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Description

TECHNICAL FIELD

[0001] The present invention involves an antenna with a low physical profile and a particular radiation pattern.

[0002] In one particular (albeit non-limiting) example application, the antenna can be placed in or on the surface of a road, a driveway, or the like, and can be used to perform radiofrequency identification (RFID) with RFID capable tags (RFID tags) which are located on the front and/or the back of passing vehicles. In this application (or like applications), the antenna would be a part of (or associated with) a RFID reader which is operable to communicate with RFID tags. Preferably, the RFID tags will be located on (or integrated as part of) the vehicles' license plates. (Or more specifically, for vehicles which have a license plate on the front and the rear, a RFID tag will preferably be placed on (or integrated as part of) one or both of a said vehicle's license plates, or for vehicles which have only one license plate, a RFID tag will preferably be placed on (or integrated as part of) the single license plate).

[0003] Notwithstanding the foregoing, it is to be clearly understood that no particular limitations are to be implied from any of the example applications or uses mentioned above or discussed below. Thus, the antenna could potentially be used in a wide range of other areas and/or applications as well. By way of example, rather than being used in "on-road" or "in-road" applications for detecting RFID tags which are placed on the front and/or back of vehicles (or on the vehicles' license plate(s)), the antenna could instead potentially find use in side and/or overhead placements to read/communicate with RFID tags on vehicles, or on goods or products which are moving past the antenna (e.g. goods or products being carried past the antenna by a machine, or on a conveyor, etc).

[0004] Nevertheless, for convenience, the invention will hereafter be described with reference to, and in the context of, the above application where the antenna communicates with RFID tags which are located on (or integrated as part of) vehicle license plates.

BACKGROUND

[0005] For the purpose of providing a background and introduction to the present invention, reference is hereby made to two earlier patent applications, namely:

- International Patent Application No. PCT/AU2015/050161 (hereinafter referred to as "patent application '161"); and
- International Patent Application No. PCT/AU2015/050384 (hereinafter referred to as "patent application '384").

[0006] Both of patent applications '161 and '384 explain, *inter alia*, that there are a number of benefits and

advantages that can arise from placing an RFID tag on a vehicle (preferably by embedding or integrating the RFID tag in one or both of the vehicle's licence plates) and also from enabling the said RFID tag to be read by an RFID reader, the antenna of which (at least) is placed on or in the road. Patent applications '161 and '384 also explain (for reasons elaborated on therein) that because of the general geometry associated with the placement location of licence plates on vehicles, and with the dimensions (especially the width) of most road lanes, a *required* read-zone (i.e. the region near the RFID reader antenna inside which the RFID reader is required to be able to communicate with an RFID tag if said tag is within said region):

- is approximately 4 m wide (2 m on either side of the antenna),
- occupies the space from about 5 m to about 1 m before the antenna in a given direction (e.g. the direction of travel in a road lane),
- occupies the space after the antenna (in the said same direction) from about 1 m to about 5 m after the antenna, and
- extends in height, at least within the horizontal zones defined in the preceding bullet points, from between about 0.3 m and about 1.3 m above ground (road) level.

[0007] Note that the dimensions of the required read-zone given above may not precisely match the required read-zone dimensions discussed in patent applications '161 and '384. Nevertheless both of those earlier patent applications clearly disclose a required read zone which is at least similar to that given above, even if the zone dimensions quoted differ slightly.

[0008] Patent applications '161 and '384 explain one way of achieving a required read-zone such as that just described, namely by using an omnidirectional vertically polarised radiation pattern, and hence by using an antenna that can provide such a radiation pattern. The required read-zone described in the bullet points above is illustrated in Figure 1. In Figure 1, the required read-zone is indicated by reference numeral 2.

[0009] Patent applications '161 and '384 further explain that the radiation pattern 3 of the RFID reader antenna should preferably have a shape that might be described as a "dropped doughnut" or "squashed toroid" - that is, a shape as shown pictorially in Figure 2. The "hole" 4 (or more technically the "radiation null" 4) which is at/near the centre on top of the "dropped doughnut" (or "squashed toroid") shaped radiation pattern 3 helps, for example, to reduce the blinding effect of high power reflections from the underside of vehicles passing over the top of the antenna. should be noted that Figure 2 merely provides an initial visually appreciable illustration of what is meant by the "dropped doughnut" or "squashed toroid" shape that the radiation pattern 3 should have.

[0010] Patent applications '161 and '384 also indicate

that RFID tag antennas (such as the antennas of RFID tags used on vehicle license plates) typically have a highly directional radiation pattern. More specifically, the radiation pattern of a RFID tag antenna on a vehicle license plate will almost invariably point generally in a direction 6 which is parallel to the licence plate's "face-on" direction, albeit pointing away from the vehicle/plate, as depicted in Figure 3. The direct radiation communication path 8 between the RFID tag antenna on the license plate and the RFID reader antenna therefore has an elevation (i.e. height/vertical) offset 5, and it may also have a directional (horizontal) offset 7, from the plate's face-on direction. Whether or not there is a directional (horizontal) offset 7 depends on the travel path of the vehicle, and in particular whether the RFID tag antenna on the vehicle's licence plate is passing directly over, or to one side of, the antenna.

[0011] Figure 4 is a plan (i.e. "top down") view of a road comprising three road lanes. All three lanes in this example carry vehicles in the same direction, and all three are approximately 4 m wide. There is an RFID reader antenna placed on/in the road in the middle of the centre lane. Figure 4 shows the following superimposed on the three-lane road:

- the *required* read-zone 2 (square regions indicated by diagonal hatching) ;
- the omnidirectional radiation pattern 3 of the RFID reader antenna (note that the omnidirectional radiation pattern 3 in Figure 4 is actually the "dropped doughnut" shape shown in e.g. Figure 2, however this has the appearance of (and is represented as) a simple circle in the "top down" view in Figure 4); and
- the *effective* read-zone 9, which in the two-dimensional "top down" view in Figure 4 has a "figure-8" shape (note: the orientation and the "figure 8" shape of the effective read zone 9 - i.e. with two round "lobes" arranged in line with the direction of travel in the centre of the middle lane - arises due to the geometry of the required read zone 2, and the convergence of the "figure 8" lobes near the RFID reader arises due to angle of read issues for the directional RFID tags on the license plates. The shape of the "figure 8" shaped effective read-zone 9 (and the factors that contribute to give it this shape) are therefore not a result of the design/configuration of the RFID reader antenna.

[0012] Patent applications '161 and '384 explain that, even if "two-way" data communication between an RFID reader and the RFID tag on a vehicle (or on/in the vehicle's license plate) is not achieved (such that positive identification of the specific vehicle ID is not achieved via RFID), nevertheless the RFID reader antenna (i.e. the same RFID reader antenna used for positive vehicle identification via RFID) may still be used to detect the presence and also, for example, the speed, etc, of the (non-positively-identified) vehicle. This may be achieved

using conventional RADAR (or "RADAR-like" or "one-way" communication) methods. See further on this below.

[0013] Patent application '161, in particular, also explains that the RFID reader (of which the RFID reader antenna forms part) may also include (or it may even contain within a common housing or structure) other sensors of importance in traffic management. These sensors could be placed on top of the antenna. This would, however, increase the overall height of the antenna. Both patent applications '161 and '384 indicate that antenna height (and minimizing or at least limiting this) is an important design factor, because vehicles must be able to safely drive/pass over the antenna without damage to the vehicle or the RFID antenna and/or reader. For the purposes of the present explanation, given that the height of traditional "cat-eye" type retro-reflective road markers is typically around 25 mm, and given that these are widely approved for use (indeed they are used extensively without causing damage to vehicles travelling on the roads on which they are installed), it shall be assumed, at least for permanent or non-temporary applications, that if the height to which an antenna or other associated RFID reader equipment projects above the road surface is 25 mm or less, this will not pose any danger or risk of damage to vehicles using the road. In other words, although there is no absolute requirement in this regard, it is envisaged that, at least where the present invention is used in permanent or semi-permanent in-road implementations, the height to which the antenna and any other associated RFID reader equipment projects above the road surface should generally be 25 mm or less. Those skilled in the field of antenna design will readily appreciate the significant challenges this creates in terms of designing an antenna capable of providing the required radiation pattern, not to mention also satisfying several other operational requirements that apply in such implementations, as discussed below.

[0014] In summary, patent application '384 refers to certain antenna designs (and antenna design methodologies) which are intended to help overcome a number of the issues and challenges just-described, particularly where (modulated and/or unmodulated) RADAR or RADAR-like transmission is the data transfer method used and with the transmitting antenna on the ground and the reflecting antenna within ~6 m and below.

[0015] Also, as has been explained (and as elaborated on more in patent applications '161 and '384), in the context of RF road vehicle detection/identification applications, there are numerous advantages that arise from placing the RFID reader, or at least the antenna thereof, on or in the road surface. However, as has further been explained just above, the placement of the antenna on/in the road surface, especially where the required read range is within 6 m from the antenna, limits (or it may entirely prevent) the use of conventional radar radiation methods in which the Earth in particular is often quantified as (i.e. it is assumed to be) a single RF element which

is homogeneous and stable/non-changing/time-invariant (or almost so).

[0016] In one particular disclosure in patent application '384, a periodic slotted ground is proposed as the base of a modified monopole antenna, such as for example an inverted F antenna or variations thereon. The proposed use of a periodic slotted ground for antennas in patent application '384 is intended to (amongst other things) help maintain a small footprint for the antenna. However, experimentation indicates that such antennas with a small-footprint periodic slotted ground may not be capable of adequately accommodating the potentially wide range of "RF" properties at road pavements (i.e. such antennas with a small-footprint periodic slotted ground may not be capable of meeting operational requirements across all of the different and widely and dynamically variable radio frequency transmission conditions/environments found at road pavements). By way of example, this can be particularly so for roads which are, say, close to the coast where the road (including the road surface and also the underlying road base, surrounding/nearby soil, etc) may sometimes be extremely dry and consequently non-conducting because of hot land winds, but which may change rapidly to moist/wet and relatively conductive because of e.g. moisture-laden salt spray from an onshore sea breeze or because of rain, etc.

[0017] Those skilled in the area of antenna design will recognise that whilst conductivity (including, but not limited to, road-surface conductivity) is one of the important parameters which can influence the radiation pattern of an on-road or in-road antenna, it is not the only relevant parameter. For instance, as another example, in road building, a range of different types of aggregates may be used. The way in which these different types of aggregates age, change, bind, compact, etc, over time differs. The numerous potential effects of this (including differing material makeup, density, porosity, surface shape and texture of the road surface, etc) can also significantly affect the radio frequency transmission conditions/environment on the road, which in turn also influences the radiation pattern of the on/in road antenna.

[0018] Furthermore, experimentation indicates that the realistic gain of an antenna having a small-footprint periodic slotted ground design, for example as in patent application '384, possibly may not exceed 1 dBiL, and realistic values may be less than 0 dBiL. (Note: "dBiL" here is the forward gain of the antenna (in decibels - dB) compared with a hypothetical isotropic antenna which uniformly distributes energy in all directions - hence dBi is shorthand for dB(isotropic) - and the "L" in dBiL signifies that linear polarization of the electromagnetic field is assumed). In any case, this low gain of antennas having a small-footprint periodic slotted ground design, like for example certain of the antennas in patent application '384, can consequently create a need to increase power output from the RFID reader (which powers the antenna) to thereby compensate for low antenna gain. However, this increase in power output from the RFID reader may in

turn cause, for example, overheating problems, especially for in-road placements because, unlike on-road placements where the reader is aboveground and heat may be able to dissipate into the air, in in-road placements the reader is (at least mostly) located in the ground and is therefore surrounded and insulated on all sides by earth/soil/road base meaning that heat is comparatively trapped and cannot easily dissipate. Therefore, an increase in power output from the RFID reader to compensate for low antenna gain may cause overheating problems especially for in-road RFID reader/antenna placements. An increase in power output from the RFID reader to compensate for the low antenna gain may also have the effect of reducing overall the reader's relative sensitivity.

[0019] In view of the foregoing, it is thought that it would be desirable if there were a method and/or appropriate antenna hardware/apparatus that could accommodate the potentially widely and dynamically variable radio frequency transmission conditions/environment that may exist on a road at different times, or on different roads at different locations at different times, so as to enable an antenna that can be placed on/in a road, or antennas that can be placed on/in roads at different locations, to achieve a desired antenna radiation pattern consistently (or at least with an acceptable degree of consistency) in all conditions at all locations. It may be particularly desirable if the tuning of in-road or on-road antennas could be made (or if it could become) a more "exact science" - that is to say, if antenna tuning could be performed in such a way that the effect on the antenna's radiation pattern resulting from tuning alterations to the size, design, configuration, etc, of the antenna (or of certain parts of the antenna) is much more predictable and reliable and therefore much less reliant on simple "trial and error" tuning. It is also thought that it would be desirable if the effective gain of an in-road or on-road antenna could be increased in comparison with the small-footprint periodic slotted ground antenna designs discussed above, preferably such that the effective antenna gain is around 3 dBiL or better.

[0020] US2007216595 discloses a mono-conical antenna serving as a dielectric-loaded antenna including: (i) a electricity supply electrode, which has a conical surface; (ii) an earth electrode, which has a flat surface that is so positioned as to face an apex of the conical surface; and (iii) a dielectric member, which is provided between the conical surface and the flat surface. The dielectric member has an outer circumferential surface which has such a slope that extends from a side of the conical surface to a side of the flat surface. This allows the dielectric-loaded antenna to have a small size, and to handle a wider frequency band in which the maximum value of the VSWR is restrained to be small.

[0021] US2010085264 discloses a multi-band antenna is provided that operates in at least two non-harmonically related frequency bands. The antenna includes a ground plane, a cone-shaped relatively high frequency

antenna element with a tip of the high frequency antenna disposed adjacent to but electrically isolated from the ground plane with a base of the cone-shaped antenna element extending away from the ground plane, and at least three relatively low frequency antenna elements electrically connected to and extending between the base of the cone-shaped antenna element and the ground plane.

[0022] US2015015447 discloses an antenna, including a ground region having a plurality of meandering slots formed therein, a generally conical radiating element supported on the ground region and spaced apart therefrom and a generally flat disk-shaped radiating element disposed between the generally conical radiating element and the ground region, the generally flat disk-shaped radiating element feeding the generally conical radiating element.

[0023] JP2006041634 discloses a traveling wave antenna provided with a radiation element, a ground conductor, and a dielectric body for covering a part or all of an outer circumferential face of the radiation element. The outer surface of the dielectric body is formed in parallel with an equi-phase plane of a radio wave emitted from between the radiation element and the ground conductor.

SUMMARY OF THE INVENTION

[0024] In a first form, the invention relates broadly to an antenna for a communication device in accordance with claim 1.

[0025] In the said antenna structure, the encompassing side of the body may extend from at or near an outer perimeter of the base plate to near an edge on the widest point on the cone. Also, the distance between the base plate and the widest point on the cone in a direction perpendicular to the base plate (this distance may be considered to be the height of the antenna) may be less (or much less) than the maximum diameter of the antenna (where the maximum diameter of the antenna may, and usually will, be the diameter of the base plate). In other words, it may be that antenna height $\ll$ antenna diameter. Furthermore, the diameter of the base plate in the antenna structure may be larger than the maximum diameter of the cone (i.e. cone diameter $<$ base plate diameter).

[0026] The base plate and the cone of the antenna structure may be made from a conductive material. The conductive material may be metal such as copper, silver or an appropriate conductive alloy thereof.

[0027] The body of the antenna structure may be made from a dielectric and physically strong material. More specifically, the material from which the body is made may have a permittivity (dielectric constant) of between approximately 3 and approximately 6. In some embodiments, the material from which the body is made may be a soda lime glass.

[0028] The body may be initially formed with a recess

or indent therein. The shape of the said recess or indent may also correspond to the shape of the cone of the antenna, and the cone of the antenna may be formed by plating a thin layer of metal onto the surface of the recess or indent.

[0029] The antenna structure may further include a top plate/lid which extends across and partly or fully covers the space which is formed by and within the open cone.

[0030] In embodiments where the base plate is metal, the metal base plate may be approximately 5-10 mm thick and it may be initially formed separately from the body and then affixed on or to the bottom/underside of the body.

[0031] In some embodiments, the antenna may be configured to be used with a signal frequency of 860-940 MHz. In these embodiments, it may be the case that:

- on the side of the base plate on which the cone is located, no point on the antenna is further than 25 mm from that side/surface of the base plate in a direction perpendicular to the base plate; and/or
- the diameter of the base plate is less than 190mm; and/or
- the encompassing side of the body extends from an outer perimeter edge of the base plate to near the edge on the widest point on the cone, and the angle between the encompassing side and the base plate, when taken in a central plane perpendicular to the base plate, is less than 40° , and preferably $33^\circ - 36^\circ$.

[0032] In a second form, the invention relates broadly to an RFID reader incorporating an antenna according to the first form of the invention (as described above), wherein the RFID reader is operable to be used in an application involving road vehicle detection and/or identification and wherein at least the antenna (and possibly also other parts of the RFID reader) is operable to be installed in the surface of the road (i.e. "in-road").

[0033] The RFID reader may further include additional electronic components, and these may be (when the RFID reader is in use) mounted below the surface of the road, beneath the antenna. Furthermore, when the RFID reader is installed in the road for use, the base plate of the antenna may be installed horizontally in (or otherwise parallel to) the surface of the road such that an upper surface of the base plate, which is the surface on the side of the base plate which has the cone (and the surface of the base plate to which the body joins), is level (i.e. substantially coplanar) with the road surface, and the antenna's body and cone may project above the upper surface of the base plate and above the level of the road surface.

[0034] When the RFID reader is installed as just described, the antenna may also be surrounded by an at least partially conductive area which is also on or applied to the road surface. If the said partially conductive area surrounding a single antenna is circular, the minimum radius of said partially conductive area may be approxi-

mately twice the wavelength (λ) of the signals to be transmitted and/or received by the antenna. Also, the partially conductive area may have a conductivity of approximately 10^3 S/m or more.

[0035] In the RFID reader according to the second form of the invention, the antenna may be operable to, in use, generate a radiation pattern having a "dropped doughnut" or "squashed toroid" shape. The antenna (and the radiation pattern generated thereby in this installation) may also be omnidirectional in the azimuth plane. In some particular embodiments, the antenna may be operable with a signal frequency of 860-940 MHz, and where this is the case the elevation range (relative to the azimuth plane) of the critical read zone in the radiation pattern may be from approximately 3° to approximately 30° elevation. Also in these embodiments, in the said radiation pattern, the path of max gain (relative to the azimuth plane) may be at approximately 30° elevation. Furthermore, in these embodiments, in the said radiation pattern, the 3dB beam width may be approximately 40° , extending from approximately 10° to approximately 50° elevation (relative to the azimuth plane), and there may be an effective radiation null at 90° elevation (relative to the azimuth plane). In some particular implementations, the effective read range of the RFID reader may be from approximately 1 m to approximately 6.4 m from the antenna in any direction along the road surface (i.e. in the azimuth plane).

[0036] In a third form, the invention relates broadly to an RFID reader incorporating an antenna according to the first form of the invention (as described above), wherein the RFID reader is operable to be used in an application involving road vehicle detection and/or identification and wherein at least the antenna (and possibly also other parts of the RFID reader) is operable to be installed or mounted in or on a partially conductive structure.

[0037] In this third form of the invention, the partially conductive structure is operable to be placed on the surface of the road ("on-road"), and when the partially conductive structure is placed on the surface of the road with (at least) the antenna installed or mounted therein or thereon, the antenna may be located a distance vertically above the road surface, possibly (or preferably) at or near the top of the partially conductive structure.

[0038] In some embodiments, the partially conductive structure may be substantially frusto-conical in shape. Where this is the case, the angle of slope of the side on the frusto-conical partially conductive structure may substantially match the angle of slope on the side of the antenna's main frusto-conical body.

[0039] In embodiments such as those described in the previous two paragraphs, if the antenna operates with a signal frequency (λ) of 860-940 MHz, the configuration (and particularly the height) of the partially conductive structure should preferably be such that the height of the antenna's base plate, when it is mounted on the partially conductive structure and the partially conductive struc-

ture is on the road surface, is not more than $\frac{3}{8}\lambda$, and preferably not more than $\frac{1}{4}\lambda$.

[0040] In the RFID reader according to the third form of the invention, the construction and/or configuration of the partially conductive structure, including in relation to its height, the angle of slope of its side, internal construction, and positioning of internal components, may be chosen and/or varied to tune the partially conductive structure so that, when the partially conductive structure is used in conjunction with (at least) the antenna, the radiation pattern has a desired "dropped doughnut"-shape.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] Preferred features, embodiments and variations of the invention may be discerned from the following Detailed Description which provides sufficient information for those skilled in the art to perform the invention. The Detailed Description is not to be regarded as limiting the scope of the preceding Summary of the Invention in any way. The Detailed Description will make reference to a number of drawings (the Specification Figures) as follows:

Figure 1 - required read-zone for an in/on road antenna.

Figure 2 - "dropped doughnut" (or "squashed toroid") shaped antenna radiation pattern.

Figure 3 - elevation/height and directional/horizontal offsets of the radiation communication path between a license plate's tag and an in/on road antenna, relative to the plate's "face-on" direction.

Figure 4 - plan view of a three lane road with an RFID reader antenna placed on/in the road in the middle of the centre lane. (Note: the fact that this Figure illustrates only a single RFID reader antenna, located in the centre lane, is for clarity of illustration only. Normally, in practice (at least where the present invention is used in in-road implementations) there will be an RFID reader antenna placed in the middle of each lane).

Figure 5 - traditional disk cone antenna with the disk and cone each formed from discrete elongate rod elements.

Figure 6 - traditional disk cone antenna having a solid disk and solid cone.

Figure 7 - RFID reader (including antenna structure) with a surrounding partially conductive area of radius R at least twice the signal wavelength λ .

Figure 8 - schematic illustration of a shape corresponding to that of the proposed antenna structure.

Figure 9 - cross-sectional view of the proposed antenna structure, also incorporating other reader equipment (i.e. in addition to the basic antenna structure), in an in-road application.

Figure 10 - annotated cross-sectional view of the proposed antenna structure etc in Figure 9.

Figure 11 - cross-sectional view of the proposed antenna structure, also incorporating certain other reader equipment (i.e. in addition to the basic antenna structure), when the antenna structure is mounted on a partially conductive substructure in the form of an on-road cradle for on-road applications.

Figure 12 - annotated cross-sectional view of the proposed antenna structure etc in Figure 11.

Figure 13 - possible different shapes/configurations for the partially conductive on-road cradle which forms part of the antenna design/structure for on-road applications/deployments.

Figure 14 - schematic representation of the possible shape and configuration of the main frusto-cone body of the antenna structure

Figure 15 - cross-sectional view of a slight alternative or variant on the proposed antenna structure, also incorporating other reader equipment (i.e. in addition to the basic antenna structure), in an in-road application

Figure 16 - annotated cross-sectional view of the slight alternative or variant antenna structure etc in Figure 15

Figure 17 - side-on and partially exploded pictorial view of another slight alternative or variant on the proposed antenna structure and other reader equipment intended for use in an in-road application.

Figure 18 - side-on pictorial view of the slight alternative or variant on the proposed antenna structure etc in Figure 17.

Figure 19 - Perspective view of the plotted antenna radiation pattern shape and directivity, illustrating that the radiation pattern is omnidirectional in the azimuth (x-y) plane (i.e. in a plane parallel to the road surface if the antenna is in-road, for example)

Figure 20 - Plot of one side (or one "lobe") of a cross-section of the radiation pattern as plotted in Figure 19, with the cross-section taken in a vertical (x-z) plane that extends through the centre of the radiation pattern in Figure 19, and also illustrating the following in the plane of this cross section: the elevation range

of the critical read zone; the elevation of the path of maximum gain; the 3dB beam width; and the radiation null at 90° to the azimuth (x-y) plane

5 DETAILED DESCRIPTION

[0042] As explained in the Background section above, it is thought that it would be desirable if there were a method and/or appropriate antenna hardware/apparatus that could accommodate the potentially widely and dynamically variable radio frequency transmission conditions/environment that may exist on a road at different times, or on different roads at different locations at different times, so as to enable an antenna that is on/in a road, or antennas that are on/in roads at different locations, to achieve a desired antenna radiation pattern consistently (or at least with an acceptable degree of consistency) in all conditions at all locations. It is thought that it would also be desirable if the tuning of in-road or on-road antennas could be a more "exact science" - that is to say, if tuning of in-road or on-road antennas could be performed in such a way that the effect on the antenna's radiation pattern resulting from tuning alterations to, for example, the size, design, configuration, relative proportions, etc, of the antenna (or of certain parts of the antenna or associated structures or components) could be more predictable and reliable and therefore less reliant on more simple/crude "trial and error" tuning. It is further thought that it would be desirable if the effective gain of an in-road or-road antenna could be increased in comparison with the small-footprint periodic ground antenna designs discussed in the Background section above, preferably such that the effective antenna gain his around 3 dBiL or better.

[0043] The various antenna structure (and associated RFID reader) configurations and designs that are discussed below with reference to the Specification Figures seek to achieve one or more of the general aims above, or at least go some way towards doing so by, in basic terms, adopting an antenna structure that turns a conventional disk-cone (a.k.a. "discone") antenna structure over, and by also surrounding the antenna structure with an at least partially conductive area or placing the antenna structure on an at least partially conductive substructure.

[0044] At this point, it is useful to note that conventional disk-cone antennas are so named due to their distinctive shape. Conventional disk-cone antenna designs consist of a "disk" at the top and a "cone" underneath wherein the cone is oriented "cone-pointing-up" such that the apex of the cone meets at or near the centre of the "disk". Often, conventional disk-cone antennas are formed from a number of straight, elongate elements with some of the elements at the top arranged in a radial manner to define a disk shape, and with other elements pointing downwards and radially outwards from at or near the centre of the disk to thus define the shape of a cone. A conventional disk-cone antenna of this general kind is illustrated

in Figure 5. Conventional disk-cone antennas can also be (and have been) made with a solid disk and a solid cone, as shown in Figure 6 for example; however this latter form is rarely used because, in the various other applications in which conventional disk-cone antennas have traditionally found use (which are unrelated and totally different to the present road vehicle detection/identification application using an on/inroad RFID reader antenna), the use of a solid disk and cone greatly increases the weight of the antenna, and it may also increase such things as potential wind loading on the antenna and its mounting, etc. This has traditionally meant that such "solid" disk-cone antennas are often unsuitable for use in all but a very select few applications.

[0045] In any case, at least in simplistic/introductory terms, as part of the present invention an antenna structure is proposed that takes a conventional disk-cone antenna and turns it over - i.e. inverts it compared to the traditional "cone-pointing-up" orientation. It is also proposed to surround the antenna structure with an at least partially conductive area, or to place the antenna structure on an at least partially conductive substructure. (Hereafter, reference to a/the "partially conductive area" should be understood as referring to an area that is either partially conductive or fully conductive (i.e. it can mean either of these - or in other words "partially conductive area" should be understood to mean an area that is at least partially conductive). Similarly, hereafter, reference to a/the "partially conductive substructure" should be understood as referring to substructure that is either partially conductive or fully conductive (i.e. "partially conductive substructure" means a substructure which is at least partially conductive)

[0046] The option of providing a partially conductive area which surrounds the antenna structure is what will generally be done for permanent (and perhaps also for semi-permanent) in-road antenna placements, as discussed further below. The alternative option of placing the antenna structure on a partially conductive substructure is what may be done in temporary on-road antenna placements, as also discussed below.

[0047] When the proposed antenna structure is surrounded by a partially conductive area, as will generally be the case for in-road antenna placements, the partially conductive area may need to have a certain minimum size. This is to help ensure that the partially conductive area adequately shields the antenna structure from the potentially widely and dynamically variable radio frequency influences of the underlying road, other "near ground" effects, etc. By way of example, if the partially conductive area surrounding the antenna structure is shaped as a circle, the partially conductive area may need to have a certain minimum radius. However, the partially conductive area of course need not be circular. Indeed it may take any number of other shapes (or indeed any shape). Of course, for such other non-circular shapes, the size of the partially conductive area should still be sufficient to provide adequate shielding to the an-

tenna structure. Referring to the example where the partially conductive area is circular, the minimum radius of the partially conductive area in this case may need, at least for the particular embodiment(s) of the antenna structure discussed below, to be approximately twice the wavelength (λ) of the signals to be transmitted and/or received by the antenna (i.e. the radius of a circular partially conductive area should be $\geq 2\lambda$). An appreciation of this can be obtained from Figure 7.

[0048] Figure 7 illustrates an antenna structure in the centre (this particular antenna structure is discussed further below), and surrounding the antenna structure is a partially conductive area. In Figure 7 the partially conductive area happens to be circular in shape with radius R of $\geq 2\lambda$, as discussed immediately above. A number of other dimensions are given for the antenna structure in Figure 7. The particular dimensions of the antenna structure given in Figure 7 apply to an antenna structure of the type described below intended for use with signals having a frequency of approximately 920 MHz. As shown in Figure 7, for example, the maximum outer diameter D of the antenna structure (at its base) is approximately $D = 180$ mm. Certain other dimensions of this particular example antenna structure are also shown. And whilst not labelled specifically in Figure 7, given that the operating frequency of the antenna is approximately 920 MHz (which corresponds to a signal wavelength λ of 326 mm), therefore the radius R of the circular partially conductive area that surrounds the antenna structure is approximately $R \geq 2 \times 326$ mm = 652 mm. This is mentioned here simply to give a general indication of scale.

[0049] In order to ensure that the partially conductive area adequately shields the antenna structure from the potentially variable radio frequency influences of the underlying road (and from other "near ground" influences), the partially conductive area (and hence the material or substance from which it is formed) should also (at least when "finished" and ready for use) have a minimum conductivity. Or in other words, the partially conductive area should (when finished/installed and ready for use) have resistivity which is below a certain maximum. For the particular antenna structure(s) proposed herein, and given the antenna power, desired radiation pattern shape, antenna gain, antenna return loss, etc, the partially conductive area (and hence the material/substance from which it is formed) should preferably (when installed, finished and ready for use) have a conductivity of approximately 10^3 S/m or more (i.e. the conductivity should preferably be approx. equal to or more than 1000 Siemens per meter). To put this another way, the partially conductive area (and hence the material/substance from which it is formed) should preferably (when finished) have a resistivity below approximately 10^{-3} Ω m (i.e. the resistivity should preferably be equal to or less than 0.001 ohm meters).

[0050] For the avoidance of doubt, the partially conductive area (which, it will be recalled, is generally what will be used for in-road deployments of the antenna struc-

ture) should be applied to the surface of the road around the antenna structure, or around the location where the antenna structure will be placed. The partially conductive area need not necessarily come into direct contact with the antenna structure (or any part of it) when the antenna structure is installed. However, in order to ensure that the partially conductive area adequately shields the antenna structure from the potentially variable radio frequency influences of the underlying road, etc, and to ensure that no significant "near ground" effects are created by the width of road (if any) exposed between the antenna structure and the partially conductive area, in the vicinity of the antenna structure and surrounding the antenna structure there should preferably only be a small space/gap between the innermost portion/edge of the partially conductive area and the outer/perimeter edge of the antenna structure. For example, in the particular embodiment(s) discussed above and also discussed further below in which the antenna structure is configured to operate with a signal frequency of approximately 920 MHz (and hence a signal wavelength λ of approximately 326 mm) the space between the partially conductive area and the outer/perimeter edge of the antenna structure should preferably be less than 5 mm. Note that no such gap is shown in Figure 7.

[0051] The fact that the partially conductive area need not necessarily be in contact with the antenna structure may help to simplify procedures involved in the creation/formation/installation/deployment of the partially conductive area, and also the installation/deployment etc of the antenna structure (regardless of which occurs first), and it may also help to simplify maintenance for both (because replacing or repairing one need not necessarily affect or require replacing or repairing the other).

[0052] In relation to the creation/formation/installation/deployment of the partially conductive area in particular, this should preferably be as economical and non-disruptive as possible, both in terms of the time, cost, complexity, etc, involved in the creation/formation/installation of the partially conductive area itself, and also given that it will usually be necessary to close the road (or at least a section of the road or the lane(s) involved) while this is taking place.

[0053] It was mentioned above that the partially conductive area should have a minimum conductivity (or in other words a resistivity which is below a certain maximum), and it was also mentioned that for the particular antenna structures proposed herein, given the antenna power, desired radiation pattern shape, etc, the conductivity should preferably be approximately 10^3 S/m or more. If the conductivity of the partially conductive area is greater than approximately 10^6 S/m, the partially conductive area may in fact be considered to be "fully" conductive, and this may actually be suitable or even ideal for providing shielding in the present antenna application; however this is certainly not a requirement and embodiments of the invention may still operate effectively with partially conductive areas where the conductivity is con-

siderably less than "fully" conductive.

[0054] A partially conductive area for which the conductivity is greater than approximately 10^6 S/m (such that the partially conductive area is, in fact, "fully" conductive) could be created if the partially conductive area were to be made from a mesh made solely or mainly of, for example, stainless steel, copper, aluminium or certain other suitably conductive metal alloys, or perhaps from steel wool or metal cloth. However, the practicalities and difficulties associated with applying such a metal mesh to the road surface (at least or especially if the mesh is a separate, stand-alone object and not embedded in or as part of some other object or substance that can be more easily applied to the road) mean that creating the partially conductive area from nothing (or little) more than such a metal alloy mesh may perhaps be less attractive than other possible alternatives (some of which are discussed below). Also, a partially conductive area which is made from nothing (or little) more than a metal mesh may also have certain associated risks/hazards, particularly e.g. if the mesh were to lift off the road surface due to improper or imperfect installation, or as a result of wear and tear, etc. Therefore, whilst the use of a partially conductive area made from nothing (or little) more than a metal alloy mesh could be highly effective in terms of its ability to shield the antenna structure from the potentially variable radio frequency influences of the underlying road (and from other "near ground" influences), and whilst embodiments of the invention could well operate with such a partially conductive area made from a simple metal alloy mesh, nevertheless for practical reasons it is thought that this is less likely to be used (or perhaps it will be used less often) than other possible alternative means for forming the partially conductive area.

[0055] As an alternative, the partially conductive area could instead be formed and applied as, for example, a paint (or as a fluid which is applied to the road in a similar manner to paint), or as an epoxy which is applied to the road, or even as a polymer which can be melted onto the surface of the road. To achieve the required minimum level of conductivity (see above), a conductor or some form of conductive component or substance could be blended or otherwise incorporated into any of these, in an appropriate quantity (in the case of conductive substances), prior to installation.

[0056] Another consideration that may affect the means chosen for forming the partially conductive area is that the surfaces of roads generally expand and contract and change shape somewhat with time. For instance, when a road is loaded as a vehicle wheel presses down thereon as it passes, the road surface will momentarily compress/change shape slightly beneath and due to the pressure imposed by the vehicle wheel. Also, expansion and contraction of the road surface can occur due to temperature fluctuations (e.g. between day and night, or with the change of season, etc). This expanding and contracting and changing of shape, often repeatedly/cyclically, can consequently create cyclic load-

ing/stress and hence fatigue in any structure which is connected or bonded thereto. This may in turn lead to fatigue-related failure, for example, of any partially conductive area which is provided thereon, especially if the partially conductive area is in the form of a rigid or brittle structure. On the other hand, the partially conductive area will generally be much less susceptible to fatigue if it is formed from a substance which has, or if its structure allows or provides (at least a degree of) resilience, flexibility, "give" or the like.

[0057] With the foregoing in mind, one means for providing the partially conductive area which, it is thought, could be suitable (including because it can provide the required conductivity but also because it may potentially be produced economically, applied to the road with minimum disruption, and provide a degree of resilience once formed) is to use a substance which can be applied as a paint, or as an epoxy infused cloth that can be laid onto the road, or as a polymer that can be melted onto the road, and whichever of these is used, a conductive component/substance possibly in the form of e.g. graphite powder may be incorporated or blended into the paint, epoxy or polymer. Other conductive components/substances (i.e. other than graphite powder) may of course also be used. Nevertheless, referring for instance to a partially conductive area which is formed from an epoxy/graphite blend, as a comparative example of the hardness of a partially conductive area formed in this way, epoxy/graphite blends are often also used in yacht building for load-bearing structures and surfaces. Also, epoxy/graphite blends can have a conductivity of up to approximately 10^4 S/m (which it will be noted is easily sufficient for the purposes of the present invention).

[0058] Another means which is thought to be possibly suitable for forming the partially conductive area is to use carbon cloth (which can have a conductivity in excess of 10^5 S/m) which is painted or epoxied onto the road surface. Such a carbon cloth may alternatively be embedded in polymer sheets which can themselves be melted onto the road surface. In other applications and industries, such as boat and yacht building and repairs etc, it has been shown that maintenance and repair of carbon cloth layers/surfaces/structures, and similarly maintenance and repair of carbon cloth infused epoxy/polymer layers/surfaces/structures, can be relatively easy, cost and time efficient, and effective, using well-understood processes and techniques (none of which require detailed explanation here).

[0059] The component, substance or element within the partially conductive area, which provides the conductivity therefore, should preferably be close (ideally as near as possible) to the upper surface of the partially conductive area when the partially conductive area is applied/formed/installed on the road. In other words, once the partially conductive area has been applied/formed/installed on the road, within the vertical thickness of the structure of the partially conductive area, the component, substance or element which provides the conductivity

should preferably be as near to the top as possible. This is because the nearer the component, substance or element which provides the conductivity is to the upper surface, the better the shielding it will provide to the antenna structure. Of course, this may also often need to be balanced against the need for the component, substance or element which provides the conductivity to be covered so as to protect it from exposure to the elements, damage or wear when vehicles drive over it, etc.

[0060] Yet another means which is thought to be possibly suitable for forming the partially conductive area is to use a form of prefabricated "patch" type product which can be applied to the road. These could be similar to in many ways to, for example, the road repair/modification product produced by South African company A J Broom Road Products (Pty) Ltd and referred to by them as the BRP Road Patch. Hence, the partially conductive area could possibly be created using something similar to the BRP Road Patch; that is to say, the partially conductive area could possibly be created using a prefabricated product that is manufactured on paper (or some other suitable substrate or base material) and onto which a bitumen rubber binder (or some other similar binder) holds bitumen pre-coated aggregate. The prefabricated product thus produced could be supplied in sheets (i.e. prefabricated sheets) which are, say, 10-15 mm thick and dimensioned to suit the intended application (see above in relation to the size of the partially conductive area). Note that, in order to accommodate this 10-15 mm thickness of a partially conductive area formed from such a patch, the thickness of the base plate in the antenna structure may also need to be increased somewhat compared with baseplate size shown and discussed with reference to the specification Figures below.

[0061] Still referring to the possibility of forming a partially conductive area using a prefabricated patch like product, as described above, the particulate/grain/pebble size of the aggregate bound in the bitumen rubber binder may also be selected to suit; for example, in order to be similar to or match the particulate/grain/pebble size of the aggregate in the road onto which the patch is to be applied. The overall colour of a said patch (including, or due to, the colour of the aggregate) may be made (or the aggregate may be blended) to generally match the colour of the road onto which the patch is to be applied, such that the patch appears to simply be a part of the road (i.e. it is indistinguishable from the road) when applied. Alternatively, the patch could be coloured, or it could have markings (e.g. border or edge markings), etc, in order to make the patch clearly visible or easy to visibly differentiate from other parts/areas of the road. This latter may be of use in situations where it is preferable, or especially where there is a requirement, for vehicle operators/drivers to be able to see (and hence so that they can know) when they are about to pass over an area/location containing an antenna that will detect and/or identify their vehicle - this can be important for privacy reasons, and/or for compliance with requirements for transparency in sys-

tems used in law enforcement and evidence collection for providing evidence which has been collected in a lawful and non-questionable fashion, etc. The aggregate, and the "particles" that make it up, may also include an appropriate quantity or proportion of particles that are lighter coloured, or reflective, or perhaps which are reflective particularly for light in particular spectral ranges such as the infrared spectrum. These lighter and/or reflective particles are not necessarily intended simply to lighten the overall colour of the patch surface (they may also have this affect to some extent, although they also may not, depending on the way in which and the proportion in which they are incorporated in the aggregate) - rather part of the purpose of including an appropriate quantity or proportion of particles that are lighter coloured, or reflective, or reflective of radiation in certain parts of the spectrum (e.g. infrared in particular) is to help reduce heating and heat retention, and perhaps provide some degree of radiant heat reflection. Reducing heating and heat retention in the partially conductive area (and in the road material beneath it) may often be important for preventing possible heating or overheating of electronics associated and located with the antenna, given that the partially conductive area and the road material beneath it surround the antenna (in these in-road applications).

[0062] A prefabricated patch like that described above may be adhered to the road surface to form the partial conductive area in any suitable way or using any suitable technique. By way of example, such patches may be adhered using cationic emulsion or anionic emulsions.

[0063] In order for a prefabricated patch like that described above to have sufficient conductivity, a conductor or some form of conductive component or substance could be included in the mixture (along with the aggregate, etc) bound within the bitumen rubber binder. Alternatively, an aluminium alloy or other metal conducting mesh could be incorporated into (or as part of the patch) such that the said conductive metal mesh (rather than simply being applied to the road as a standalone mesh) is applied to the road as part of the patch product. As a further alternative, particulate or granular aluminium (or other metal) could actually be included in (i.e. as part of) the aggregate which is pre-coated in bitumen in the initial formation/fabrication of the patch. The patch thus produced would then potentially have the necessary conductivity, by virtue of the aluminium (or other metal) contained in and as part of the aggregate. This may also have the benefit of providing a useful option for the recycling of waste aluminium (or other metal) from other sources.

[0064] It has been mentioned that, at least (or particularly) for applications where the antenna structure is installed "in-road", it is proposed to surround the antenna structure with a partially conductive area. It has also been explained that the partially conductive area should have a certain minimum size, in order to adequately shield the antenna structure. In situations where only a single an-

tenna structure is used (e.g. installed in the road) at a given location, the antenna structure will have its own associated partially conductive area. However, there may be situations where multiple of the antenna structures are used at a given location. To help visualise this, consider Figure 4. Figure 4 actually shows a situation where only a single antenna structure is used at the depicted location - the antenna structure is mounted "in-road" in the middle of the centre lane of the road. However, in other situations, it could be that multiple of the antenna structures are used, e.g. in a line across the road. For instance, there could be situations in which there is an antenna structure mounted in-road in the centre of each lane of the road, such that the antenna structures together form a line across the road. In such situations, the multiple antenna structures need not necessarily each have their own associated partially conductive areas. Instead, a single partially conductive area could be provided and shared by some or all of the antenna structures. As one possibility, a single partially conductive area shared by all of the antenna structures (where the multiple antenna structures form a line across the road) could be provided as a wide strip extending across all lanes (i.e. across the width) of the road. In order to provide sufficient shielding for the respective antenna structures, the width of this partially conductive strip which extends across the road (i.e. the dimension of the strip in a direction parallel to the direction of travel in the road lanes) may need to be approximately 4λ or more (i.e. $\geq$ four times the wavelength of the signal used by the antenna structures). It should be noted though that, in situations where multiple of the antenna structures are used at a given location, each one (or one or more of them) could still have its own associated (and un-shared) partially conductive area. However, from a practical point of view, the time, cost, effort, etc, associated with installing or creating a separate partially conductive area around each antenna structure may be greater than for installing or creating a single larger partially conductive area (e.g. like the wide strip extending across the road mentioned above) which is shared by some or all of the antenna structures. Another possible benefit is that the said strip could be coloured, or it could have markings (e.g. edge markings extending across the road before and after the antenna structures in the vehicles' direction of travel), or it could have a different surface texture or stone/particle size or the like, etc, in order to make the strip clearly visible (or perhaps audible when driven over), which (like above) may be of use where vehicle operators need to be able to see when they are about to pass over an area/location where their vehicle will be detected and/or identified (or at least know or be alerted when this happens). Also, like above, the strip may incorporate lighter coloured or reflective particles to assist in minimising heating and heat retention, etc.

[0065] Turning now to consider the antenna structure, as has been explained, one of the proposals presented herein is an antenna structure that, in effect (and in basic

terms), inverts a conventional disk-cone antenna structure. However, it should be noted that this simple statement also oversimplifies the present invention, and in particular it oversimplifies the proposed antenna structure, because quite apart from being inverted compared to a conventional disk-cone antenna, there are also a number of other important differences between a conventional disk-cone antenna structure and the presently proposed antenna structure. Several of these other differences, including those differences discussed below, are very important.

[0066] A number of the important differences between a conventional disk-cone antenna structure and the presently proposed antenna structure (aside from the basic orientation) relate to relative sizes and proportions of different parts of the antenna structure. For instance, in a conventional disk-cone antenna, the height of the antenna (i.e. the distance in the antenna's axial direction between the disk and the widest point on the cone) is generally greater (often much greater) than the maximum diameter of the antenna (which is generally on the cone). In other words, in a conventional disk-cone antenna, antenna height $\gg$ antenna diameter. In contrast to this, in the presently proposed antenna structure, the height of the antenna (i.e. the distance in the antenna's axial direction between the disk and the widest point on the cone) is less (generally much less) than the maximum diameter of the antenna (which is on the disk - see below). That is to say, in the presently proposed antenna structure, antenna height $\ll$ antenna diameter (or equivalently, antenna diameter $\gg$ antenna height).

[0067] Furthermore, in a conventional disk-cone antenna, the diameter of the antenna's disc is generally smaller than the maximum diameter of the antenna's cone. In other words, in a conventional disk-cone antenna, cone diameter $>$ disk diameter. In contrast, in the presently proposed antenna structure, the diameter of the antenna's disc is larger than the maximum diameter of the cone (i.e. cone diameter $<$ disk diameter).

[0068] It is also important to stress that conventional disk-cone antennas are designed, and they are generally implemented, in applications where the antenna is mounted a considerable distance above the ground (above planet Earth) and transmits omnidirectionally in a broadcast manner. More specifically, traditional disk-cone antennas are invariably mounted at a height above the ground which is much greater than the wavelength (λ) of the signal being transmitted, and in fact a major purpose of the antenna's disk in disk-cone antennas designed for use in such applications is to, in essence, force or direct the antenna's radiation pattern downward towards the earth. (This last is important because of the earth's inherently low conductivity and its other radio propagation influencing properties, which tend to push the radiation pattern of an antenna upwards away from the earth, as is also explained elsewhere). Configurational differences between a conventional disk cone antenna and the presently proposed antenna structure, including

(but not limited to) those mentioned above related to relative proportions of the antenna structure, exist in no small part in order to allow the presently proposed antenna structure to operate, and to provide the required radiation pattern, when placed in, on or in very close proximity to the ground (planet Earth).

[0069] Additionally, a point which is extremely important to understand here is that, according to all conventional thinking in the field of antenna design, the very notion of placing any form of disk cone antenna (or indeed any form or variant of dipole or monopole type antenna) in, on or close to the ground goes against all conventional thinking. This simply would not be done, because according to conventional thinking, the use of this kind (or any of these kinds) of antenna in this way just would not work, given that these kinds of antennas have always been designed and intended for use, e.g. in placements far above (i.e. much more than a wavelength above) planet Earth, and for much more far field transmission distances, whereby the effect of planet Earth on radio propagation can be considered much more constant/homogeneous, etc.

[0070] The basic configuration (and in particular aspects of the shape) of an antenna structure that is in accordance with the present invention is illustrated schematically in Figure 8. It is important to note that Figure 8 does not fully depict the antenna structure - there are numerous parts and features of the proposed antenna structure which are not illustrated in Figure 8. Therefore, it is to be understood that Figure 8 is presented merely as a schematic illustration of the overall shape of the proposed antenna structure, or at least of certain important parts/portions thereof.

[0071] Figure 8 shows that the antenna structure has an overall circular-based and upwardly-tapering frusto-conical shape 10. In other words, the general/overall outer shape 10 of the antenna structure is that of a cone with a circular base, but the cone is terminated/truncated/"cut-off" well before it reaches a point/apex, and the termination/"cut-off" is in a plane parallel to the circular base.

[0072] Also, formed/indented and extending vertically downwards into the "cut-off" top of the antenna structure is a comparatively inverted circular cone shaped opening 12. The inverted cone shaped opening 12 tapers inwards from its widest point at the top down to a convergence point 14. (Hence, the convergence point 14 is the lowermost point on the inverted cone shaped opening 12.) Note that the convergence point 14 is located on or very close to the plane of circular base of the main frusto-cone 10 (in fact, in embodiments discussed below, the convergence point 14 and the plane of circular base meet, and this meeting point is the location of the antenna's feed point). Importantly, the inverted cone shaped opening 12 (and more specifically the conducting material (metal) that is provided thereon - see below) is what forms the operative "cone" of the antenna structure - i.e. this is the part of the antenna structure which corresponds gen-

erally to the cone portion in a conventional disk-cone antenna - and this "cone" is therefore one of the operative/radiating parts of the proposed antenna. Thus, the inverted cone shaped opening 12 (which in subsequent discussion will be synonymous with the conducting material actually formed or provided thereon to thus create the said cone-shaped radiating element) will hereafter be referred to simply as the "cone". (Note: in Figure 8 the cone is labelled with reference numeral 12, but in later Figures the cone of the antenna structure may have a different label.) It is to be noted from Figure 8 that the orientation of the cone 12 is inverted/upside-down relative to the orientation of the cone portion in a conventional disk cone antenna (see Figure 5 and Figure 6).

[0073] It is also to be noted in Figure 8 that, at its widest point at the top, the circular opening formed by the open top/mouth of the cone 12 is narrower than the outer diameter of the main frusto-cone shape 10 at the height of the "cut-off". Therefore, at least in Figure 8, there is a flat annular (i.e. a horizontal, flat and ring-shaped) rim 16 formed in between the outer diameter at the top of the main frusto-cone shape 10 and the edge of the circular opening formed by the open top/mouth of the cone 12. However, whilst the overall antenna structure shape is shown in Figure 8 with the rim 16, this rim 16 may not be present in the actual antenna structure. For example, there may instead be provided a slight indent or recess extending vertically down into the top of the "cut-off"/truncation in the antenna's main frusto-cone shape 10 - see 16a in Figure 14 - the slight indent or recess 16a being for receiving a lid or top plate of the antenna structure. (The lid/top plate is discussed further below.) The uppermost portion of the sloping side of the frusto-cone shape 10 may in fact provide a wall or lip surrounding the indent/recess 16a, and the said wall or lip may help to locate and retain the lid / top plate of the antenna structure (i.e. it may help to stop the lid from becoming dislodged or sliding off the top of the antenna structure). The holes 17 (again these are visible in Figure 14) may facilitate screwing or bolting the antenna's lid/top plate in place in the recess 16a.

[0074] In the embodiments of the antenna structure described in further detail below (additional details and features of which are depicted in several of the other Figures) the particular antenna structure is one that is operable with a signal of frequency 860-940 MHz, and in terms of the general overall shape and reference numbers shown in Figure 8:

- the vertical height of the antenna structure 10 is 25 mm;
- the outer diameter of the antenna structure 10 at its lowest and widest point (i.e. the diameter of its circular base) is 180 mm;
- the outer diameter of the frusto-cone at the highest/"cut-off"/truncation point (which is the outer diameter of the rim 16 in Figure 8, if present) is approximately 104-110 mm (and consequently, if a ver-

tical cross-section were to be taken through the centre of the antenna, the angle between the sloping/encompassing side of the antenna structure 10 and the plane of the base when viewed in said cross section would be around 33°-36°); and

- the inner diameter of the rim 16 (again, if present) is approximately 80 mm

[0075] It may be useful to note that, the height of 25 mm (or a height not exceeding 25 mm) above the road surface, is one that is commonly approved in the regulations/standards governing on-road and road-surface devices in most jurisdictions. Thus, for example, in most countries/jurisdictions, the allowable height for devices like e.g. conventional retro-reflective "cat eyes" and the like, is typically up to 25 mm. These regulations/standards typically also require, particularly for devices like "cat eyes" and the like, that the sides of such devices should be at an angle of elevation of no more than 45° to the plane of the road surface. This requirement (along with the above-mentioned 25 mm height restriction) is to allow the wheels of cars and other road going vehicles to roll over the said devices without an undue jolt or impact. Furthermore, these regulations/standards typically allow for the maximum diameter of such on-road or road-surface devices to be no more than 190 mm (i.e. 190 mm or less). It will be noted that the dimensions and shape parameters of the antenna structure as listed in the previous paragraph conform to these requirements. The significance of the fact that the antenna structure *both* conforms to these requirements *and that it is also operable* to provide the radiation pattern discussed herein (i.e. the significance of the fact that it can and does achieve both) will be readily appreciated by those skilled in the field of antenna design and it should not be underestimated.

[0076] It is explained above that the cone 12 depicted in Figure 8 is the part of the antenna structure which corresponds generally to the cone portion in a conventional disk-cone antenna. The proposed antenna structure also has a disk portion/component (again this is a functional/radiating part of the antenna) which corresponds generally to the disk portion in a conventional disk-cone antenna. However, the disk portion/component in the proposed antenna structure is not depicted in Figure 8. It is depicted, though, in several of the other Figures which show that the disk portion/component is a flat circular disk of conductive material (typically metal) having a diameter the same as, and located immediately beneath, the bottom of the main frusto-cone 10. In fact, the disk portion/component will generally be applied or attached to the underside of the main frusto-cone 10.

[0077] It should also be noted that, in situations where the proposed antenna structure is surrounded by a partially conductive area (typically this will be where the antenna structure is installed/deployed in in-road applications), the partially conductive area that surrounds the antenna structure, even though this need not necessarily be in direct contact with any part of the antenna structure,

nevertheless functions "in effect" as something of an extension of the antenna structure's actual disk portion/component. In other words, the partially conductive area (even though it is not necessarily connected to the antenna structure) functions as an extension of the antenna structure's disk portion/component in terms of the influence it has on the antenna's overall radiation pattern.

[0078] It has been mentioned that the cone 12, and also the disk portion/component, of the antenna structure are made from a conductive material (typically, although not necessarily or exclusively, metal - see below). However, the main frusto-cone shape 10 of the antenna structure, which may be referred to as the antenna structure's main frusto-cone body 10, is itself made from a strong/structural dielectric material. The material which is thought most likely to be used for this is glass (and there are many different forms or types of glass that may be suitable), although other strong or structural and dielectric materials could also be used. Glass does have the benefit, though, of being transparent, translucent or at least somewhat permissive to penetration by light, which can have advantages - see below. Preferably, the glass or other strong/structural and dielectric material should have a relative permittivity (or dielectric constant) of between approximately 3 and approximate 6. As possible alternatives to glass, other materials which might be used for making the frusto-cone body 10 include, for example, concrete, certain strong/structural/engineering polymers such as nylons and Teflons, certain alumina (although these may not have the benefit of being transparent or otherwise permissive to penetration by light, at least not to the same extent as glass).

[0079] As explained above, the cone 12 and the disk portion/component are functional/radiating parts of the antenna structure. The glass or other strong/structural and dielectric material from which the antenna structure's main frusto-cone body 10 is made (and hence the frusto-cone body 10 itself) is not a radiating part of the antenna; however the main frusto-cone body 10 is still very much a functional part of the antenna because its form, material and associated RF properties (in other words its size, shape, configuration, material and dielectric properties, etc.) significantly affect the radiation pattern of the antenna and specifically contribute to (or assist in) forming the radiation pattern with the desired "dropped doughnut" shape. Therefore, design choices in relation to the size, shape, configuration, dielectric and other material properties, and other aspects of the design of the antenna structure's main frusto-cone body 10 have been made with great care and attention, because (again) even though this body 10 is not a radiating part of the antenna, it is still an important functional part of the antenna because any changes to its design (even slight changes) would (or could) significantly affect the antenna's radiation pattern (and in particular the shape thereof).

[0080] In addition to being functional in the sense of being influential on the overall radiation pattern of the antenna, the main frusto-cone body 10 of the antenna

structure is also functional in the sense of being structural - that is, it is one of the primary components which provides the physical supporting structure of the antenna (and gives it its physical strength). This can be understood quite simply. As has been mentioned, components such as the cone 12 are made from a conductive material (typically metal). In fact, the cone, for example, will generally be made from a thin layer or film of metal, perhaps less than a millimetre or only a fraction of a millimetre in thickness. The cone is also elevated relative to (i.e. it is located vertically above) the antenna's disk (and also relative to the surface of the ground/road in an in-road installation for example). Naturally, thin layers or films of metal such as this, especially if elevated/upstanding and unsupported in "free space", can be very flexibly and flimsy. It should also be recognised that, by simple virtue of its location in its intended (especially in-road) application, the proposed antenna structure may often be directly run over by vehicles travelling along the road in/on which the antenna is installed. Clearly, it is essential for the antenna structure to be able to withstand such forces and impacts repeatedly and over a long period of time without damage or affect on the antenna's functioning or performance. It is therefore also equally clear there needs to be something to prevent any otherwise thin/flimsy pieces or layers or films of metal that make up or are comprised in the antenna structure (in particular the cone 12) from simply being crushed/flattened and completely destroyed by such vehicle impacts. It is this function that the main frusto-cone body 10 of the antenna structure helps to provide. In other words, the main frusto-cone body 10 provides a physical structure which not only can withstand such vehicle impacts itself, but it also provides a supporting foundation for other parts of the antenna such as the cone, etc, which themselves could not withstand such impacts but which can withstand such impacts when mounted or formed on (and hence supported on or by) the main frusto-cone body 10.

[0081] An actual antenna structure in accordance with one embodiment of the invention, and an RFID reader 100 of which the antenna structure forms part, will now be discussed in further detail initially with reference to Figure 9. An annotated version of Figure 9 is also given as Figure 10; however for convenience reference will be made to Figure 9 only.

[0082] It is to be noted firstly that Figure 9 is a view of an RFID reader 100 which incorporates the proposed antenna structure as well as other RFID reader equipment. It should also be noted from the outset that Figure 9 depicts a situation where the RFID reader 100 is installed in an "in-road" installation. In other words, at least some parts of the RFID reader 100, and other associated equipment, are located at or below the level of the road surface RS, whereas other parts are located above the level of the road surface RS. And as will be readily appreciated, Figure 9 is a side-on cross-sectional view, and hence parts of the RFID reader 100 as well as other associated equipment which are located both above and

below the level of the road surface RS can be seen.

[0083] As just mentioned, the RFID reader 100 in Figure 9 is installed in an "in-road" installation. In fact, prior to the installation of the RFID reader 100 in the road, an appropriately-shaped recess/hole/cavity (hereafter the "cavity" 110) must first be first dug, cut, bored or otherwise formed in the road, in order to receive the RFID reader 100 and the associated parts and equipment therein. In fact, there are several distinct portions of the cavity 110, each for receiving and accommodating different parts of the RFID reader 100. The first/main portion of the cavity 110 is labelled 111 in Figure 9. This main portion of the cavity is circular/cylindrical and, at least in this particular embodiment, is approximately 120-125 mm wide, and approximately 30-35 mm deep (i.e. it extends approximately 30-35 mm vertically down below the road surface RS). The main portion 111 of the cavity 110 is sized and shaped to receive a cylindrical "cup"-like container component 160 which is made of metal or other heat-conductive material and to which other parts of the RFID reader 100 attach, as discussed below. At/near the top of the main portion 111 of the cavity 110, and in fact extending around the outer perimeter of the main portion 111, there is a wider but shallower second portion 112 of the cavity 110. In other words, the second portion 112 of the cavity extends vertically much more shallowly into and below the road surface RS than the main portion 111 (typically the second portion 112 will be only a few millimetres deep), although the diameter of the second portion 112 (typically approximately 180 mm) is considerably greater/wider than that of the first portion 110. The second portion 112 of the cavity receives the outer/perimeter portion of the RFID reader 100; in particular the underside of the base plate 140 (the base plate 140 is discussed below). And finally, optionally, in the bottom of the main portion 111, typically at or near the centre thereof, a third portion 113 of the cavity 110, which in this particular embodiment is in the form of a bore or shaft, extends vertically downwards considerably more deeply than any other part of the cavity 110. This optional bore/shaft portion 113 (if provided) should be shaped to receive a heat sink 105. In the embodiment depicted in Figure 9, the (optional) heat sink 105 happens to be an elongate (and vertically-oriented) cylindrical rod, made of metal or some other heat-conductive material, which is ≥ 50 mm long and about 12 mm in diameter. Of course, the heat sink (and the portion 113 of the cavity in which it is received) could take a range of other shapes and sizes. Figure 15 provides an example of an alternative embodiment with a much larger heat sink 205 designed for dissipating much larger amounts of heat, as compared with the embodiment in Figure 9. The larger heat sink 205 in Figure 15 is actually (again) outwardly cylindrical, but it also has a rectangular-box/prism-shaped hollow interior, as indicated in Section H-H in Figure 15. The said interior may be used for housing electronic parts and equipment associated with the RFID reader in that embodiment - see below. In any event, the size and shape of the heat sink

may vary depending on the heat dissipation requirements in a given application (e.g. some RFID readers may generate more heat than others, depending on the equipment or amount of power used in the RFID reader, or depending on the equipment's thermal efficiency, and heat sink size and dissipation requirements may also vary according to how warm the ground and ambient environment is, and how much sun exposure there is at the location in question, etc.)

[0084] In Figure 9, the heat sink 105 is attached, mounted or otherwise secured to the underside of the container 160 (there is actually a recess in the underside of the container 160 into which the top of the heat sink 105 is received - screwed in this case). The function of the heat sink 105 (and likewise the heat sink 205) is to receive heat generated by the RFID reader electronics and which is conducted into the heat sink 105 (e.g. from the RFID reader and its electronics and, in the case of Figure 9, via the metal container 160) and to dissipate said heat into the soil/road base surrounding the heat sink. Dissipating heat in this way may often be important as it may help to prevent overheating within the RFID reader (i.e. overheating which might otherwise damage or at least interfere with the proper operation of the RFID reader electronics, etc).

[0085] It should also be noted that, after the cavity 110 (including its various portions - see above) have been formed, but before the container 160 and the heat sink 105 are inserted (and also before the rest of the RFID reader 100 is subsequently attached to the container 160), an adhesive 108 is first applied to at least the walls/surfaces of the various portions of the cavity 110. Once the adhesive 108 has been applied at least to the walls/surfaces of the cavity 110, the container 160 and the heat sink 105 are then inserted so that when the adhesive 108 sets, the container 160 and the heat sink 105 thereby become adhered and secured in their respective portions (111 and 113) of the cavity. Typically the other parts of the RFID reader 100 will also be attached to (screwed into) the container 160 (see below) before the adhesives sets, so that the underside of the base plate 140 also becomes adhered to and secured in the second portion 112 of the cavity (i.e. the other parts of the RFID reader also become secured in place by the adhesive when it sets). Thus, in Figure 9, the adhesive 108 entirely (or at least mostly) fills the space between the walls of the cavity and the various parts of the RFID reader. (In other words, the adhesive 108 fills the space beneath the base plate 140 in the portion 112 of the cavity, the adhesive 108 also fills the space between the outside of the container 160 and the wall and floor of the cavity in the main portion 111 of the cavity, and the adhesive 108 further fills the space between the outer surface of the heat sink 105 and the walls and floor of the cavity in the portion 113.) Preferably, the adhesive 108 should be one that conducts heat well (to assist in heat dissipation), and it should also be one that is sufficiently strong to adequately secure the various parts of the RFID reader (see

above) and prevent them from being easily dislodged, etc, but at the same time it should (preferably) not be so strong as to inhibit or prevent removal and/or replacement of the RFID reader (or parts thereof, e.g. the container or the heat sink) in case this proves necessary for any reason. Also, the adhesive 108, which may be up to a few millimetres thick, may have or provide some inherent flexibility or resilience, and this may in turn provide at least some degree of shock absorbency for when the RFID reader is secured thereby and vehicles drive directly over the top of the antenna structure. By way of example, certain commercial silicon (or silicon-based) and bitumen (or bitumen-based) adhesives may be suitable for use as the adhesive.

[0086] As a possible (non-illustrated) variant to the above (and this may apply to other embodiments discussed below as well), it is possible that different adhesives may be used at different locations. For example, an adhesive which is comparatively weak but also highly effective at heat transfer (i.e. an adhesive which conducts heat well) may be used in the portions 111 and 113, such that heat from the container 160 and from the heat sink 105 is effectively dissipated, yet removal of these sub-road-surface components (if necessary for maintenance or repair etc) is not impeded or made more difficult by an overly strong adhesive bond. At the same time though, a different adhesive with a much greater bond strength may be used, for example, in the portion 112 which secures the underside of the antenna structure in the surface of the road.

[0087] Also depicted in Figure 9 is the partially conductive area (discussed above) which, at least in "in-road" deployments, is applied directly to the road surface RS and surrounds the RFID reader 100. In Figure 9, the partially conductive area is indicated by reference numeral 90. Importantly, in the cross-sectional view in Figure 9, the two sides of the Figure are cut off and therefore the full width of the partially conductive area 90 is not necessarily illustrated. In other words, the partially conductive area 90 may (and it typically will) extend further outward away from the RFID reader 100 than is depicted in Figure 9. The partially conductive area 90 may be applied to or otherwise formed on the road surface either before or after the RFID reader 100 and its associated equipment are installed (and secured by adhesive) in the cavity 110. In fact, the partially conductive area 90 may even be applied/formed before the cavity 110 itself is created. However, it may often be the case that at least the location where the cavity 110 will be created must be previously-determined (and typically marked) before the partially-conductive area 90 is formed on the road, so that the partially conductive area can be correctly positioned relative to the cavity 110 (into which the RFID reader 100 will be installed) in order to provide adequate shielding to the RFID reader 100 when (and in the location in which) it is subsequently installed.

[0088] In Figure 9, the main frusto-cone body of the RFID reader (recall that this is also a functional part of

the antenna structure) is made of glass. Preferably, the glass used is a form of soda lime glass.

[0089] The antenna structure's cone is labelled with reference number 120 in Figure 9. In the embodiment depicted in Figure 9, the cone 120 is preferably formed as a thin layer (less than or a millimetre or even only a fraction of a millimetre thick) of metal such as e.g. copper, silver or an appropriate conductive alloy thereof (other metals or indeed other conductive materials might also be used). The thin metal (or conductive material) layer which forms the cone 120 may be formed on or applied to the glass body in any suitable way, although it is thought that one (if not the most) appropriate means for achieving this, where the conductive material used is metal, may be by plating the metal that forms the cone 120 directly onto the inverted cone shape in the top of the glass body.

[0090] When the antenna structure is in its installed configuration, as shown for example in Figure 9 (Figure 9 being an in-road installation although the same also applies in and on-road installation), the main frusto-cone body, which is made of glass, effectively sits directly on top of the antenna structure's disc portion/component, which takes the form of a base plate 140. Like the cone 120, the base plate 140 is preferably formed of metal such as e.g. copper, silver or an appropriate conductive alloy thereof (other metals or indeed other conductive materials might also be used). The baseplate will, however, typically be relatively thick (compared to other radiating/metal parts of the antenna structure), for example, with a thickness of 5-10 mm. The metal plate which forms the base plate 140 may be applied or connected to the underside of the glass body in any suitable way. In one appropriate means for achieving this, the base plate 140 could be formed initially separately from the glass body and then affixed thereon (e.g. using an adhesive, or some form of mechanical fastening, etc).

[0091] In addition to being a functional radiating component of the antenna, the base plate 140 is also functional in the sense of being structural - that is, it is another of the primary components which provides the physical supporting structure of the antenna (and gives it its physical strength). More specifically, and especially where the base plate 140 is formed as a solid metal plate which is 5-10 mm thick, the baseplate 140 provides a rigid/solid base for the glass frusto-cone body. And because the glass frusto-cone body sits directly on top of the base plate 140, the base plate 140 effectively "underpins" the frusto-cone body (i.e. it supports it from underneath) and thereby prevents the glass body from e.g. unduly deforming or cracking, etc, when a vehicle drives over it.

[0092] In addition, the base plate 140 also incorporates, or it has attached thereto, a mounting block (hereafter the "screw mount") 150. The screw mount 150 projects out relative to the plane of the base plate 140 in the opposite direction to the direction in which the glass frusto-cone body extends from the base plate. Thus, in the installed configuration shown in Figure 9, where the

glass frusto-cone sits on top of and effectively points upwards relative to the base plate 140, the screw mount 150 consequently projects vertically downwards from the underside of the base plate 140. The distance by which the screw mount 150 projects out (downward) from the underside of the base plate 140 will typically be around 5 mm-15 mm. The outer diameter of the screw mount 150 is smaller than the diameter of the base plate 140, and indeed the outer diameter of the screw mount 150 is approximately the same as the internal diameter of the wall of the cylindrical cup-shaped container 160. In fact, in embodiments like the one depicted in Figure 9, the outer (vertical) cylindrical wall of the screw mount 150 is threaded, and at least the upper portion on the inside of the wall of the cup-shaped container 160 is also correspondingly threaded. Accordingly, after the adhesive 108 has been applied into the cavity 110, and the container 160 and heat sink 105 have been inserted into the cavity, etc., the way in which the antenna structure is attached to the container 160 (the antenna structure being the baseplate 140, the frusto-cone body, the screw mount 150, etc., all of which are already assembled together) is that the said antenna structure is positioned on top of the container 160 and turned so that the screw mount 150 screws into the threaded portion at the top of the container 160. The antenna structure is then "screwed down" sufficiently that the outer perimeter portion on the underside of the base plate 140 becomes received in (and pressed into and secured by) the adhesive 108 which is in the second portion 112 of the cavity, as shown in Figure 9.

[0093] The various dimensions of the antenna structure (i.e. the antenna structure which is incorporated in or as part of the RFID reader 100, as just described) in Figure 9 generally correspond to those dimensions described above with reference to Figure 8. For instance, the diameter of the cone 120 is approximately 104 mm, and the height of the cone 120 is 25 mm or less. Also, the base plate (disc) has an outer diameter of approximately 180 mm. However, it is very important to understand that these dimensions (and this applies equally to the explanations and dimensions given above with reference to Figure 8 and to other embodiments of the invention as well) are all given by way of illustrative example only. These particular dimensions apply to an antenna structure (which is incorporated in or as part of the RFID reader 100) that is tuned to operate with a specific signal frequency (approximately 860-940 MHz), as well as with an appropriate partially conductive area/structure and dielectric structure (the main frusto-conical body). It is to be clearly understood that the size, shape, dimensions, etc., of the various parts of the antenna structure (or at least of some of them) would change, for example, for antennas designed to operate at different signal frequencies. Furthermore, as will be readily understood by those skilled in the field of antenna design, the antenna's various dimensions, and also the shape, material used, material thickness, material properties and other such

parameters of the antenna and its various parts, may all be varied for the purpose of tuning the antenna to achieve the required radiation pattern based on the signal frequency used and other use case requirements.

[0094] Next it should be noted from Figure 9 that, even when the screw mount 150 is screwed fully into the container 160 (such that the base plate 140 is received in the portion 112 of the cavity just below road level RS), there is still a remaining vertical space/gap 155 inside the container 160 in between the underside of the screw mount 150 and the internal base of the container 160. Items or pieces of electronic equipment associated with the RFID reader 100 (or some of them) may be mounted in (i.e. they may reside in) the said gap 155.

[0095] It should also be noted from Figure 9 that the gap 155 is not the only opening or space where electronic components can be accommodated. There is also space for mounting certain components in the space between the upper surface of cone 120 and beneath the RFID reader's "top plate" or "lid" 130. The space below the lid 130 but above the upper surface of the cone 120 is labelled with reference number 135 in Figure 9. The lid 130, in fact, provides a protective covering or barrier over the top of any electronic components that may be located in space 135 (i.e. to prevent them from exposure to the elements or damage from vehicles rolling over the top of the reader, etc). The space 135 may be a particularly useful location in which to house sensors such as, for example sensors for detecting or measuring sound, gas, etc. Other electronic components which might be (or might also be) housed within the space 135 include equipment for providing conventional radar or imaging functions, and equipment for enabling other forms of wireless connectivity (e.g. a Wi-Fi or Bluetooth connection to facilitate such communication between electronic equipment located inside the RFID reader and remote computers or devices). The space 135 could further incorporate, or it may be used to house, a vibration sensor. A vibration sensor could be particularly useful, for example, because sensing vibrations as vehicles pass can be used to determine an "axle count" and/or axle spacing of passing vehicles (e.g. this can in turn enable, even without the use of RFID, the determination of whether the passing vehicle is e.g. a car, or a truck, or a multiply-articulated road train, and this kind of thing can further in turn be useful for monitoring and managing the integrity of the road surface, determining the need for or scheduling maintenance, traffic management, etc).

[0096] It is also discussed elsewhere herein that RFID readers, and this includes readers incorporating the presently-proposed antenna structure, may be used to provide not only "two-way" data exchange but also "one-way" (or RADAR-like) data exchange. It is further explained elsewhere that "one-way" data exchange in particular, may be useful for the purposes of vehicle detection. The presently-proposed RFID reader may make use of this, in particular, because the amount of power required for two-way communication can be much more

than for one-way communication. Accordingly, vehicle detection achieved using "one-way" data exchange could be used, for example, to help minimise power consumption by enabling the RFID reader to operate normally in the lower-powered one-way communication mode, and then only switch to the higher-power two-way communication mode (by switching on the RF communication equipment required for this) when a vehicle is actually detected by a one-way data exchange occurrence, and hence only when the need for actual/positive vehicle identification is required. (The duty cycle in the RFID reader equipment will preferably be such that the high power RF communication equipment required for two-way data exchange can be turned on in a matter of milliseconds, so even if a vehicle is only detected when it is, say, 6 m from the antenna, the time delay in switching on the high power RF equipment should not prevent proper vehicle identification via RFID ("two-way" data exchange), especially if the vehicle is moving at normal road speeds.) In addition to saving power, only using the higher power level required for two-way communication when necessary may also significantly help to reduce heat generation and the risk of overheating in the RFID reader.

[0097] As has been mentioned previously, in the embodiment depicted in Figure 9, the antenna structure (when it is screwed onto the container, etc, as discussed above) is incorporated in and as part of the RFID reader 100. For instance, in the RFID reader 100, the cone 120 is the antenna's "cone" (i.e. it is the radiating part which corresponds approximately to the cone of a traditional disk cone antenna), and similarly the base plate 140 is the antenna's "disk" (i.e. it is the radiating part which corresponds approximately to the disc of a traditional disk cone antenna). The feed point of the antenna is actually at the meeting point where the tip/apex of the cone 120 meets the base plate (the disc) 140.

[0098] It has also been mentioned that the antenna's main glass frusto-cone body is not a radiating part of the antenna structure; however the main frusto-cone body is still very much a functional part of the antenna because its form, material and associated RF properties (in other words its size, shape, configuration, material and dielectric properties, etc,) significantly affect the radiation pattern of the antenna, and specifically contribute to (or assist in) forming the radiation pattern with the desired "dropped doughnut" shape. It has further been mentioned that the choice of glass (including or particularly soda lime glass) as the strong and dielectric material from which the main frusto-cone body is made may have the additional benefit of being transparent or translucent or at least somewhat permissive to penetration by light. The reason this may be beneficial is because, included among other electronic parts or components provided in or as part of the RFID reader 100 (e.g. provided in or extending through the disk/base plate 140), there may be one or more components that incorporate lights, LEDs or the like and which, when illuminated, are visible from

outside the RFID reader 100 and even from a distance away from the RFID reader (especially at night or in low light conditions). Such lights or LEDs could be used, for example, to provide indications as to the current operational status of the RFID reader 100 or individual parts or functions of it. For instance, as a simple example, a red light/LED could be provided which "turns on" in situations where there is a fault or malfunction or warning associated with the operation of the RFID reader (e.g. where there is a component malfunction, or a power supply failure or disruption, or an "almost empty" battery or backup battery, etc). However, such lights, LEDs or the like which may be contained within (but visible from without) the RFID reader 100 might also be used for a range of other purposes. For example, because the RFID reader 100 in these "in-road" applications is positioned in the surface of the road (i.e. in the surface on which vehicles are travelling and to which the vehicle's drivers are paying close attention), LEDs or lights in the RFID reader may also be used to provide various forms of signalling to vehicles. For example red and green lights could be used for indicating lanes that are open or closed for vehicle travel, or for indicating the permitted direction of travel in a lane (this last might be useful e.g. in places which implement "tidal flow" traffic management which facilitates vehicular travel, within a given lane, in different directions at different times of day, to help accommodate large volumes of traffic flow in one direction or other at different times of day). There could also be other possible uses, for example a flashing light could be used to provide a warning to road users of an upcoming incident or danger further down the road. Or, red, yellow and green signals could be provided in an RFID reader located just before an intersection with traffic lights, and the red, yellow or green lights in the RFID reader could be changed instantaneously/simultaneously and correspondingly with the change in signal at the traffic lights. The illumination of, or light signals emitted from, any lights or LEDs inside the RFID reader could also be visible and detectable to cameras or other imaging devices, for example those located at the side of the road and used for law enforcement or traffic management purposes. It will be appreciated that the possible uses mentioned above for lights, LEDs or the like which may be provided in or as part of the RFID reader are merely examples, and there may be many other uses or applications for this.

[0099] Figure 9 also shows that the RFID reader incorporates a number of tuning screws/struts 190. These tuning screws 190 may help to further support or strengthen the overall structure of the antenna. Furthermore, where tuning screws 190 are present, the number, arrangement, angle, length, thickness, points of contact with antenna radiating elements, etc, of the screws are selected or varied in order to tune the antenna. In other words, the configuration and design of the tuning screws 190 plays a role in the overall tuning of the antenna to achieve the desired radiation pattern. It should also be noted that, in the embodiment in Figure 9 for example, the tuning

screws 190 extend through the glass of the frusto-cone cone body and "screw into" the metal base plate 140. It is therefore possible that tightening or loosening the tuning screws 190, or tightening or loosening one or some of them more or less than others, to thereby slightly (even if only minutely) change/distort the shape of the antenna structure by compressing some parts more than others may also be used to perform fine tuning of the antenna, for example final fine tuning at the time of installation.

[0100] The antenna screws 190 may be hollow, and they may therefore also provide one or more conduits for cables, wires or the like extending between electronic parts and equipment located in the space 155 beneath the screw mount 150 and electronic parts and equipment located in the space 135 above the cone 120 below the lid 130. Holes in the antenna structure's main frusto-cone body, which receive the tuning screws 190 and allow them to pass through the frusto-cone body, are labelled 192 in Figure 14.

[0101] Turning now to Figure 15, this Figure depicts an RFID reader 200 in accordance with a generally similar but slightly different/varying embodiment compared to the embodiment depicted in Figure 9. An annotated version of Figure 15 is also given as Figure 16; however for convenience reference will be made to Figure 15 only. Furthermore, parts, features, and aspects of the design of the RFID reader 200 (and the antenna structure it incorporates) in Figure 15 which are the same or equivalent to corresponding parts, features, etc., of the RFID reader 100 (and its antenna structure) in Figure 9 will not be described. Therefore, the embodiment in Figure 15 will be described mainly only insofar as it differs in material or notable ways from the embodiment in Figure 9.

[0102] One aspect of the design of the RFID reader 200 in Figure 15 that differs from the embodiment in Figure 9 is that the underside of the base plate 240 is provided with a number of downwardly-depending ground-engaging portions 241. These ground-engaging portions 241 could be provided as a number of discrete "legs" extending down from the main base plate 240 at different radii and different locations around the base plate. Alternatively, these ground-engaging portions 241 could be provided as concentric rings of different radii extending around (and depending downward from) the main base plate 240. However, if the ground engaging portions 241 are provided as concentric rings, the rings may also need to incorporate a number or series of holes or spaces to allow the adhesive 108 to squeeze through and into the spaces between the rings, so that the adhesive can become properly dispersed and distributed beneath the base plate 240 when the RFID reader 200 is pressed down into the adhesive upon installation.

[0103] As shown in Figure 15, one of the ground-engaging rings 241 (or this could equally be a number of ground-engaging legs extending around beneath the base plate 240 at the appropriate radius) is positioned directly beneath the thickest portion of the glass frusto-cone. The reason for locating one (or a series) of ground-

engaging portions directly beneath the thickest portion of the glass frusto-cone is because, when a vehicle drives directly over the antenna structure, and especially when the tire is directly on top of the antenna structure, the vehicle's tires will contact (and hence pressure from the weight of the vehicle will press directly down from) the points which are the highest points on the antenna structure. Therefore, placing one (or a series) of ground-engaging portions directly beneath the highest point on the antenna structure may help to bear this weight most effectively, and prevent damage to the antenna structure, or even flexure of the antenna structure which whilst not necessarily damaging may nevertheless affect the antenna's radiation pattern while the shape of the antenna is distorted.

[0104] As also shown in Figure 15, another of the ground-engaging rings 241 (or this could again equally be a number of ground-engaging legs extending around beneath the base plate 240) is positioned directly beneath the outermost circumference of the base plate 240. This may help to prevent the outermost portions of the antenna structure from being pressed down or deflected relative to the more central parts thereof. In addition to providing support for the antenna structure (e.g. when it is loaded by the weight of a vehicle, etc., as just described), the ground-engaging portions 241 also help to correctly position the base plate of the antenna in the vertical direction - specifically by ensuring that the plane of the base plate (or the plane of its upper surface) sits vertically in line with (or in the plane of) the road surface and/or the semiconductive area on the road surface.

[0105] Another aspect of the design of the RFID reader 200 in Figure 15 that differs from the embodiment in Figure 9 is that, instead of having a screw mount (like the screw mount 150) that screws into a container (like the container 160), the RFID reader 200 in Figure 15 instead has a vibration/shock absorber/buffer 260 near the centre on the underside of the base plate 240, and it is this vibration buffer 260 that screws directly into an internally threaded portion on the top of the heat sink 205. As mentioned above, the heat sink 205 in Figure 15 is much larger than the heat sink 105 in Figure 9 and it is designed for dissipating much larger amounts of heat. As also mentioned above, the large heat sink 205 in Figure 15 is outwardly cylindrical and it has a rectangular-box/prism-shaped hollow interior, as indicated in Section H-H in Figure 15. This hollow interior may be used for housing electronic parts and equipment associated with the RFID reader.

[0106] One or more vertical bores or shafts may be provided, extending between the space above the cone and the space below the antenna, in order to provide a conduit for cabling, wiring, etc., running between electronics mounted in the respective spaces. In Figure 15 (and in Figure 9 too), one bore is actually shown extending vertically down from the point where the cone meets the base plate into the space below the antenna (in Figure 15 the latter space is the space inside the heatsink and

in Figure 9 it is the space inside the container). However, as those skilled in the field of antenna design will readily appreciate, the particular central bore depicted in both of these Figures is aligned with the central feed point of the antenna, and in order to achieve the required antenna impedance (which may be e.g. 50 Ω and in which case the diameter of the said depicted central bore should be at least approx. 1 mm), this particular central bore which is depicted in Figure 15 and Figure 9 must remain open/empty (i.e. it cannot be used as a conduit for cabling, etc). However, other bores could be provided at other off-axis locations which could be used as conduits.

[0107] In terms of powering the antenna (and the other electronic components incorporated in or associated with the RFID reader) - and this applies to the embodiments in both Figure 9 and Figure 15 as well as other possible embodiments/variants used in "in-road" applications - this may be done in any manner of ways. For example, by using an induction loop, or by connecting one or more current (power) carrying cables directly to the RFID reader structure. Such current (power) carrying cables could be installed in shallow slots or trenches formed in the road (e.g. cut/dug in the road and then covered over after the cable has been laid). Figure 15 shows, as an example, the way such a power cable 270 could extend underneath the antenna and into the space inside the heat-sink (where the powered electronics are located).

[0108] Also, communication and data transfer between the RFID reader and other computers or devices which are separate or external from the RFID reader may be achieved, and again, this may be done in any suitable way. Due to the rugged environment and the permanent (or at least semi-permanent) nature of the installation in "in-road" applications, simply connecting a cable (like an ethernet cable or the like) may often not be suitable for achieving data transfer. However, other conventional wireless communication methods (e.g. Wi-Fi, Bluetooth, etc) may be used, or if the RFID reader is powered by a power cable then conventional "data over power" methods may also be used for communicating. Where a wireless communication method is used, e.g. Wi-Fi or Bluetooth, an additional antenna may be required to support this. Such an antenna could be incorporated inside the cone of the RFID reader, or possibly even in the lid of the RFID reader itself (e.g. if the additional antenna used for Wi-Fi or the like were to be a simple slot antenna formed as a slot in the lid).

[0109] Turning now to Figure 17 and Figure 18, these Figures depict (in partly-exploded and assembled form, respectively) an RFID reader 300 in accordance with another embodiment that is generally similar but slightly different/varying compared to the embodiments depicted in Figure 9 and Figure 15. Actually, the embodiment in Figure 17 and Figure 18 is somewhat similar to the embodiment in Figure 15, for example in that it incorporates a large hollow sub-road heatsink 305 inside which much of the RFID reader's electronics are housed, etc. Figure 17 and Figure 18 are perhaps slightly more pictorial (and

less schematic) than Figure 9 and Figure 15, and e.g. more of the electronics etc housed inside the heatsink 305 are actually shown. Nevertheless, once again, parts, features, and aspects of the design of the RFID reader 300 (and the antenna structure it incorporates) in Figure 17 and Figure 18 which are the same or equivalent to corresponding parts, features, etc, of the RFID reader (and its antenna structure) in Figure 9 and Figure 15 generally will not be described. Where such features are described or referred to, they will be given like labelling (e.g. the antenna's base plate, which is labelled 140 in Figure 9, is labelled 240 in Figure 15 and 340 in Figure 17 and Figure 18). Also, whilst Figure 17 and Figure 18 depict (to some extent) the electronics housed inside the heat-sink 305, a detailed explanation of these electronics, including in relation to the constituent parts/components, their layout, their interconnection and their operation, etc, is not necessary for present purposes.

[0110] Another aspect of the design of the RFID reader 300 in Figure 17 and Figure 18 that is quite similar to the embodiment in Figure 15 is that the RFID reader 300 has a vibration absorber (shock buffer) 360. However, unlike Figure 15 where the vibration absorber 260 screws into an internally threaded portion on the top of the heat sink 205, in Figure 17 and Figure 18, interposed between the vibration absorber 360 and the antenna structure there is an upper spacer component 362, and interposed between the vibration absorber 360 and the heatsink 305 there is a lower spacer component 364.

[0111] As best shown in Figure 17, the vibration absorber 360 itself has three portions, namely an upper portion 361, a lower portion 363 and a divider portion 365. The upper portion 361 and lower portion 363 are both cylindrical and both have the same outer diameter (which is smaller than the outer diameter of the heatsink 305). The vertical thickness of the upper portion 361 is greater than the vertical thickness of the lower portion 363. The divider portion 365 is vertically between the upper portion 361 and the lower portion 363, and the outer diameter of the divider portion 365 is greater - the divider portion has an outer diameter approximately equal to the outer diameter of the heatsink 305. The divider portion 365 therefore forms, in effect, a thick ring extending circumferentially (horizontally) around the vibration absorber 360 between the upper and lower portions.

[0112] The upper spacer component 362 is shaped as a cylindrical/annular ring. It's outer cylindrical surface matches the size and shape (i.e. the outer diameter) of the outer surface of the heatsink 305. The internal surface of the upper spacer component 362, which is also cylindrical and parallel to its outer surface, has a smaller diameter. The internal diameter of the upper spacer component 362 is actually equal to (or very slightly larger than) the outer diameter on the upper cylindrical portion 361 of the vibration absorber. The vertical thickness of the upper spacer component 362 is also equal to the vertical thickness of the vibration absorber's upper por-

tion 361. Therefore, when the RFID reader 300 is assembled, as shown e.g. in Figure 18, the upper spacer 362 effectively sits on top of the vibration absorber's divider portion 365, and the upper spacer 362 extends around the circumference of the vibration absorber's upper portion 361. Thus, when the RFID reader 300 is assembled, the annular upper horizontal surface of the upper spacer component 362 contacts the underside of the antenna's base plate 340, but the upper surface on the vibration absorber's upper portion 361 also engages directly against the underside of the antenna's base plate 340.

[0113] Unlike the upper spacer component 362, the lower spacer component 364 is not really cylindrical/annular. Rather, the lower spacer component 364 is shaped more like a flat circular disc, although it does have a wide shallow recess formed/indented into its upper horizontal surface, and there is also a narrow, axially-located through-bore extending through its full vertical thickness. The shallow recess in the upper horizontal surface of the lower spacer component 364 is actually the same size and shape as (or very slightly larger than) the shape of the vibration absorber's lower portion 363. Therefore, when the RFID reader 300 is assembled as shown e.g. in Figure 18, the vibration absorber 360 effectively sits directly on top of the lower spacer component 364, and the lower portion 363 of the vibration absorber inserts into and fits snugly within the shallow recess in the upper horizontal surface of the lower spacer component 364. At the same time, the underside of the vibration absorber's divider 365 rests directly on top of the annular rim that surrounds the recess on the upper surface of the lower spacer component 364.

[0114] When the RFID reader 300 is assembled as shown in Figure 18 and actually installed, the heatsink 305 (along with the electronics housed therein) will already be inserted into the accommodating cavity below the surface of the road, and in fact the heatsink 305 will be relatively fixedly secured within the said sub-road cavity. Thereafter, the lower spacer component 364, the vibration absorber 360, the upper spacer component 362 and the antenna structure will all be installed on top, in the configuration just described (and as part of the final installation the antenna structure, etc, will also be adhered/secured in place with its base plate 340 level with the road surface, as described above). However, it is important to note that, even after final installation, as a result of the configuration just described, if a vehicle drives over the top of the installed antenna structure, the slight downward displacement of the antenna structure this may cause can be accommodated/absorbed because, even if heatsink 305 (and hence the lower spacer component 364 too which is directly on top of the heatsink) may be unable to deflect due to being fixedly secured in the sub-road cavity, nevertheless when the antenna structure is slightly displaced downwards, (at least) the upper spacer component 362 will still push down on divider portion 365 of the vibration absorber, and because the divider portion 365 (and indeed the entire vi-

bration absorber 360) is formed from a resilient/squashy/vibration absorbent material, consequently the divider portion 365 (at least) will "squash" to accommodate the downward displacement of the antenna structure without displacing the heatsink or causing any damage to it or to any electronics housed therein.

[0115] It was mentioned above that there is a narrow, axially-located through-bore extending through the full vertical thickness of the lower spacer component 364. It should now be noted that there is also an axially-located through-bore extending through the full vertical thickness of the vibration absorber. These axial bores exist to provide conduits for electrical cables which connect and extend between the electronics housed within the heatsink 305 and the feed point of the antenna structure. (Recall that the antenna's feed point is at the point where the antenna's cone and baseplate intersect.) In the partially-exploded view in Figure 17, the coaxial connector used for connecting these cables to the antenna's feed point is visible. It will also be noted that the vertical through bore extending through the thickness of the vibration absorber 360 is larger than the small through bore extending through the thickness of the lower spacer 364. This is because the bore in the vibration absorber 360 must be large enough to accommodate the coaxial connector just mentioned.

[0116] Next, it should be noted that, apart from being partially-exploded vs assembled views, respectively, Figure 17 and Figure 18 actually also differ slightly from one another in one other way. In both of these Figures, there is an end plate 390 located on the bottom end of the main heatsink 305. In Figure 17, this end plate 390 therefore forms the base of the main heatsink 305, and there are no other parts of the RFID reader assembly beneath it. However, in Figure 18, the end plate 390 is not the lowermost part of the assembly. Instead, in Figure 18, there is an additional section (or an extension) of heatsink extending below (i.e. extending more deeply into the ground) below the end plate 390. In the latter case of Figure 18, the end plate 390 therefore forms a connecting plate between the upper (main) section of heatsink 305, and the lower heatsink extension. Actually, in the case of Figure 18 where there is an extension to the heatsink, the heatsink extension does not directly contact the underside of the end plate 390. Rather, interposed between the underside of the end plate 390 and the upper surface of the heatsink extension there is a component that is substantially identical to the lower spacer component 364, although in comparison with the lower spacer component 364, this component is actually installed upside-down between the underside of the end plate 390 and the upper surface of the heatsink extension. In any event, it should be noted that the heatsink extension in Figure 18 is similar to the upper main portion of the heatsink 305 in that it is hollow and could therefore potentially accommodate electronics (although there are no electronics shown therein in Figure 18), and there are also appropriate through bores in the end plate 390, etc, which could

(if necessary) provide conduits for any cabling etc required between the cavity inside the main heatsink 305 in the cavity inside the heatsink extension.

[0117] It is explained elsewhere herein that the radiation pattern generated by the RFID reader's antenna in use should preferably have a shape that may be described as a "dropped doughnut" or "squashed toroid" - that is, a shape as shown pictorially in Figure 2. However, it is also explained above that Figure 2 merely provides a visually appreciable illustration of what shape is meant by "dropped doughnut" or "squashed toroid". On the other hand, having now described the construction of the RFID reader in a number of possible embodiments, and having described the configuration of the antenna structure, it is useful now to define more precisely the technical parameters of the desired radiation pattern. This will therefore now be explained with reference to Figure 19 and Figure 20, which illustrate the antenna's radiation pattern (and parameters thereof) for a signal frequency of 860-940 MHz.

[0118] Figure 19 is a "heat map" style plot of the directivity of the desired antenna radiation pattern. The point to note firstly (and this point is equally well illustrated in Figure 2) is that the antenna is omnidirectional in the azimuth (i.e. x-y) plane. That is to say, if the plane of the ground (or the plane of the road surface) on which the antenna is sitting is the x-y (azimuth) plane (i.e. if the x- and y- axes are perpendicular to one another but both run along the surface of the ground/road) and if the z-axis points vertically upwards perpendicular to the x-y (azimuth) plane from the centre of the antenna, then it is true that the amount of energy the antenna emits, and the way the energy intensity varies with elevation (i.e. the way the energy intensity varies with the angle relative to the azimuth plane) is the same in any radially outward direction from the z-axis (i.e. in any x,y direction). The colours in the heat map in Figure 19 illustrate, in effect, the intensity of the antenna's radiation, and the way this varies according to direction. As just mentioned, the antenna is omnidirectional in the azimuth plane, however a better understanding of the way the energy intensity varies with the angle of elevation relative to the azimuth plane can be gained from the cross-sectional view of the radiation pattern in Figure 20.

[0119] Figure 20 illustrates that, in the desired radiation pattern,

- the elevation range of the critical read zone is from 3° to 30° elevation;
- the path of max gain is at 30° elevation;
- the 3dB beam width is 40°, extending from 10° to 50° elevation;
- there is a radiation null at 90° elevation.

[0120] Also, although this is not directly depicted in Figure 19 and Figure 20, the effective read range is from 1m to 6.4m from the antenna.

[0121] The particular embodiments discussed above

with reference to Figure 9 (and Figure 10), Figure 15 (and Figure 16) and Figure 17 and Figure 18 all involve an RFID reader which incorporates the presently proposed antenna structure and which is configured to be installed in an "in-road" deployment (such in-road deployments typically also require a partially-conductive area associated with the antenna, as discussed above). However, as also explained or alluded to elsewhere herein, there may often also be a need (or there may be situations where it would be beneficial) to be able to use or deploy an RFID reader (which, again, incorporates the presently-proposed antenna structure) for use in vehicle detection and/or identification but where a permanent (or semi-permanent) "in-road" installation of the RFID reader is not possible or required. Therefore, in order to be able to use or deploy an RFID reader (incorporating the proposed antenna structure) in situations where an "in-road" installation is not possible or required, an additional proposal is made whereby the RFID reader can be used or deployed in "on-road" placements. Basically, instead of being installed permanently (or semi-permanently) in the road, this enables the RFID reader to be deployed temporarily or for only a period of time, effectively, by being placed on the road and without the need to apply anything permanently to the road, or to dig holes in the road, or make any other changes whatsoever to the road. Such on-road deployments could be used or required, for example, by law enforcement personnel when setting up temporary roadblocks for performing random vehicle inspections or driver drug/alcohol testing, or during temporary roadworks or maintenance, or when there is a need to create temporary traffic diversions (but still achieve law enforcement functions at the same time), or for a discrete period of time in order to take measurements and gain information (data) about traffic and vehicle flows and the like in a certain location, etc.

[0122] An RFID reader, of which the proposed antenna structure forms part, and which is configured for use in on-road deployments, will now be discussed in further detail with reference to Figure 11. An annotated version of Figure 11 is also given as Figure 12; however for convenience reference will be made to Figure 11 only.

[0123] It is to be noted firstly that Figure 11 is, once again, a view of an RFID reader which incorporates the proposed antenna structure well as other RFID reader equipment. It should also be noted from the outset that, unlike Figure 9 (and Figure 10) and Figure 15 (and Figure 16) which all depict a situation where the RFID reader is installed in an "in-road" installation, Figure 11 (and Figure 12) depicts a situation where the RFID reader is used in an "on-road" deployment. In other words, in Figure 11, all parts of the RFID reader, as well as other associated equipment, are located above the level of the road surface RS. And as will be readily appreciated, Figure 11 is a side-on cross-sectional view.

[0124] It is also to be noted that the configuration of the RFID reader itself in Figure 11 is in almost all respects identical to the RFID reader in Figure 9 (accordingly like

parts and features of the RFID reader are referred to using like reference numerals in both Figure 9 and Figure 11). However, instead of the RFID reader being installed in a cavity 110 which is dug or bored into the road (as in Figure 9), the RFID reader in Figure 11 is instead installed

[0125] In the embodiment discussed herein with reference to Figure 11, the partially conductive substructure takes the form of a partially conductive on-road-locatable cradle 300 (hereafter the "on-road cradle" 300). Basically, the on-road cradle 300 can sit directly on the surface of the road, and the RFID reader 100 is received in (and it is mounted to) the top of the on-road cradle 300. The shape of the on-road cradle 300, at least in the depicted embodiment, is frusto-conical. In Figure 11, the angle/slope of the sides of the frusto-conical cradle 300 match the angle of slope of the sides of the RFID reader's main frusto-cone. However, this need not necessarily always be the case, and Figure 13 provides an example where the shape of the on-road cradle 300 (and in particular the angle of slope of its sides) does not match the angle of slope of the sides of the RFID reader's main frusto-cone body.

[0126] The way in which the RFID reader 100 is mounted to the top of the on-road cradle is that a cylindrical recess is provided in the top of the on-road cradle 300, and at least the top portion of the internal wall of the said cylindrical recess is threaded. The threads on the outer vertical wall of the screw mount 150 (see above) screw directly into these threads in the on-road cradle. So, in effect, the cylindrical recess in the top of the on-road cradle 300 is equivalent to those in the container 160 used in the embodiment in-road in Figure 9, and the way in which the RFID reader 100 attaches thereto is the same in both cases, except that there is no adhesive involved when attaching the RFID reader 100 to the on-road cradle 300. When the RFID reader 100 is thus mounted to the on-road cradle 300, the same (or an equivalent) space 155 is left beneath the screw mount 150 where electronic parts and components of or associated with the RFID reader may be located.

[0127] One difference in Figure 11, compared with Figure 9, relates to the size of the heat sink 105. In Figure 9, the heat sink 105 is long and extends into the ground. This is in order to help dissipate heat from the in-road RFID reader into the ground. However, in Figure 11, the heat sink 105 is comparatively much smaller. This is because, in Figure 11, the on-road cradle 300 is itself made from (or made mostly from) metal. Therefore, in Figure 11, much of (or possibly the whole of) the on-road cradle 300 actually also operates as part of (or as an extension of) the heat sink 105. In other words, some or all of the on-road cradle can help to absorb/receive heat generated by the RFID reader or its associated electronics and to dissipate this into the atmosphere (and importantly, in this on-road deployment, the whole structure is located above the road surface, and much of it is exposed to the ambient atmosphere, which helps significantly with heat

dissipation).

[0128] Another thing to note about the on-road cradle 300 is its important function, in an on-road deployment scenario, in helping to shield the RFID reader 100 (and in particular the antenna structure) from the potentially widely and dynamically variable radio frequency influences of the road, other "near ground" effects, etc. So, in effect, the on-road cradle 300 provides the same shielding function and properties as is provided by the partially conductive area used in in-road deployments. In order that the antenna be adequately shielded from the road, other "near ground" effects, etc, the size and configuration (and particularly the height) of the cradle should be such that the height of the antenna's base plate, when it is mounted on the cradle (and when the cradle is sitting on the road surface) is not more than $\frac{3}{8}\lambda$, and preferably not more than $\frac{1}{4}\lambda$ (the closer to $\frac{1}{4}\lambda$ the better the shielding).

[0129] Given the height of the RFID reader and cradle, it will be understood that (unlike in the in-road embodiments described above where the antenna/reader is located in the road lane (normally in centre thereof)), in these on-road embodiments the cradle on which the reader is mounted will generally be positioned for use between lanes, or to the side of the lane or road. This is because the cradle is simply too high for most vehicles to be able to drive directly over the top of it. The fact that the cradle (and reader) is positioned for use between lanes, or to the side of the lane or road, also means that the required read zone for communicating with the RFID tags on passing vehicle license plates is different. However, given that the situations where such on-road reader deployments will be used will mostly involve temporary road blocks, traffic diversions and the like, it follows that vehicle speeds around such on-road reader deployments will also normally be lower (often much lower) than the speeds involved in normal free-flow traffic. Accordingly, the size of the required read zone (given the much lower vehicle speeds) may be much smaller than for the in-road deployments more often used for normal, free-flow traffic. Thus, the changed read zone due to the location of the cradle/antenna (i.e. between lanes or to the side, rather than in-lane) is unlikely to cause any problems in terms of read performance.

[0130] A further issue to consider is that, in on-road deployments, which will (by their nature) often be temporary or transient, there often will not be any available pre-installed or existing power supply lines to provide power for the RFID reader. Therefore, instead, batteries (typically rechargeable batteries although replaceable batteries might also be used) and associated power supply electronics are provided inside the on-road cradle 300 itself and these are used to power the RFID reader.

[0131] Yet a further point to note (following on from above) is that, because the RFID reader 100 is positioned on/in the top of the on-road cradle 300 and the reader 100 is therefore located vertically much higher than in in-road deployments, and because this means that it may

no longer be feasible for vehicles to be able to drive directly over the top of the RFID reader, it therefore follows that, in these on-road deployments, the on-road cradle 300 bearing the RFID reader 100 may be similar to "witches hats" and the like used in traditional road traffic management in that vehicles must drive around between them.

[0132] There are also other ramifications arising from the fact that, in on-road deployments, the RFID reader is located above the road surface. As shown in Figure 13 for example, the height to which the antenna's ground plane (i.e. the base plate 140) is elevated when the RFID reader is mounted to the on-road cradle 300 may be around 75 mm to 85 mm. Given that, at least in the embodiment discussed herein, the signal frequency with which the antenna is configured to operate is approximately 920 MHz (wavelength $\lambda=326$ mm), it follows that the height to which the antenna's ground plane is elevated when the reader is mounted to the on-road cradle 300 is approximately $\lambda/4$. As those skilled in the art may appreciate, raising the antenna ground plane by this amount (as a proportion of the operating signal wavelength) may have the effect of somewhat reducing the impact or effect of the dynamically variable radio frequency influences of the road, other "near ground" effects, etc, and it may further have the effect of pulling the radiation pattern down (in relation to or in comparison with a free space placement). Nevertheless, the construction and configurations of the on-road cradle 300, including in relation to its height, the angle of slope of its sides, internal construction, positioning of internal components, etc, are chosen or varied in order to, in effect, help tune the on-road cradle 300 so that, when it is used in conjunction with the RFID reader (including the proposed RFID antenna structure) in on-road deployments, the two together (i.e. the RFID reader when used mounted upon the on-road cradle 300) provide the desired radiation pattern (which, as explained above, is a "dropped doughnut"-shape). The different shapes of the on-road cradle depicted in Figure 13 are examples of the way in which the on-road cradle shape may be varied for this purpose.

[0133] In the present specification and claims (if any), the word 'comprising' and its derivatives including 'comprises' and 'comprise' include each of the stated integers but does not exclude the inclusion of one or more further integers.

[0134] Reference throughout this specification to 'one embodiment' or 'an embodiment' means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearance of the phrases 'in one embodiment' or 'in an embodiment' in various places throughout this specification are not necessarily all referring to the same embodiment.

[0135] In compliance with the statute, the invention has been described in language more or less specific to structural or methodical features. It is to be understood that the invention is not limited to specific features shown or

described since the means herein described comprises preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the scope of the appended claims.

Claims

1. A road antenna for a communication device (100), where the antenna is capable of operation when installed in or on the ground (90), the road antenna having a structure comprising:

a circular conductive base plate (140),
a radiating cone (120), wherein the cone has an apex that points towards the center of the circular base plate (140), the apex is positioned on or near the base plate (140) on one side of the base plate (140), and the cone (120) opens/expands away from the base plate (120), and
a solid frusto-conical body (10), wherein the body has an encompassing side which extends from the base plate (140) to near an edge on the widest point on the cone (120), and the material of the body substantially fills the space inside the encompassing side and between the base plate (140) and the cone (120), **characterized in that:**
the road antenna further comprises a number of adjustable tuning screws or adjustable tuning struts (190) extending between the cone (120) and the base plate (140).

2. The road antenna as claimed in claim 1, wherein the encompassing side of the body extends from at or near an outer perimeter of the base plate (140) to near an edge on the widest point on the cone (120).

3. The road antenna as claimed in claim 1 or 2, wherein the distance between the base plate (140) and the widest point on the cone (120) in a direction perpendicular to the base plate (140) is less than the maximum diameter of the antenna, and/or the diameter of the base plate (140) is larger than the maximum diameter of the cone (120).

4. The road antenna as claimed in any one of the preceding claims, wherein the body is made from a dielectric material that has a relative permittivity of between approximately 3 and approximately 6.

5. The road antenna as claimed in any one of the preceding claims, wherein:

the body comprises a recess or indent therein, the shape of the recess or indent corresponding to the shape of the cone of the antenna, and the cone is a thin layer of metal on the surface

of the recess or indent.

6. The road antenna as claimed in any one of the preceding claims wherein the antenna structure further includes a top plate/lid (130) which extends across and partly or fully covers the space (135) which is formed by and within the open cone (120). 5
7. The road antenna as claimed in any one of the preceding claims, wherein the base plate (140) is metal, approximately 5-10 mm thick and is initially formed separately from the body and then affixed on or to the bottom/underside of the body. 10
8. The road antenna as claimed in any one of the preceding claims, wherein the antenna is configured to be used with a signal frequency of 860-940 MHz and wherein:
 - on the side of the base plate (140) on which the cone (120) is located, no point on the antenna is further than 25 mm from that side/surface of the base plate (140) in a direction perpendicular to the base plate (140); 20
 - the diameter of the base plate (140) is less than 190 mm; and/or 25
 - the encompassing side of the body extends from an outer perimeter edge of the base plate (140) to near the edge on the widest point on the cone (120), and the angle between the encompassing side and the base plate (140), when taken in a central plane perpendicular to the base plate (140), is less than 40°, and preferably 33° - 36°. 3035
9. The road antenna as claimed in any one of the preceding claims, wherein the adjustable tuning screws or adjustable tuning struts (190) extend through the frusto-conical body and screw into the base plate (140) for strengthening and/or tuning of the antenna by tightening or loosening. 40
10. An RFID reader (100), incorporating a road antenna as claimed in any one of the preceding claims, wherein the RFID reader (100) is operable to be used in an application involving road vehicle detection and/or identification and wherein at least the antenna is in the surface of the road. 45
11. The RFID reader (100) as claimed in claim 10 wherein,
 - the base plate (140) of the antenna is in the surface of the road such that an upper surface of the base plate (140), which is the surface on the side of the base plate which has the cone (120), is generally level with the road surface, the antenna's body and cone (120) project 55

above the upper surface of the base plate (140) and above the level of the road surface, and the antenna is also surrounded by an at least partially conductive area (90) which is also on the road surface.

12. The RFID reader (100) as claimed in claim 11 wherein the partially conductive area (90) surrounding the antenna is circular, and wherein the minimum radius of said partially conductive area is approximately twice the wavelength λ of the signals to be transmitted and/or received by the antenna.
13. The RFID reader (100) as claimed in claim 11 or 12 wherein the partially conductive area has a conductivity of approximately 10^3 S/m or more.
14. The RFID reader (100) as claimed in any one of claims 10 - 13 wherein the antenna is operable to, in use, generate a radiation pattern having a dropped doughnut or squashed toroid shape.
15. The RFID reader (100) as claimed claim 14, where the antenna is configured to operate with a signal frequency of 860-940 MHz, wherein:
 - the elevation range of the critical read zone in the radiation pattern is from approximately 3° to approximately 30° elevation;
 - in the radiation pattern, the path of max gain is at approximately 30° elevation;
 - in the radiation pattern, the 3dB beam width is approximately 40°, extending from approximately 10° to approximately 50° elevation;
 - in the radiation pattern, there is an effective radiation null at 90° elevation;and/or ▪ the effective read range of the RFID reader is from approximately 1 m to approximately 6.4 m from the RFID reader antenna in any direction along the road surface.
16. An RFID reader (100), incorporating an antenna as claimed in any one of claims 1-9, wherein the RFID reader is operable to be used in an application involving road vehicle detection and/or identification and wherein at least the antenna is operable to be installed or mounted in or on a partially conductive structure, and wherein the partially conductive structure is operable to be placed on the surface of the road, and when the partially conductive structure is placed on the surface of the road with the antenna installed or mounted therein or thereon, the antenna is located a distance vertically above the road surface.
17. The RFID reader (100) as claimed in claim 16, wherein the partially conductive structure is substantially frusto-conical in shape, and optionally the angle

of slope of the side on the frusto-conical partially conductive structure substantially matches the angle of slope on the side of the antenna's main frusto-conical body and/or where the antenna operates with a signal frequency of 860-940 MHz, wherein the partially conductive structure is configured such that the height of the antenna's base plate (140), when the base plate (140) s

mounted on the partially conductive structure and the partially conductive structure is on the road surface, is not more than $\frac{3}{8}\lambda$, and preferably not more than $\frac{1}{4}\lambda$, wherein λ is the wavelength corresponding to the operating signal frequency.

Patentansprüche

1. Straßenantenne für eine Kommunikationsvorrichtung (100), wobei die Antenne betrieben werden kann, wenn sie im oder am Boden (90) installiert ist, und die Straßenantenne eine Struktur aufweist, die aufweist:

eine runde leitfähige Grundplatte (140), einen Strahlungskegel (120), wobei der Kegel eine Spitze aufweist, die zur Mitte der runden Grundplatte (140) weist, die Spitze an oder nahe der Grundplatte (140) an einer Seite der Grundplatte (140) positioniert ist und der Kegel (120) sich von der Grundplatte (120) weg öffnet/erweitert, und einen massiven kegelstumpfförmigen Körper (10), wobei der Körper eine umfassende Seite aufweist, die sich von der Grundplatte (140) weg bis nahe einer Kante am weitesten Punkt des Kegels (120) erstreckt, und das Material des Körpers im Wesentlichen den Raum innerhalb der umfassenden Seite und zwischen der Grundplatte (140) und dem Kegel (120) ausfüllt, **dadurch gekennzeichnet, dass:** die Straßenantenne ferner eine Anzahl einstellbarer Abstimmerschrauben oder einstellbarer Abstimmstreben (190) aufweist, die sich zwischen dem Kegel (120) und der Grundplatte (140) erstrecken.

2. Straßenantenne nach Anspruch 1, wobei sich die umfassende Seite des Körpers von nahe eines äußeren Umkreises der Grundplatte (140) bis nahe einer Kante am weitesten Punkt des Kegels (120) erstreckt.
3. Straßenantenne nach Anspruch 1 oder 2, wobei die Distanz zwischen der Grundplatte (140) und dem weitesten Punkt des Kegels (120) in einer Richtung

senkrecht zur Grundplatte (140) kleiner als der maximale Durchmesser der Antenne ist und/oder der Durchmesser der Grundplatte (140) größer als der maximale Durchmesser des Kegels (120) ist.

4. Straßenantenne nach einem der vorhergehenden Ansprüche, wobei der Körper aus einem Dielektrikum hergestellt ist, das eine relative Dielektrizitätskonstante zwischen etwa 3 und etwa 6 aufweist.

5. Straßenantenne nach einem der vorhergehenden Ansprüche, wobei: der Körper einen Ausschnitt oder eine Einkerbung in sich aufweist, wobei die Form des Ausschnitts oder der Einkerbung der Form des Kegels der Antenne entspricht und der Kegel an der Fläche des Ausschnitts oder der Einkerbung eine dünne Metallschicht ist.

6. Straßenantenne nach einem der vorhergehenden Ansprüche, wobei die Antennenstruktur ferner eine obere Platte/einen Deckel (130) aufweist, die/der sich über den Raum (135) erstreckt, der durch und in dem offenen Kegel (120) gebildet ist, und diesen teilweise oder vollständig bedeckt.

7. Straßenantenne nach einem der vorhergehenden Ansprüche, wobei die Grundplatte (140) aus Metall ist, etwa 5-10 mm dick ist und anfänglich getrennt von dem Körper gebildet ist und dann auf oder am Boden/an der Unterseite des Körpers befestigt wird.

8. Straßenantenne nach einem der vorhergehenden Ansprüche, wobei die Antenne eingerichtet ist, um mit einer Signalfrequenz von 860-940 MHz verwendet zu werden, und wobei:

- an der Seite der Grundplatte (140), an der sich der Kegel (120) befindet, kein Punkt an der Antenne in einer Richtung rechtwinklig zur Grundplatte (140) weiter als 25 mm von der Seite/Fläche der Grundplatte (140) entfernt ist;
- der Durchmesser der Grundplatte (140) weniger als 190 mm beträgt; und/oder
- die umfassende Seite des Körpers sich von einer äußeren Umfangskante der Grundplatte (140) bis nahe der Kante am weitesten Punkt des Kegels (120) erstreckt, und der Winkel zwischen der umfassenden Seite und der Grundplatte (140) in einer zentralen Ebene senkrecht zur Grundplatte (140) gemessen kleiner als 40° und bevorzugt 33° - 36° ist.

9. Straßenantenne nach einem der vorhergehenden Ansprüche, wobei sich die einstellbaren Abstimmerschrauben oder die einstellbaren Abstimmstreben (190) durch den kegelstumpfförmigen Körper erstrecken und sich in die Grundplatte (140) schrauben,

um die Antenne durch Anziehen oder Lockern zu verstärken und/oder abzustimmen.

10. RFID-Reader (100), in den eine Straßenantenne nach einem der vorhergehenden Ansprüche integriert ist, wobei der RFID-Reader (100) betrieben werden kann, um in einer Anwendung verwendet zu werden, die das Erkennen und/oder Identifizieren von Strahlenfahrzeugen umfasst und wobei sich mindestens die Antenne in der Straßenfläche befindet. 5
11. RFID-Reader (100) nach Anspruch 10 wobei, 10
 - sich die Grundplatte (140) der Antenne so in der Straßenfläche befindet, dass eine obere Fläche der Grundplatte (140), die die Fläche an der Seite der Grundplatte ist, die den Kegel (120) aufweist, allgemein bündig mit der Straßenfläche ist, 15
 - der Körper und Kegel (120) der Antenne über die obere Fläche der Grundplatte (140) und über die Ebene der Straßenfläche hervorstehen und die Antenne außerdem durch einen mindestens teilweise leitfähigen Bereich (90) umschlossen ist, der sich auch auf der Straßenfläche befindet. 20
12. RFID-Reader (100) nach Anspruch 11 wobei der teilweise leitfähige Bereich (90), der die Antenne umschließt, rund ist, und wobei der Mindestradius des teilweise leitfähigen Bereichs etwa zweimal die Wellenlänge λ der Signale beträgt, die durch die Antenne übertragen und/oder empfangen werden sollen. 25
13. RFID-Reader (100) nach Anspruch 11 oder 12 wobei der teilweise leitfähige Bereich eine Leitfähigkeit von etwa 10^3 S/m oder mehr aufweist. 30
14. RFID-Reader (100) nach einem der Ansprüche 10 bis 13, wobei die Antenne betrieben werden kann, um in Verwendung eine Strahlungsstruktur zu erzeugen, die die Form eines abgesenkten Donuts oder eines komprimierten Torus aufweist. 35
15. RFID-Reader (100) nach Anspruch 14, wobei die Antenne eingerichtet ist, um mit einer Signalfrequenz von 860-940 MHz zu arbeiten, wobei: 40
 - der Anhebungsbereich der kritischen Lesezone in der Strahlungsstruktur von einer Anhebung von etwa 3° bis etwa 30° reicht; 45
 - der Pfad des maximalen Zuwachses in der Strahlungsstruktur bei einer Anhebung von etwa 30° liegt; 50
 - die 3-dB-Strahlweite in der Strahlungsstruktur etwa 40° beträgt und sich von einer Anhebung von etwa 10° bis etwa 50° erstreckt; 55
 - es in der Strahlungsstruktur bei einer Anhe-

bung von 90° eine effektive Nullstrahlung gibt; und/oder

- der effektive Lesebereich des RFID-Readers von etwa 1 m bis etwa 6,4 m von der RFID-Reader-Antenne in jeder Richtung entlang der Straßenfläche reicht.

16. RFID-Reader (100), in den eine Antenne nach einem der Ansprüche 1 bis 9 integriert ist, wobei der RFID-Reader betrieben werden kann, um in einer Anwendung verwendet zu werden, die das Erkennen und/oder das Identifizieren von Straßenfahrzeugen umfasst, wobei mindestens die Antenne betrieben werden kann, um in oder an einer teilweise leitfähigen Struktur installiert oder montiert zu werden, und wobei die teilweise leitfähige Struktur betrieben werden kann, um an der Straßenfläche platziert zu werden, und sich die Antenne, wenn die teilweise leitfähige Struktur mit der darin oder daran installierten oder montierten Antenne an der Straßenfläche platziert wird, in einer Distanz vertikal über der Straßenfläche befindet. 10
17. RFID-Reader (100) nach Anspruch 16, wobei die teilweise leitfähige Struktur eine im Wesentlichen kegelstumpfförmige Form aufweist und optional der Neigungswinkel der Seite an der kegelstumpfförmigen teilweise leitfähigen Struktur im Wesentlichen zu dem Neigungswinkel an der Seite des kegelstumpfförmigen Hauptkörpers der Antenne passt und/oder wobei die Antenne mit einer Signalfrequenz von 860-940 MHz arbeitet, wobei die teilweise leitfähige Struktur so eingerichtet ist, dass die Höhe der Grundplatte (140) der Antenne, wenn die Grundplatte (140) an der teilweise leitfähigen Struktur montiert ist und die teilweise leitfähige Struktur sich an der Straßenfläche befindet, nicht mehr als $3/8 \lambda$, und bevorzugt nicht mehr als $1/4 \lambda$, beträgt, wobei λ die Wellenlänge ist, die der Betriebssignalfrequenz entspricht. 15

Revendications

1. Une antenne routière pour un dispositif de communication (100), où l'antenne est capable de fonctionner lorsqu'elle est installée dans ou sur le sol (90), l'antenne routière ayant une structure comprenant : 20
 - une plaque de base conductrice circulaire (140), un cône rayonnant (120), dans lequel le cône a un sommet qui pointe vers le centre de la plaque de base circulaire (140), le sommet est positionné sur ou près de la plaque de base (140) sur un côté de la plaque de base (140), et le cône (120) s'ouvre / se développe à l'écart de la plaque de base (120), et 25
 - un corps tronconique solide (10) dans lequel le

- corps a un côté englobant qui s'étend de la plaque de base (140) jusqu'à près d'un bord du point le plus large sur le cône (120), et le matériau du corps remplit sensiblement l'espace à l'intérieur du côté englobant et entre la plaque de base (140) et le cône (120), **caractérisé en ce que** :
- l'antenne routière comprend en outre un certain nombre de vis d'accord réglables ou d'entretoises d'accord réglables (190) s'étendant entre le cône (120) et la plaque de base (140).
2. L'antenne routière selon la revendication 1, dans laquelle le côté englobant du corps s'étend depuis un périmètre extérieur ou proche d'un périmètre extérieur de la plaque de base (140) jusqu'à près d'un bord du point le plus large sur le cône (120).
 3. L'antenne routière selon la revendication 1 ou 2, dans laquelle la distance entre la plaque de base (140) et le point le plus large sur le cône (120) dans une direction perpendiculaire à la plaque de base (140) est inférieure au diamètre maximal de l'antenne, et/ou le diamètre de la plaque de base (140) est supérieur au diamètre maximal du cône (120).
 4. L'antenne routière selon l'une quelconque des revendications précédentes, dans laquelle le corps est constitué d'un matériau diélectrique qui présente une permittivité relative comprise entre environ 3 et environ 6.
 5. L'antenne routière selon l'une quelconque des revendications précédentes, dans laquelle :

le corps comprend un évidement ou une entaille dans celui-ci, la forme de l'évidement ou de l'entaille correspondant à la forme du cône de l'antenne, et

le cône est une fine couche de métal sur la surface de l'évidement ou de l'entaille.
 6. L'antenne routière selon l'une quelconque des revendications précédentes, dans laquelle la structure d'antenne comprend en outre une plaque supérieure / un couvercle (130) qui s'étend sur et couvre partiellement ou totalement l'espace (135) qui est formé par et dans le cône ouvert (120).
 7. L'antenne routière selon l'une quelconque des revendications précédentes, dans laquelle la plaque de base (140) est en métal, d'une épaisseur d'environ 5 à 10 mm et est initialement formée séparément du corps, puis fixée sur ou au fond / à la face inférieure du corps.
 8. L'antenne routière selon l'une quelconque des revendications précédentes, dans laquelle l'antenne est configurée pour être utilisée avec une fréquence de signal de 860 à 940 MHz et dans laquelle :
 - sur le côté de la plaque de base (140) sur lequel est situé le cône (120), aucun point de l'antenne n'est éloigné de plus de 25 mm de ce côté / surface de la plaque de base (140) dans une direction perpendiculaire à la plaque de base (140) ;
 - le diamètre de la plaque de base (140) est inférieur à 190 mm ; et / ou
 - le côté englobant du corps s'étend depuis un bord du périmètre extérieur de la plaque de base (140) jusqu'à près du bord du point le plus large sur le cône (120), et l'angle entre le côté englobant et la plaque de base (140), lorsqu'il est pris dans un plan central perpendiculaire à la plaque de base (140), est inférieur à 40°, et de préférence 33° à 36°.
 9. L'antenne routière selon l'une quelconque des revendications précédentes, dans laquelle les vis d'accord réglables ou les entretoises d'accord réglables (190) s'étendent à travers le corps tronconique et se vissent dans la plaque de base (140) pour renforcer et / ou accorder l'antenne par serrage ou desserrage.
 10. Un lecteur RFID (100), incorporant une antenne routière selon l'une quelconque des revendications précédentes, dans lequel le lecteur RFID (100) peut être utilisé dans une application impliquant la détection et / ou l'identification de véhicules routiers et dans lequel au moins l'antenne est dans la surface de la route.
 11. Le lecteur RFID (100) selon la revendication 10, dans lequel,

la plaque de base (140) de l'antenne est dans la surface de la route de sorte qu'une surface supérieure de la plaque de base (140), qui est la surface sur le côté de la plaque de base qui comporte le cône (120), est généralement au niveau de la surface de la route,

le corps et le cône de l'antenne (120) font saillie au-dessus de la surface supérieure de la plaque de base (140) et au-dessus du niveau de la surface de la route, et

l'antenne est également entourée d'une zone au moins partiellement conductrice (90) qui se trouve également sur la surface de la route.
 12. Le lecteur RFID (100) selon la revendication 11, dans lequel la zone partiellement conductrice (90) entourant l'antenne est circulaire, et dans lequel le rayon minimal de ladite zone partiellement conductrice est approximativement deux fois la longueur d'onde A des signaux à émettre et / ou à recevoir

par l'antenne.

13. Le lecteur RFID (100) selon la revendication 11 ou 12, dans lequel la zone partiellement conductrice a une conductivité d'environ 10^3 S/m ou plus. 5
14. Le lecteur RFID (100) selon l'une quelconque des revendications 10 à 13, dans lequel l'antenne peut fonctionner pour, en utilisation, générer un diagramme de rayonnement ayant une forme d'anneau ou de tore écrasé. 10
15. Le lecteur RFID (100) selon la revendication 14, où l'antenne est configurée pour fonctionner avec une fréquence de signal de 860 à 940 MHz, dans lequel : 15
 - la plage d'élévation de la zone de lecture critique dans le diagramme de rayonnement est d'environ 3° à environ 30° d'élévation ;
 - dans le diagramme de rayonnement, le chemin de gain maximal est à environ 30° d'élévation ; 20
 - dans le diagramme de rayonnement, la largeur du faisceau de 3dB est d'environ 40° , s'étendant d'environ 10° à environ 50° d'élévation ; 25
 - dans le diagramme de rayonnement, il y a un nul de rayonnement effectif à 90° d'élévation ; et / ou
 - la plage de lecture effective du lecteur RFID est d'environ 1 m à environ 6,4 m de l'antenne du lecteur RFID dans n'importe quelle direction le long de la surface de la route. 30
16. Un lecteur RFID (100), incorporant une antenne selon l'une quelconque des revendications 1 à 9, dans lequel le lecteur RFID peut être utilisé dans une application impliquant la détection et / ou l'identification de véhicules routiers et dans lequel au moins l'antenne peut être installée ou montée dans ou sur une structure partiellement conductrice, et dans lequel la structure partiellement conductrice peut être placée sur la surface de la route, et lorsque la structure partiellement conductrice est placée sur la surface de la route avec l'antenne installée ou montée dans ou sur celle-ci, l'antenne est située à une distance verticale au-dessus de la surface de la route. 35 40 45
17. Le lecteur RFID (100) selon la revendication 16, dans lequel la structure partiellement conductrice est de forme sensiblement tronconique, et éventuellement l'angle de pente du côté de la structure tronconique partiellement conductrice correspond sensiblement à l'angle de pente du côté du corps tronconique principal de l'antenne et / ou lorsque l'antenne fonctionne avec une fréquence de signal de 860 à 940 MHz, dans lequel la structure partiellement conductrice est configurée de telle sorte que 50 55

la hauteur de la plaque de base de l'antenne (140), lorsque la plaque de base (140) montée sur la structure partiellement conductrice et la structure partiellement conductrice se trouve sur la surface de la route, n'est pas supérieure à $\frac{3}{8}\lambda$, et de préférence pas supérieure à $\frac{1}{4}\lambda$, où λ est la longueur d'onde correspondant à la fréquence du signal de fonctionnement.

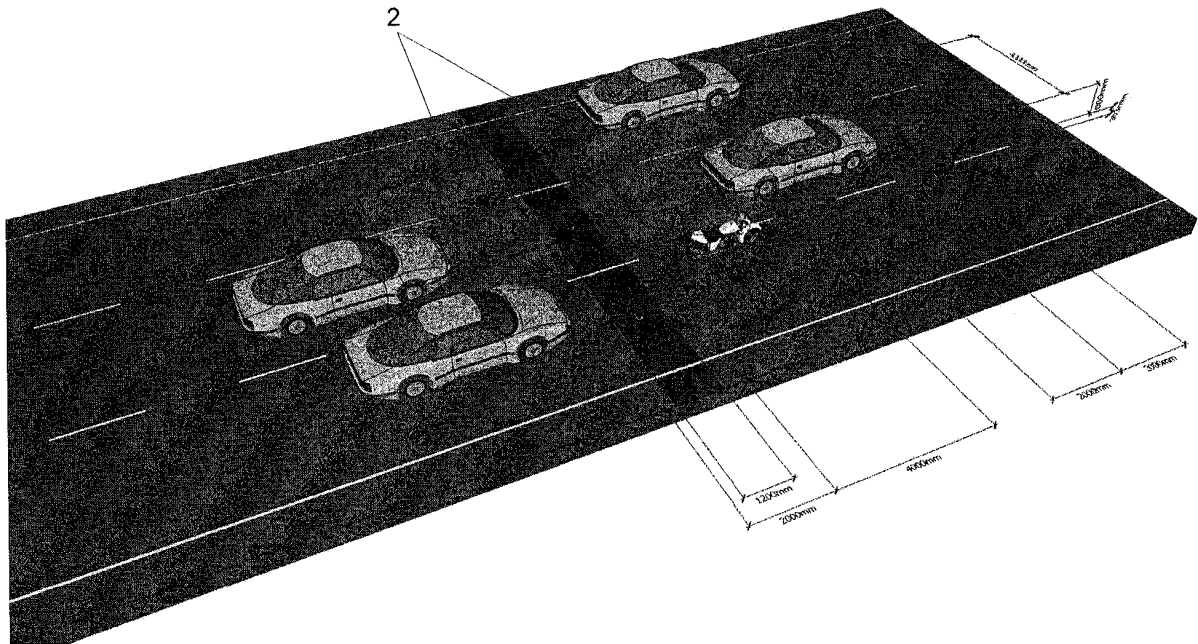


Figure 1 – required read-zone for an in/on road antenna

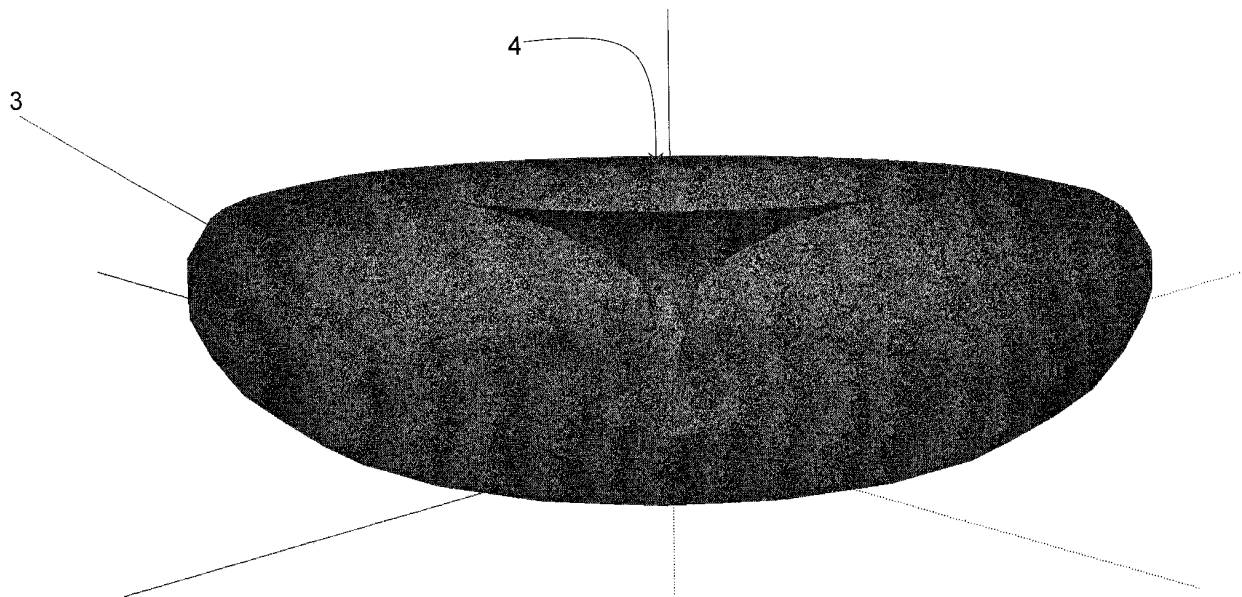


Figure 2 - "dropped doughnut" (or "squashed toroid") shaped antenna radiation pattern

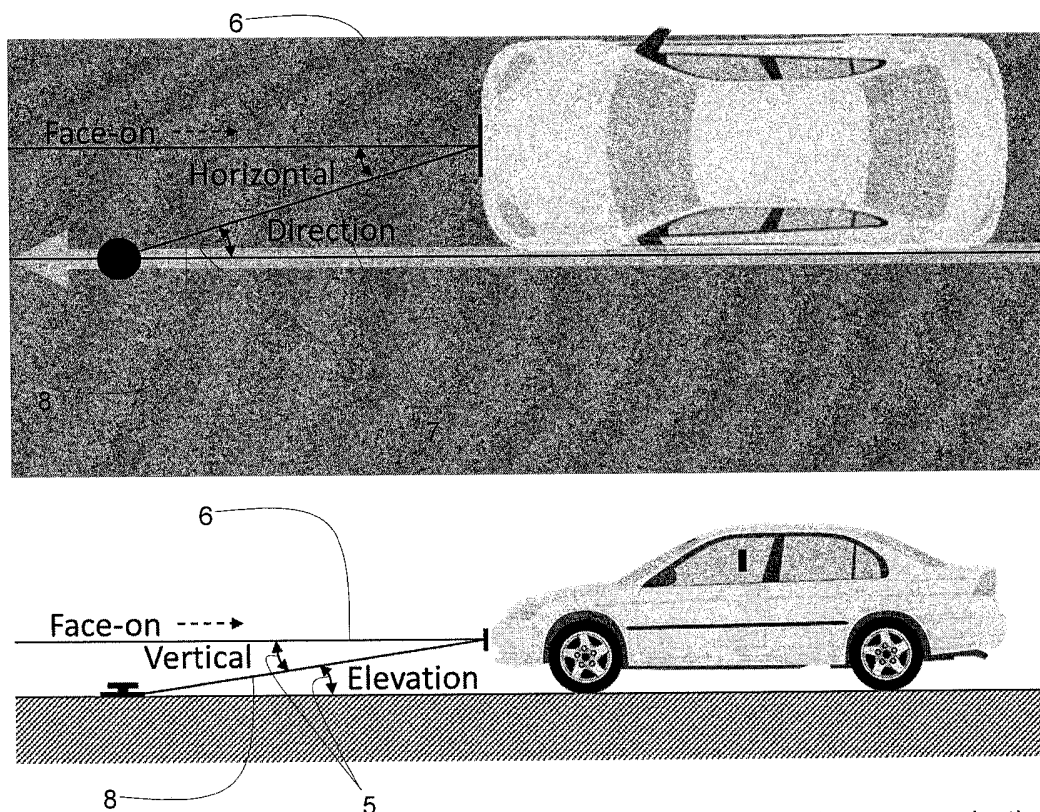


Figure 3 – elevation/height and directional/horizontal offsets of the radiation communication path between a license plate's tag and an in/on road antenna, relative to the plate's "face-on" direction

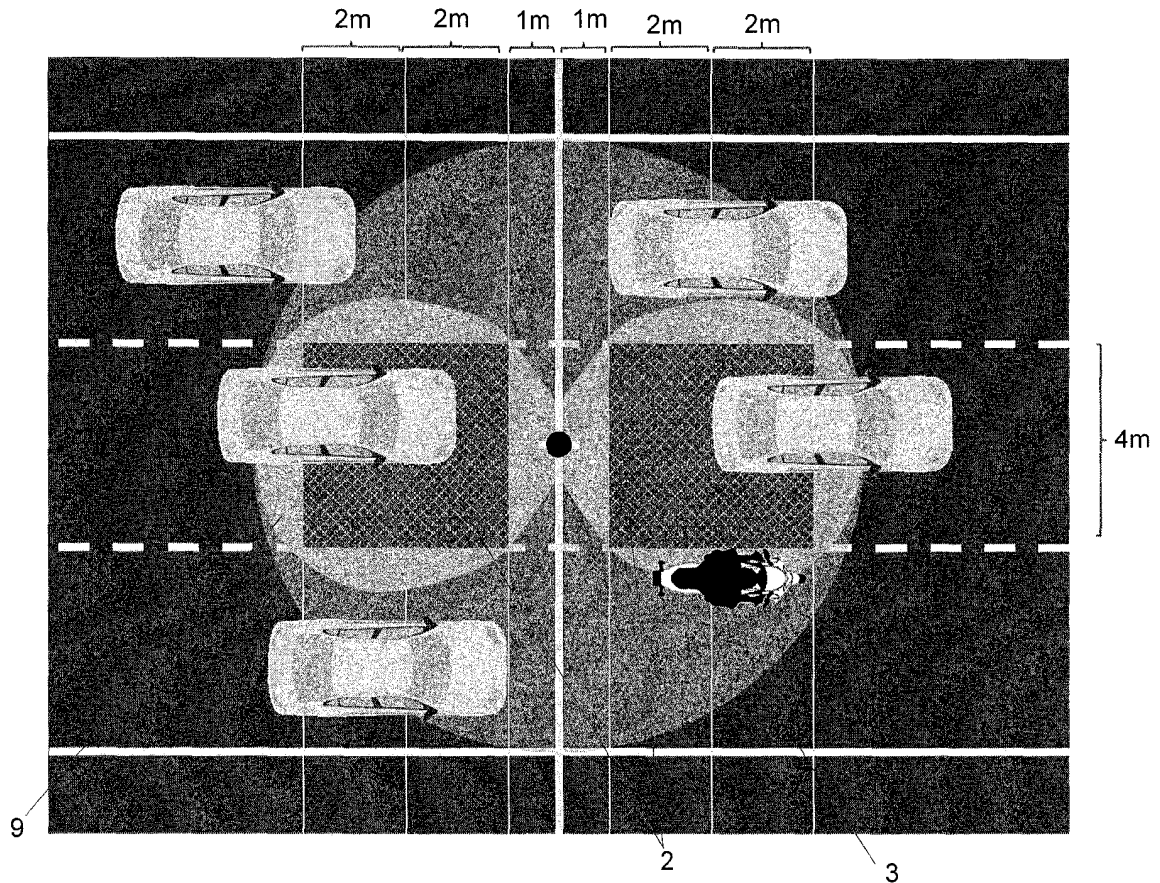


Figure 4 - plan view of a three lane road with an RFID reader antenna placed on/in the road in the middle of the centre lane. (Note: the fact that this Figure illustrates only a single RFID reader antenna, located in the centre lane, is for clarity of illustration only. Normally, in practice (at least where the present invention is used in in-road implementations) there will be an RFID reader antenna placed in the middle of each lane)

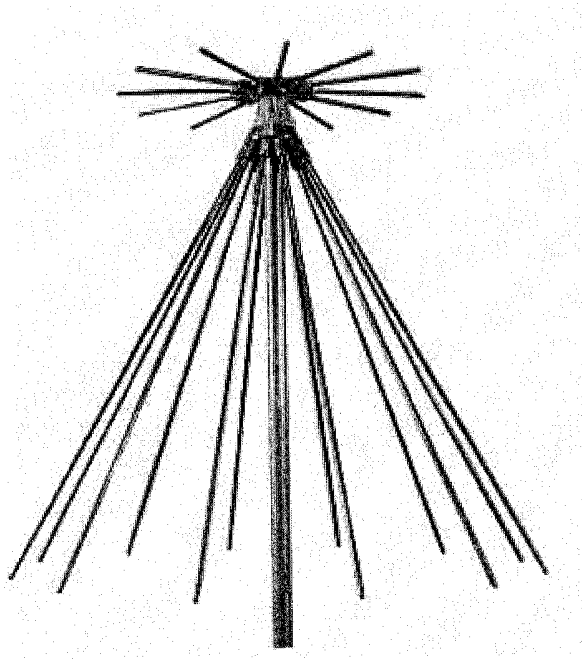


Figure 5 - traditional disk cone antenna with the disk and cone each formed from discrete elongate rod elements

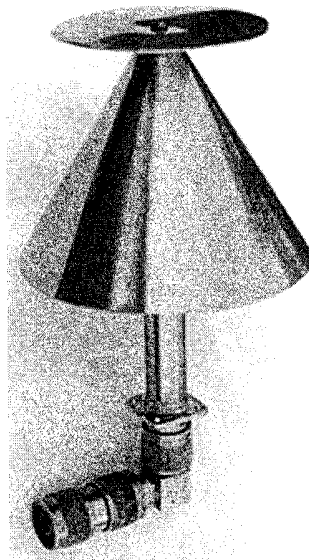


Figure 6 - traditional disk cone antenna having a solid disk and solid cone.

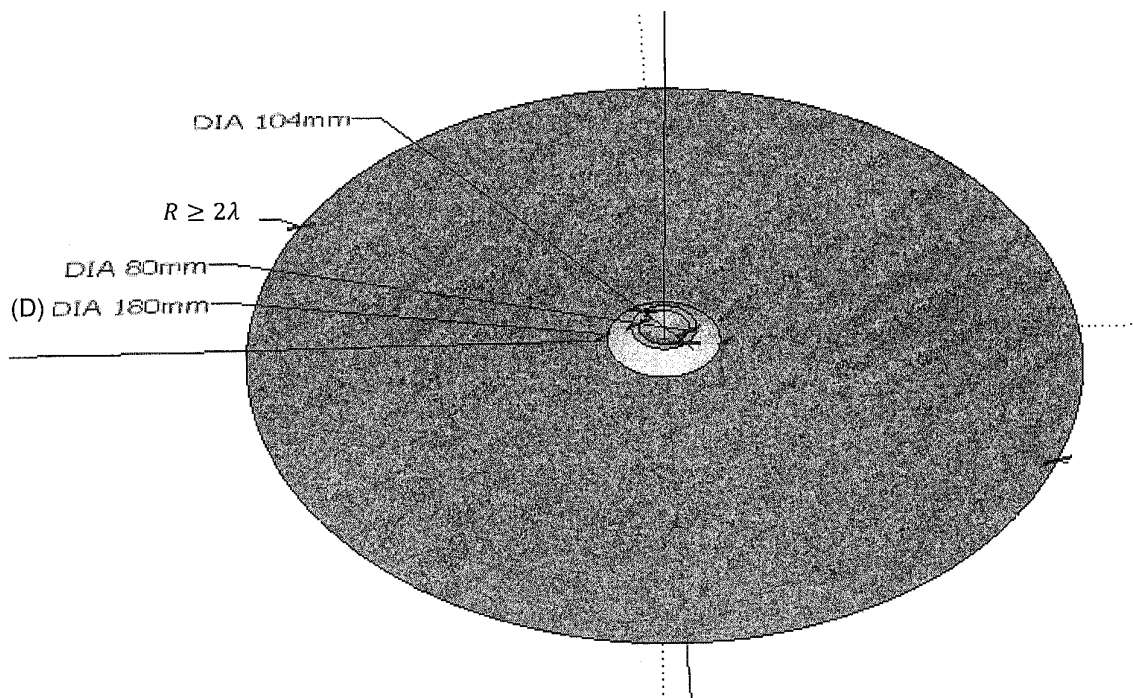


Figure 7 – RFID reader (including antenna structure) with a surrounding partially conductive area of radius R at least twice the signal wavelength λ

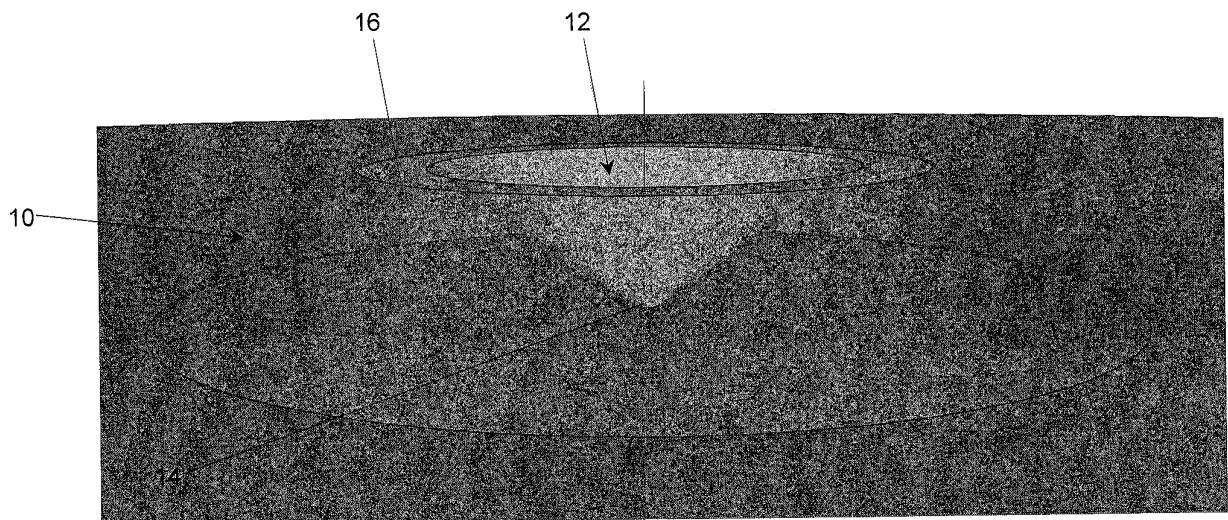


Figure 8 – schematic illustration of a shape corresponding to that of the proposed antenna structure

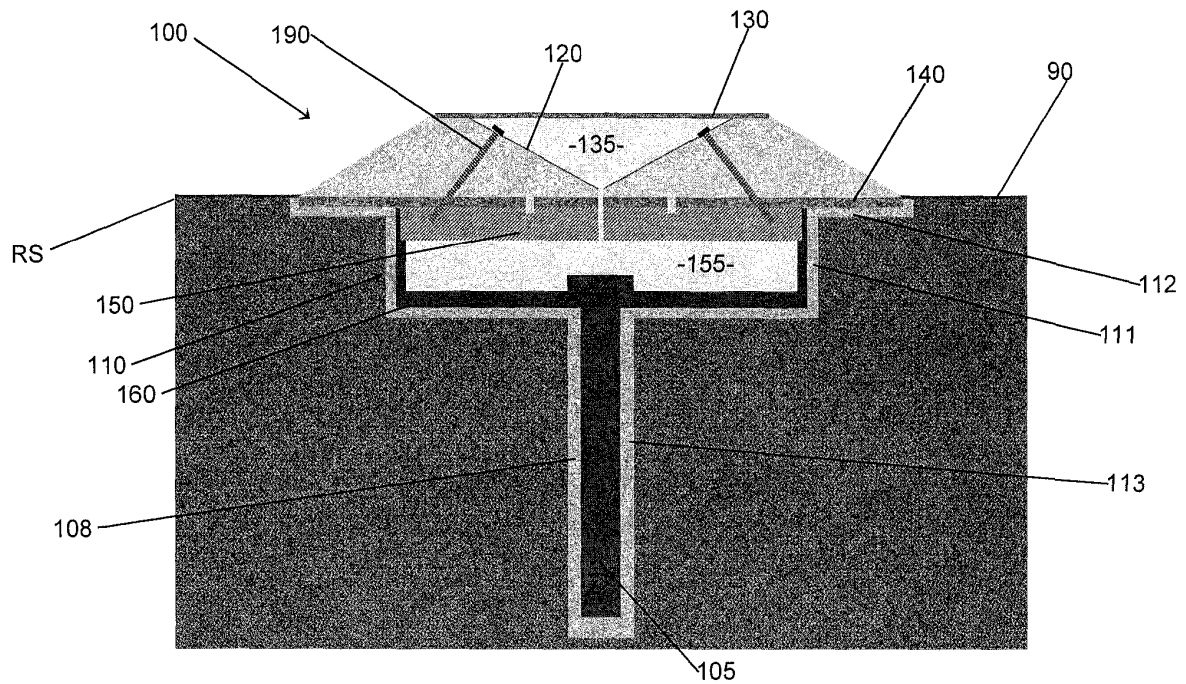


Figure 9 – cross-sectional view of the proposed antenna structure, also incorporating other reader equipment (i.e. in addition to the basic antenna structure), in an in-road application

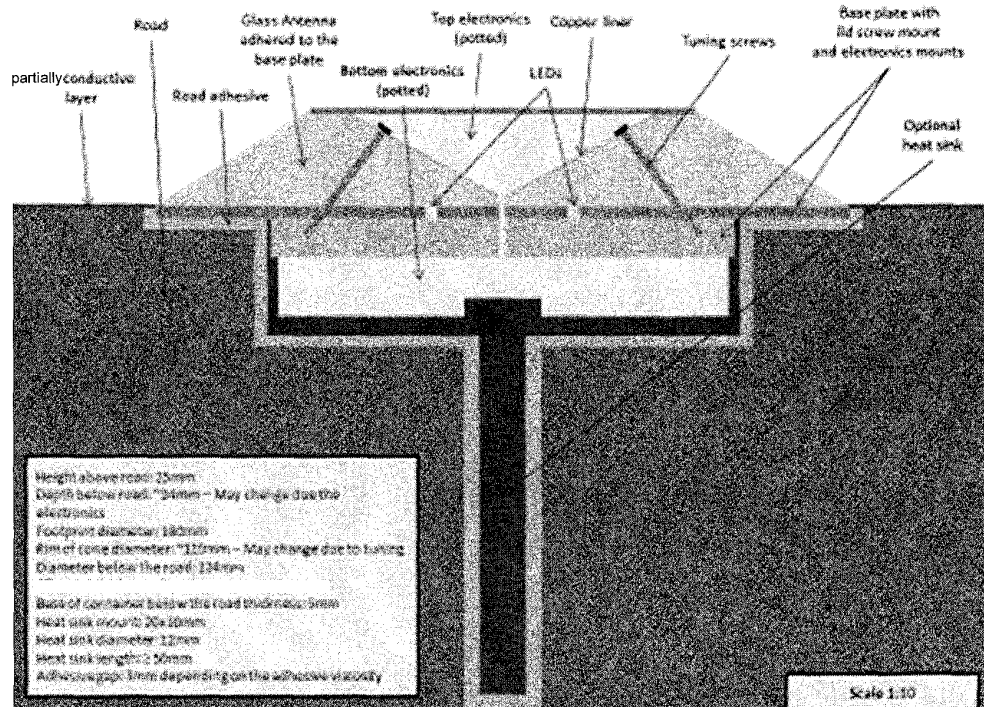


Figure 10 – annotated cross-sectional view of the proposed antenna structure etc in Figure 9

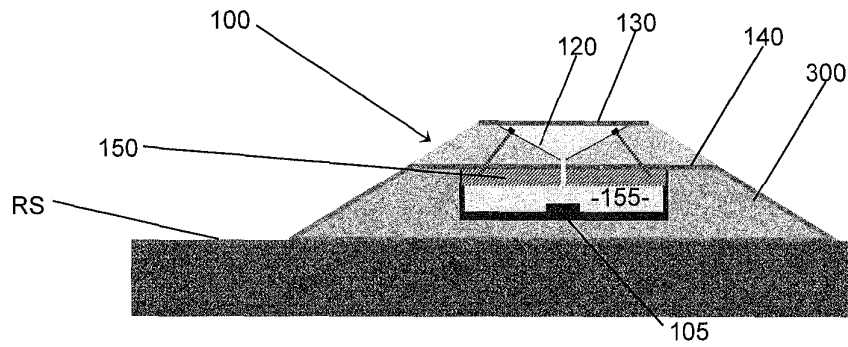


Figure 11 - cross-sectional view of the proposed antenna structure, also incorporating certain other reader equipment (i.e. in addition to the basic antenna structure), when the antenna structure is mounted on a partially conductive substructure in the form of an on-road cradle for on-road applications

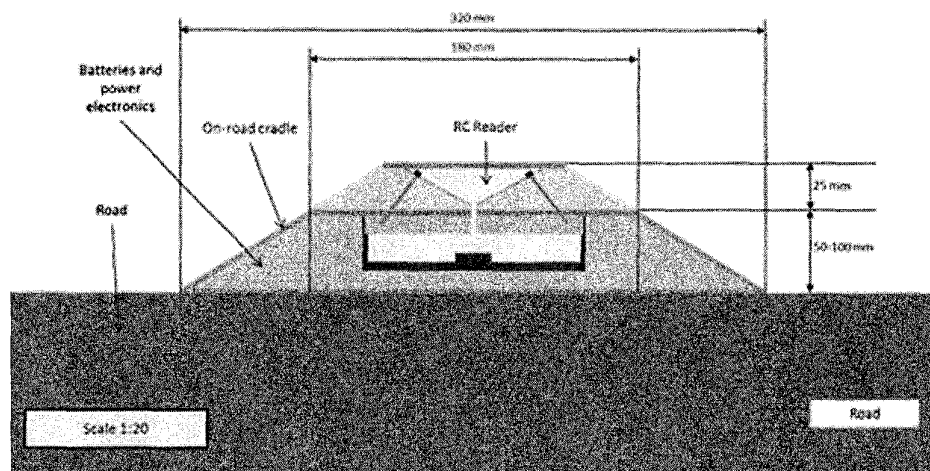


Figure 12 – annotated cross-sectional view of the proposed antenna structure etc in Figure 11

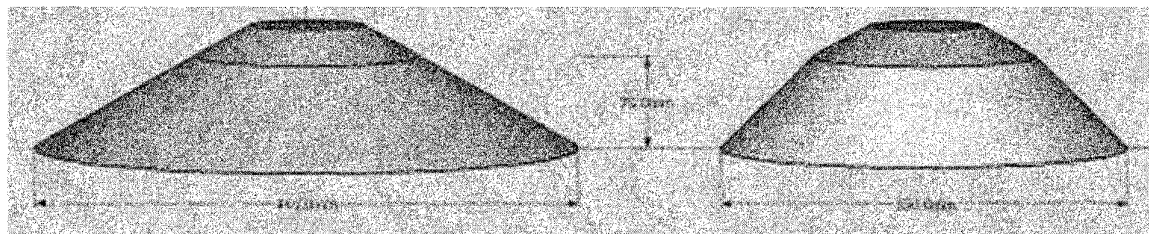


Figure 13 – possible different shapes/configurations for the partially conductive on-road cradle which forms part of the antenna design/structure for on-road applications/deployments

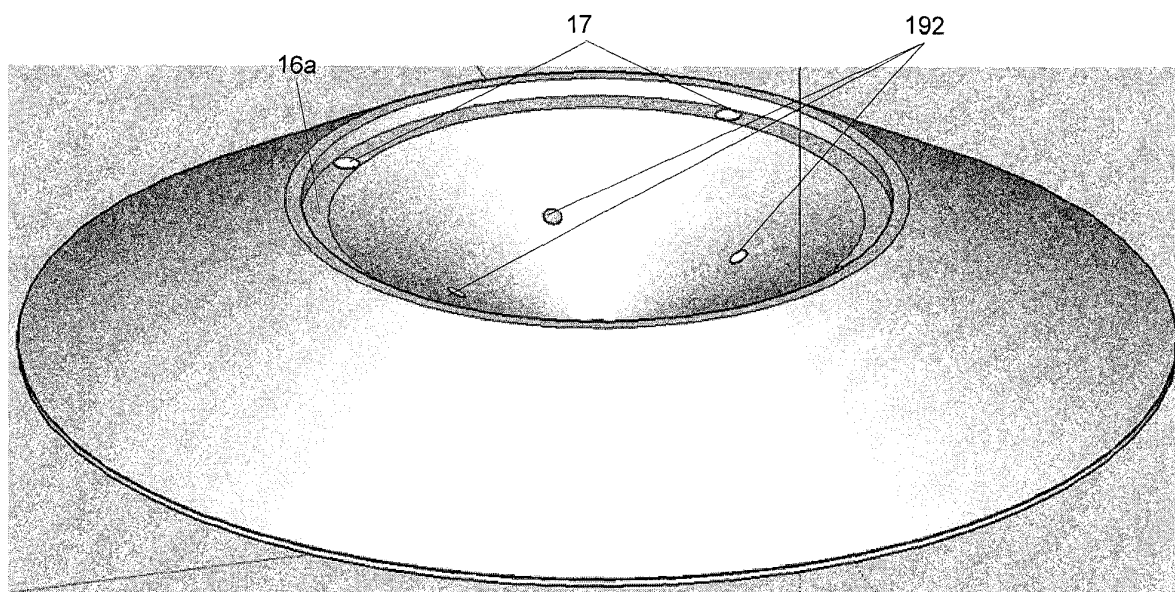


Figure 14 – schematic representation of the possible shape and configuration of the main frusto-cone body of the antenna structure

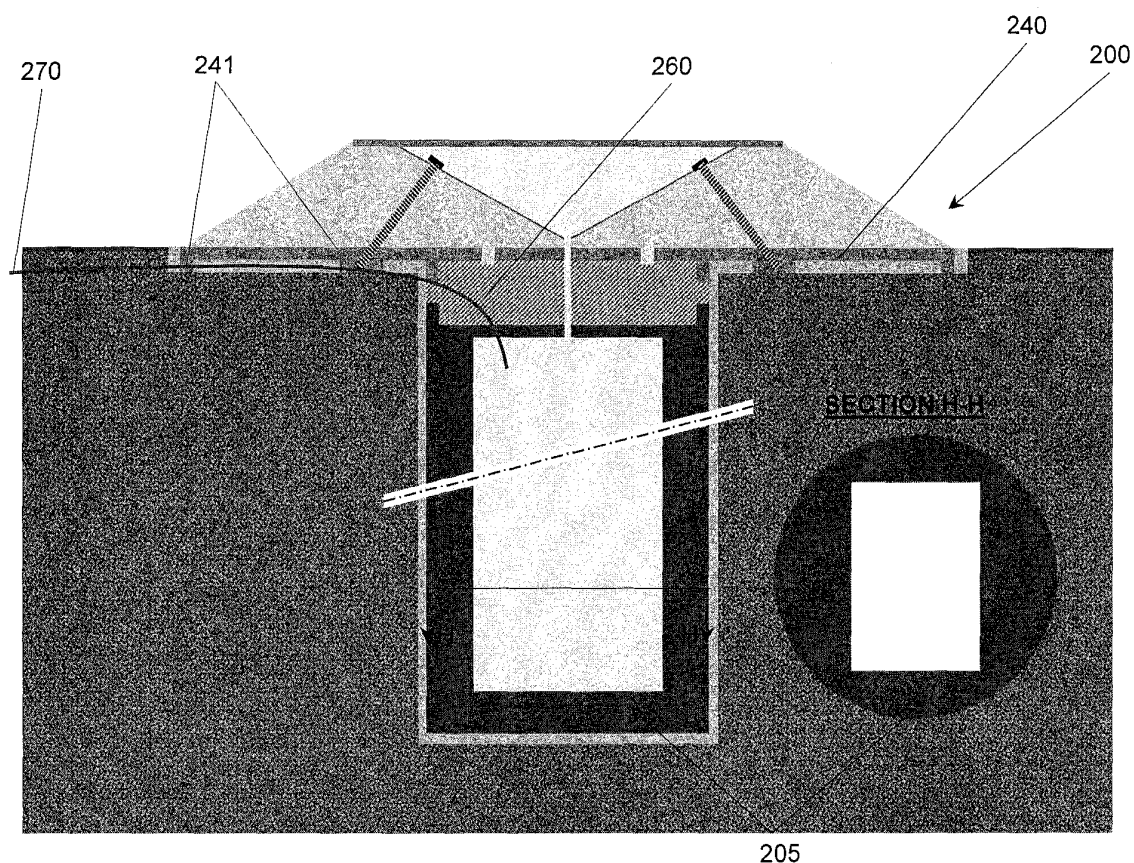


Figure 15 - cross-sectional view of a slight alternative or variant on the proposed antenna structure, also incorporating other reader equipment (i.e. in addition to the basic antenna structure), in an in-road application

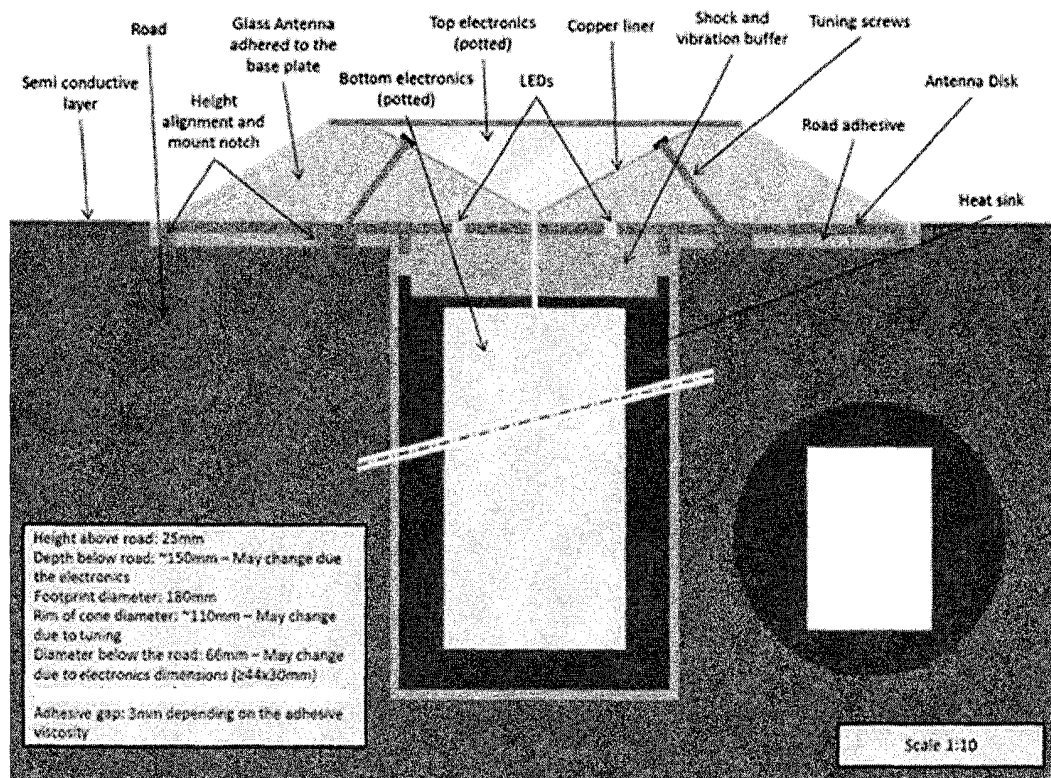


Figure 16 - annotated cross-sectional view of the slight alternative or variant antenna structure etc in Figure 15

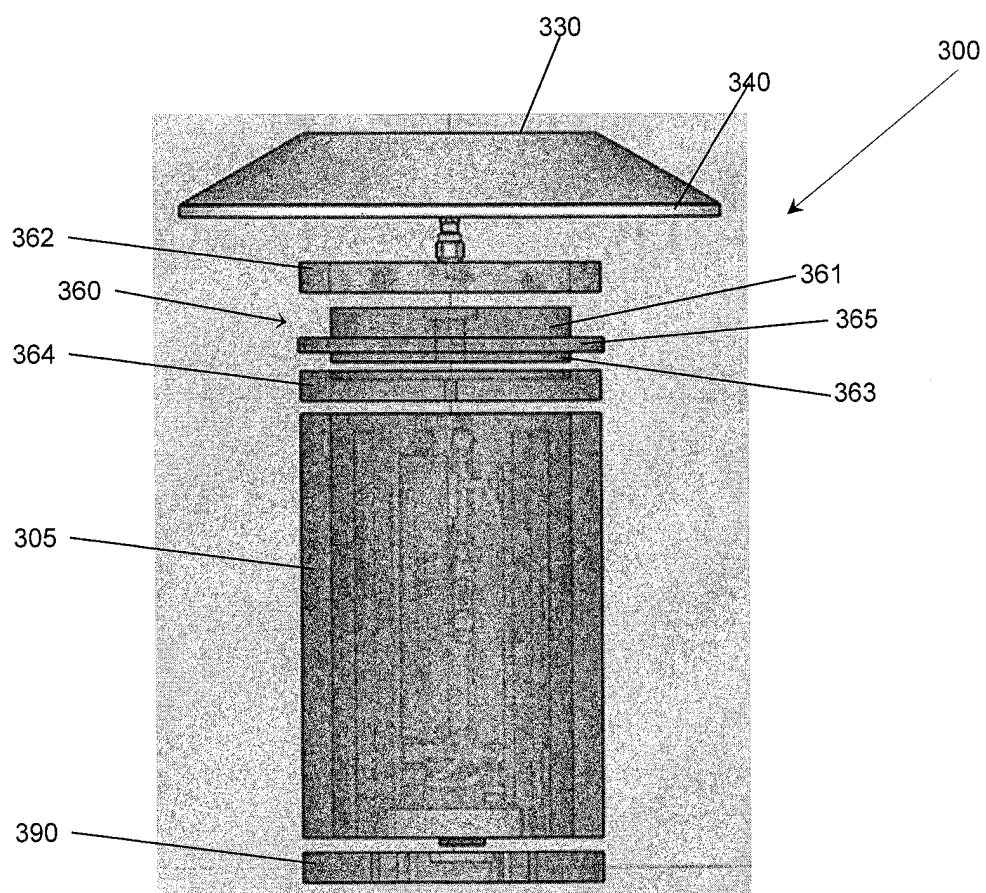


Figure 17 – side-on and partially exploded pictorial view of another slight alternative or variant on the proposed antenna structure and other reader equipment intended for use in an in-road application

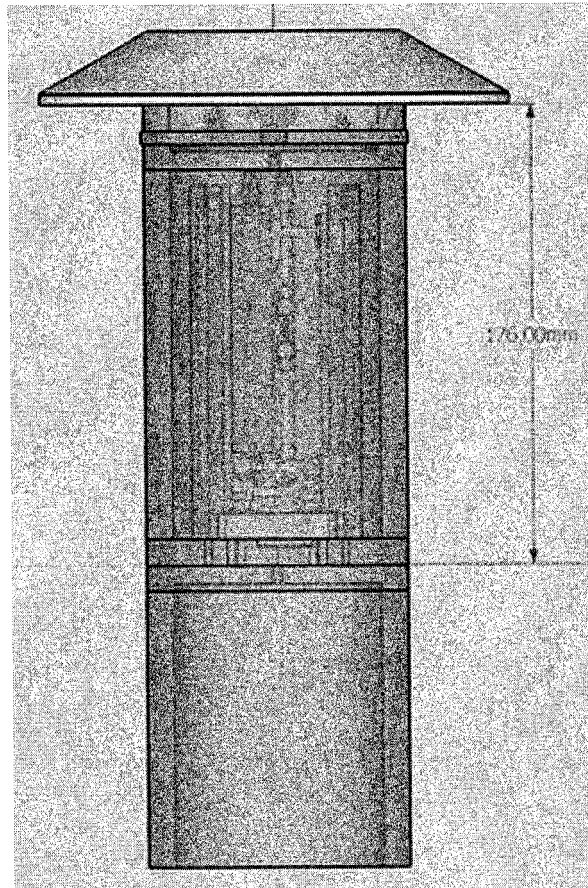


Figure 18 - side-on pictorial view of the slight alternative or variant on the proposed antenna structure etc in Figure 17

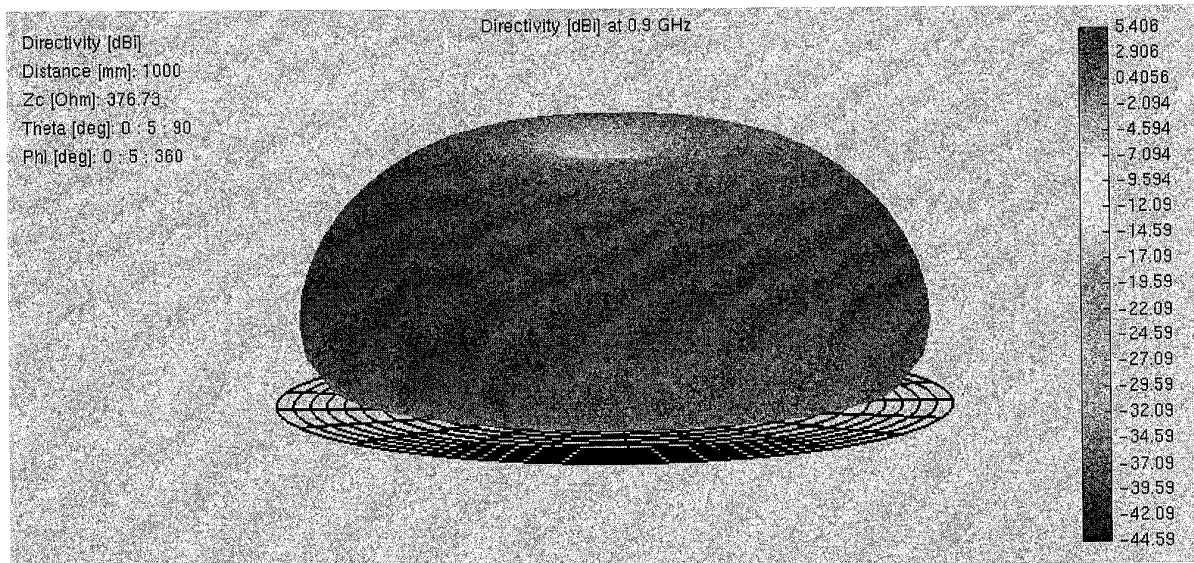


Figure 19 - Perspective view of the plotted antenna radiation pattern shape and directivity, illustrating that the radiation pattern is omnidirectional in the azimuth (x-y) plane (i.e. in a plane parallel to the road surface if the antenna is in-road, for example)

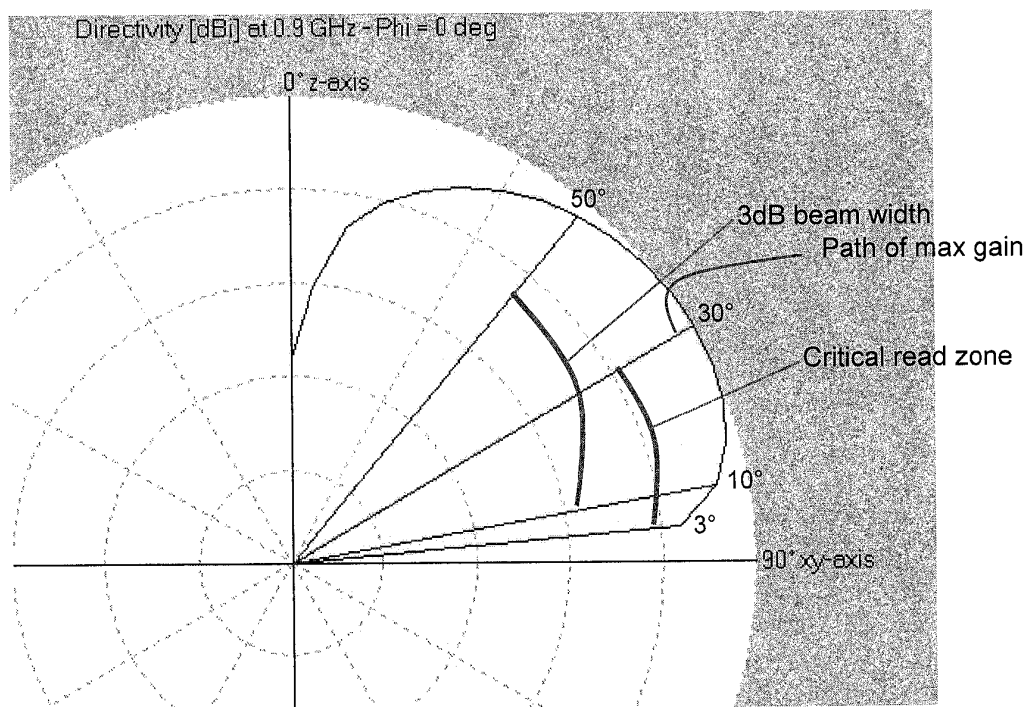


Figure 20 – Plot of one side (or one "lobe") of a cross-section of the radiation pattern as plotted in Figure 19, with the cross-section taken in a vertical (x-z) plane that extends through the centre of the radiation pattern in Figure 19, and also illustrating the following in the plane of this cross section: the elevation range of the critical read zone; the elevation of the path of maximum gain; the 3dB beam width; and the radiation null at 90° to the azimuth (x-y) plane

REFERENCES CITED IN THE DESCRIPTION

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