-\Gamma'}; \text{ Where } \Gamma \text{ is the slab reflection coefficient.}$$

Therefore, the reflection coefficient in medium 1 can be represented as:

$$\Gamma_1 = \frac{E_{1-}}{E_{1+}} = \frac{\frac{1}{\tau}(\rho_1 * E'_{1+} + E'_{1-})}{\frac{1}{\tau}(E'_{1+} + \rho_1 * E'_{1-})} * \left(\frac{1/E'_{1+}}{1/E'_{1+}} \right) = \frac{\rho_1 + \Gamma_1'}{1 + \rho_1 \Gamma_1'} = \frac{\rho_1 + \Gamma_2 e^{-2jk_2 L}}{1 + \rho_1 \Gamma_2 e^{-2jk_2 L}} \quad (3)$$

Where Γ is the exponential decay of field in the medium and k_2 is the wave number in the medium 2.

5 Moreover, $\Gamma_2 = \frac{\rho_2 + \Gamma_2'}{1 + \rho_2 \Gamma_2'}$.

For the antenna of Figure 1, $\Gamma_2' = 0$ since the wave is propagating into free space. Therefore the final equation for the reflection coefficient in medium 1 is:

10 $\Gamma_1 = \frac{E_{1-}}{E_{1+}} = \frac{\rho_1 + \rho_2 e^{-2jK_2 L}}{1 + \rho_1 \rho_2 e^{-2jK_2 L}}; \quad (4)$

To get a high reflecting dielectric, the terms in the numerator should be negative. For the antenna of Figure 1, in the non-radiating regions, $n_1 < n_2$, and ρ_1 so is negative; $n_2 < n_3$, and so ρ_2 is positive and so $e^{-2jk_2 L}$ should be negative. Therefore, L should be equal to:

15 $L = (x+1) \frac{\lambda}{4} \quad (5)$

Where x is an even integer and λ is the wavelength of the electromagnetic wave propagating into medium 2. This equation gives an indication as to the width of the outer ring of the antenna, which is useful in the design phase.

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Figures 3 and 4 show simulations of the far field radiation pattern for the antenna of Figure 1 when the outer ring is located in a first position, Figure 3, and when it is rotated 90 degrees to the right, Figure 4.

Figure 5 illustrates the far-field response of a liquid based version of the antenna of Figure 1 in which the dielectrics have permittivities of 79 and 3.1 and measured at 1.264GHz. This shows the response for three successive rotations of the antenna, these being 15, 90 and 112 degrees. The antenna dimensions were the same as used for the simulations of Figures 3 and 4. The thickness of the outer ring closely matches that determined by equation 5.

In a variation of Figure 2, the antenna could be composed of stacked dielectric materials of different dielectric constant surrounded by an annular ring of the same height to operate at several bands.

Figure 6 shows a modified version of the antenna of Figure 2. This antenna 10 has a hemispherical steerable dielectric resonator 5 that is carried on a ground plane 9. This is excited by a single 50Ω coaxial feed at the centre of the resonator 5. An outer shell 6 surrounds the hemispherical resonator, but is not connected to it. This means that the shell 6 is freely rotatable relative to the resonator. The outer shell 6 has two segments 7,8 that have different dielectric characteristics. Part 7 of the shell has similar or close dielectric and magnetic properties to the resonator 5, whereas part 8 has very high dielectric properties compared to the resonator 5. Hence, in this case part 7 acts as the radiating portion and part 8 acts as the non-radiating portion. Rotation of the outer shell 6 generates a 3D directional radiation pattern that can be steered in any desired direction. With two hemispheres, a true 3D radiation pattern could be achieved over 360° solid angle.

Figure 7 shows an alternative way of exciting the antenna of Figure 6. This is done using a slot located under the centre of the resonator and fed by a 50Ω microstrip. In this case, a ground plane 11 is provided between a dielectric substrate 12 and the resonator 14. Formed on the substrate 12 is a 50Ω microstrip line, which feeds a slot 17 that is located at the centre of the resonator 14. Surrounding the resonator 14 is an outer shell that forms an anisotropic radiator. This has two parts, a first part 15 that has different dielectric and magnetic properties from the resonator 14, and a second part 16 that has similar or close

dielectric and magnetic properties to those of the resonator 14. Hence, in this case part 16 acts as the radiating portion and part 15 acts as the non-radiating portion. As for Figure 4, rotation of the outer shell generates a 3D directional radiation pattern that can be steered in any desired direction, using only a single feed to transfer energy into the radiating portion.

Figure 8 shows a liquid based system for microstrip or printed antenna (known also as patch antenna) formed from manipulation of suspended particles. Here, conductive particles 23 are coated by dielectric 22 and suspended in a liquid 25. The suspension is confined in a vessel 21 that is carried on a substrate 28 that is in turn carried on a ground plane 29. Applying an electric field in selected regions between the liquid and the ground plane 29 results in an antenna. This is because at high frequencies the dielectric particles short out. By manipulating the coated particles 22 and 23 using the applied field, the conductive particles can be caused to form a patch of the desired shape or array of shapes.

In Figure 8, the antenna has a plurality of generally rectangular shaped strips of aggregated particles 31 suspended in liquid. However, although strips 31 are shown, other patch shapes can be formed by suitably manipulating the particles suspended in the liquid 25 using the applied field. For example, the shape of the conductive patches 32 could be triangular, square, rectangular and cylindrical, where each patch is an island of aggregated particles. Manipulation of the dielectric coated particles can be achieved by an electric means or using the dielectrophoretic techniques. The island of aggregated suspended particles forms the radiating part of the antenna, and consequently the shape of the island defines the shape and/or direction of the radiated beam. By using dielectrophoresis the suspended particles in the liquid can be manipulated towards or away from a region by a judicious choice of drive electrode. This effect is determined by the dielectric difference between the liquid and suspended particles. Usually the liquid medium has a lower dielectric constant than the suspended particles. In addition the particles may be a mixture of dielectric and magnetic, for example ferrite, material.

Figure 9 shows a liquid base hemispherical antenna. This is formed from liquid dielectrics 46 in which are suspended particles 44. The particles 44 may be all dielectric or a dielectric attached to a ferromagnetic. The dielectric liquid 46 is contained in a vessel 45 positioned on a ground plane 43. Where the particles 44 are dielectric, they can be manipulated in solution using an applied electric field, or for example using dielectrophoresis, thereby to form one or more islands 47 of aggregated particles. Where the particles 44 are ferromagnetic, they can be manipulated in solution using static magnetic fields to form one or more islands 47 of aggregated particles. As before, these can be of any desired shape 48. This allows a regional dielectric or magnetic gradient in a particular part of the antenna to manipulate the boresight in a similar way to that described previously. By attaching ferromagnetic particles having permeability to some dielectric particles then the regional permittivity or permeability in a specific location in the antenna radiation may also be varied.

The antenna of the present invention has numerous practical advantages. For example, for the antennas of Figures 2, 6 and 7, because the radiation beam is steered using rotation of the outer ring, there is no need for complicated electrical contacts for switching between different antenna segments. Hence, only a single feed is required to transfer energy into and from the antenna. This greatly simplifies the structure. In addition, the structure can be made small enough to fit into hand held wireless devices. Regional manipulation of the permittivity or permeability can achieve directivity in any direction in 3 dimensions in a very small antenna. It also allows MIMO communications to be fully integrated into a small mobile wireless device, in which a number of antennas provide a separate signal paths. In addition, because the backlobe is very low, it allows power reduction in communication thereby increasing user density and battery life. It also provides a means for determining the angle of signal arrival, which can be useful for locating devices. Also, the specific absorption rate is lower than for more conventional antennas because radiation can be actively directed away from the user. Lastly in the conductive form the desired shape can be formed merely by varying an electric or magnetic field (depending on the choice of the dielectric and conductive characteristics of both the medium and the

suspended particles). With an array of such elements a radiation beam can be formed in the desired direction.

A skilled person will appreciate that variations of the disclosed arrangements are possible without departing from the invention. For example, although the antenna has been described in terms of transmission of a signal, it could equally be used in reception mode. In addition, although the invention has been described with reference to low loss permittivity materials, this could equally well be achieved with low loss permeability materials such as ferrites. Also, rather than having a cylindrical resonator with an enclosing annular ring as shown in Figure 1, disks, hemispheres or spheres may be used. Hence, a three-dimensional radiation pattern could be generated and steered. Also, the segments surrounding the resonator could be laminated. This would increase the gain of the main lobe and reduce the back lobe, although it would increase the dimensions of the structure.

Moreover, the proposed antenna could be designed with a smaller ground plane similar to the HDRA (high dielectric resonator antennas) manufactured by Antenova Ltd. to modify the bandwidth, as described in US 0242996 A1, the contents of which are herein incorporated by reference. Furthermore, whilst the descriptions of Figures 8 and 9 refer to the use of solid particles suspended in the liquid, this is not essential and the suspended particles may be solid, liquid, semi-solid or semi-liquid. Accordingly the above description of the specific embodiment is made by way of example only and not for the purposes of limitation. It will be clear to the skilled person that minor modifications may be made without significant changes to the operation described.

Claims

1. An antenna comprising a radiator that has a radiating portion for allowing radiation to be transmitted and/or received and a non-radiating portion for preventing radiation transmission and/or reception, and means for changing the position and/or shape of the radiating portion.
2. An antenna as claimed in claim 1 comprising a source/resonator of dielectric and/or magnetic material.
3. An antenna as claimed in claim 2 wherein the radiating portion has a similar relative permittivity and/or relative permeability to that of the source/resonator.
4. An antenna as claimed in claim 2 or claim 3 wherein the non-radiating portion has a higher relative permittivity and/or relative permeability to that of the source/resonator.
5. An antenna as claimed in any of the preceding claims wherein the radiator comprises a plurality of segments, at least one of which defines the radiating portion.
6. An antenna as claimed in claim 4 wherein the segments are placed at regular intervals.
7. An antenna as claimed in any of claims 1 to 4 wherein the radiator is non-segmented.
8. An antenna as claimed in any of the preceding claims wherein the radiator is one of annular, cylindrical, spherical, and hemispherical.

9. An antenna as claimed in any of the preceding claims wherein the radiator includes at least one of a liquid, gel and solid.

10. An antenna as claimed in claim 9 wherein when at least one of a liquid and gel is used; dielectric and/or magnetic and/or conductive particles are added to modify the dielectric and/or magnetic and/or conductive properties of the radiator.

11. An antenna as claimed in claim 10 wherein the particles are one of solid, liquid, semi-solid or semi-liquid.

12. An antenna as claimed in any of claims 9 to 11 wherein the means for changing the position and/or shape of the antenna are operable to vary the distribution of the and/or magnetic and/or conductive particles.

13. An antenna as claimed in any of claims 1 to 12 wherein the means for changing the position are operable to move the whole radiator relative to the source, thereby to position the radiating portion.

14. An antenna as claimed in claim 13 wherein the means for changing the position are operable to rotate the radiator relative to the source.

15. An antenna as claimed in any of the preceding claims wherein the means for changing the position and/or shape of the radiating portion comprise a mechanical drive and/or an electric field and/or a magnetic field.

16. An antenna formed from conductive particles suspended in a dielectric liquid or gel, the antenna comprising means for causing one or more groups or patches of the conductive particles to form a conductive path to a radiation source, the conductive path acting as a radiator, and means for changing the distribution of the particles, thereby to vary the position and/or direction of the radiation emitted.

17. An antenna as claimed in claim 16 wherein each patch antenna system is of any desired shape.

5 18. An antenna as claimed in any of claims 10 to 17 including at least liquid medium in which particles are suspended.

19. An antenna as claimed in any of the preceding claims, wherein only a single feed is required to transfer energy into and/or from the radiating portion.

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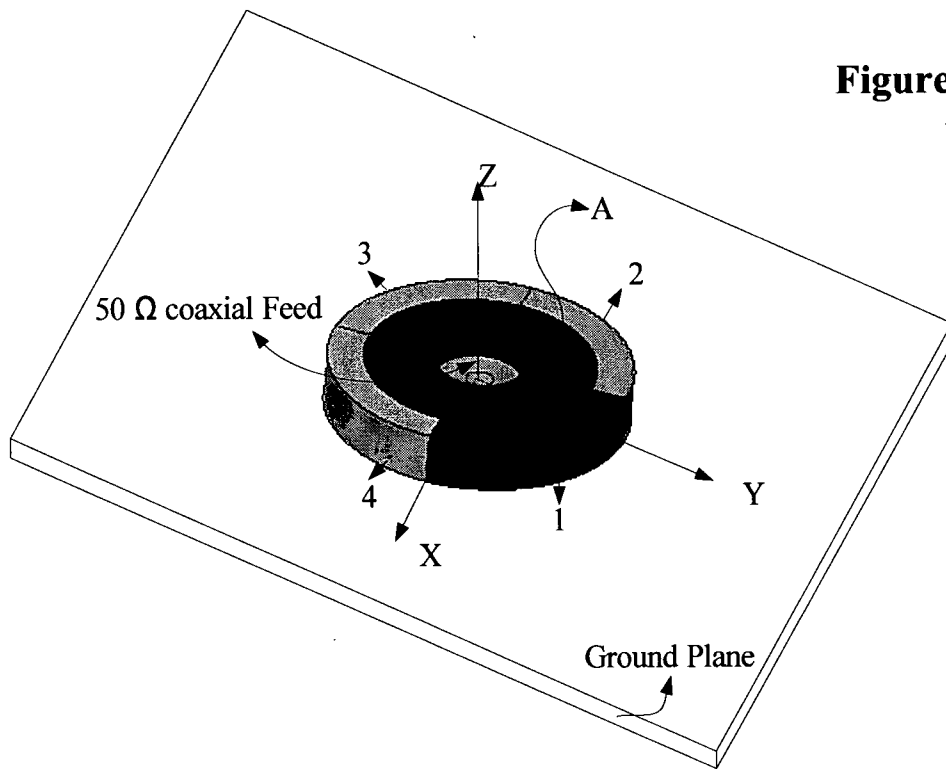


Figure 1

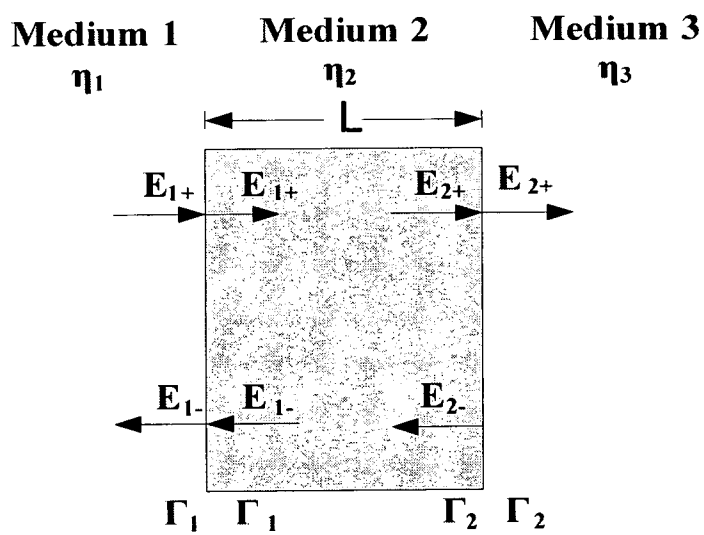


Figure 2

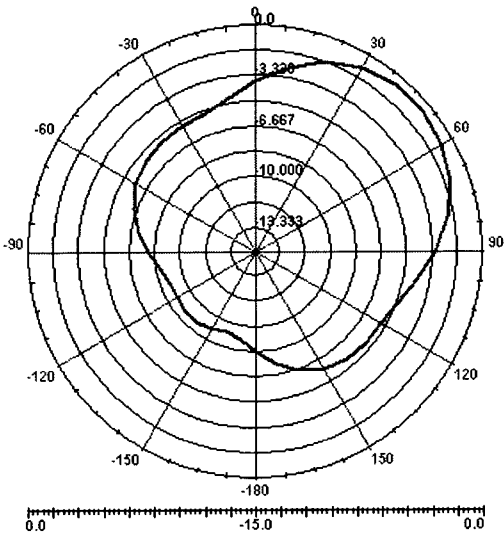


Figure 3

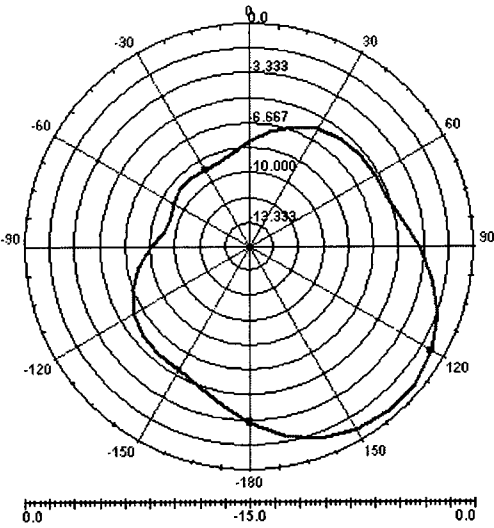
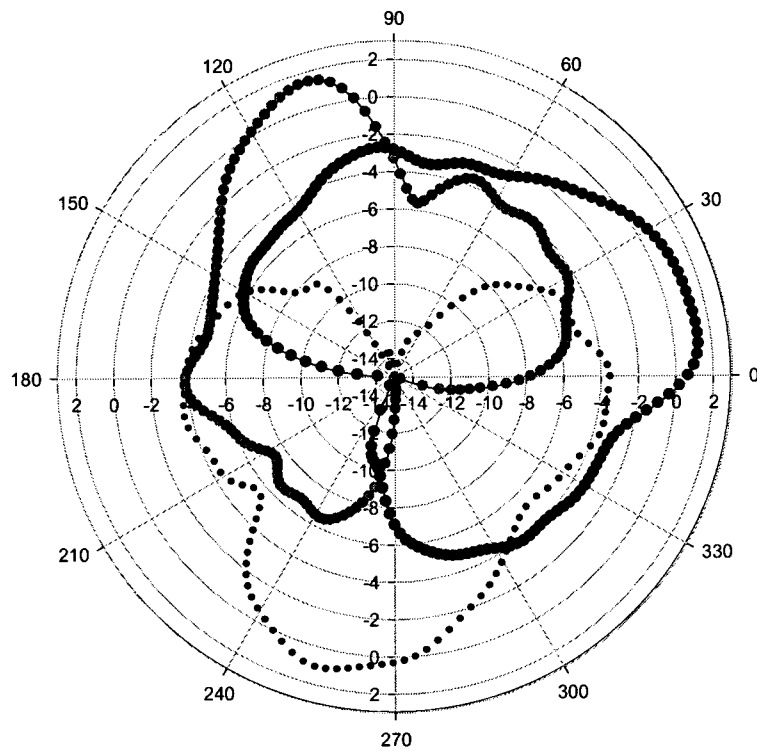


Figure 4

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- Co-Polarised Far Field Radiation Pattern in the H_Plane when the ring rotates 112 degrees
- Co-Polarised Far Field radiation Pattern in the H_Field when the ring rotates 15 degrees
- Co-Polarised Far Field Radiation Pattern when the ring rotates 90 degrees

Figure 5

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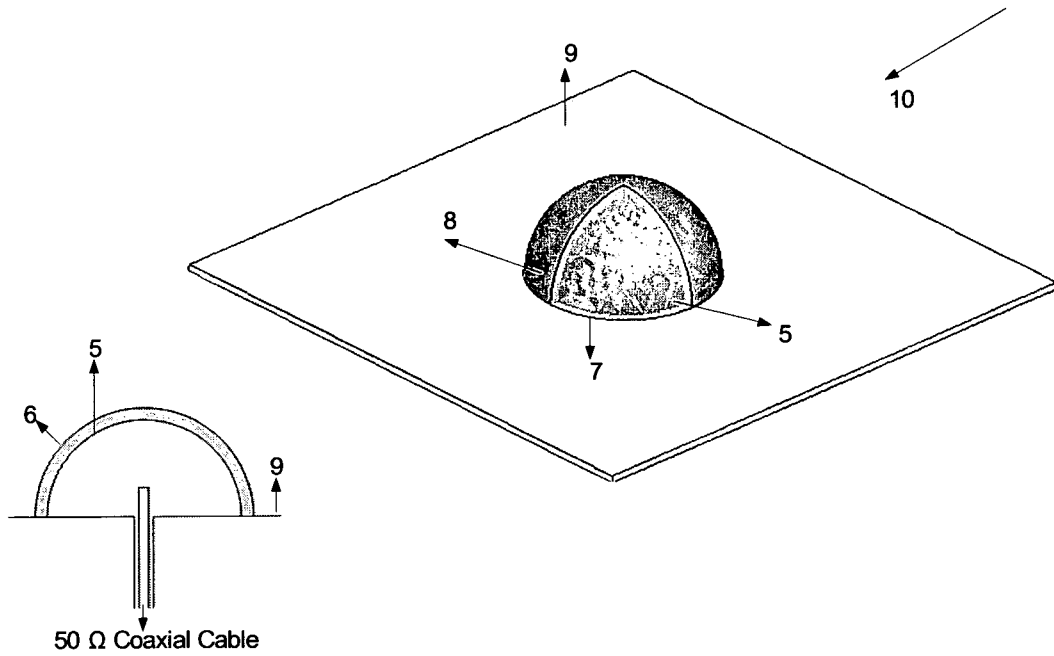


Figure 6

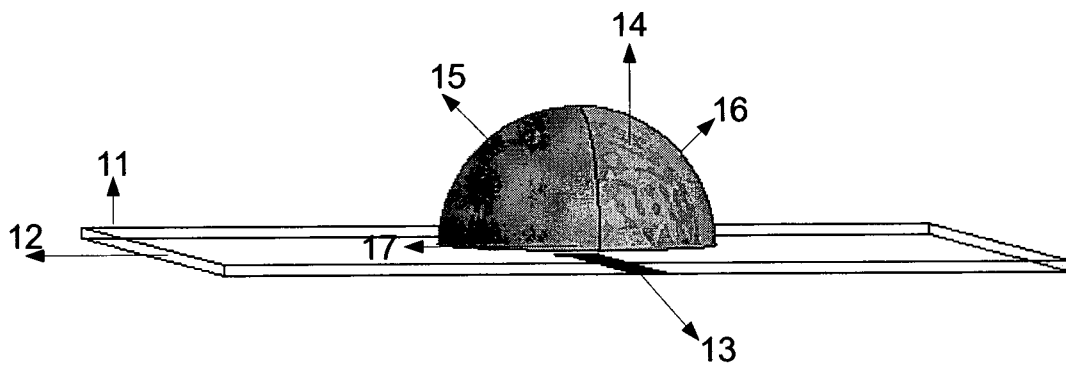


Figure 7

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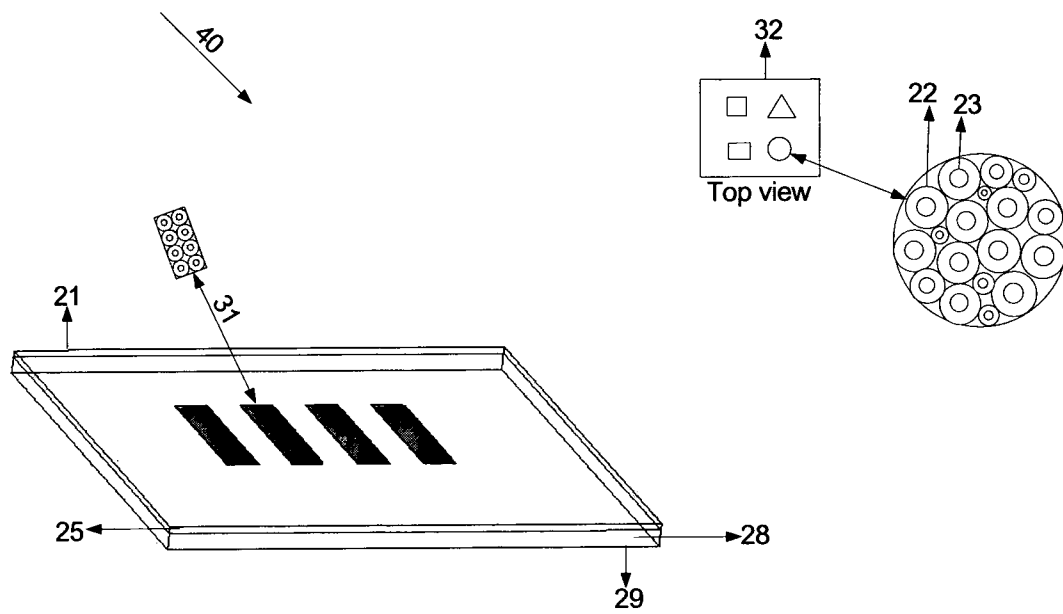


Figure 8

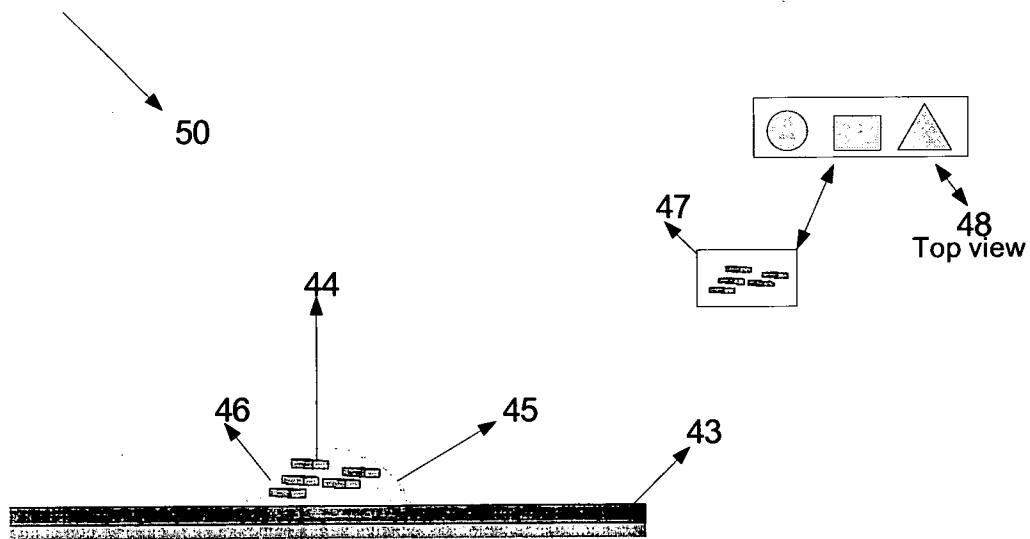


Figure 9