May 16, 1950 A. ALFORD 2,508,085

ANTENNA

Filed June 19, 1946

Fig. 1.

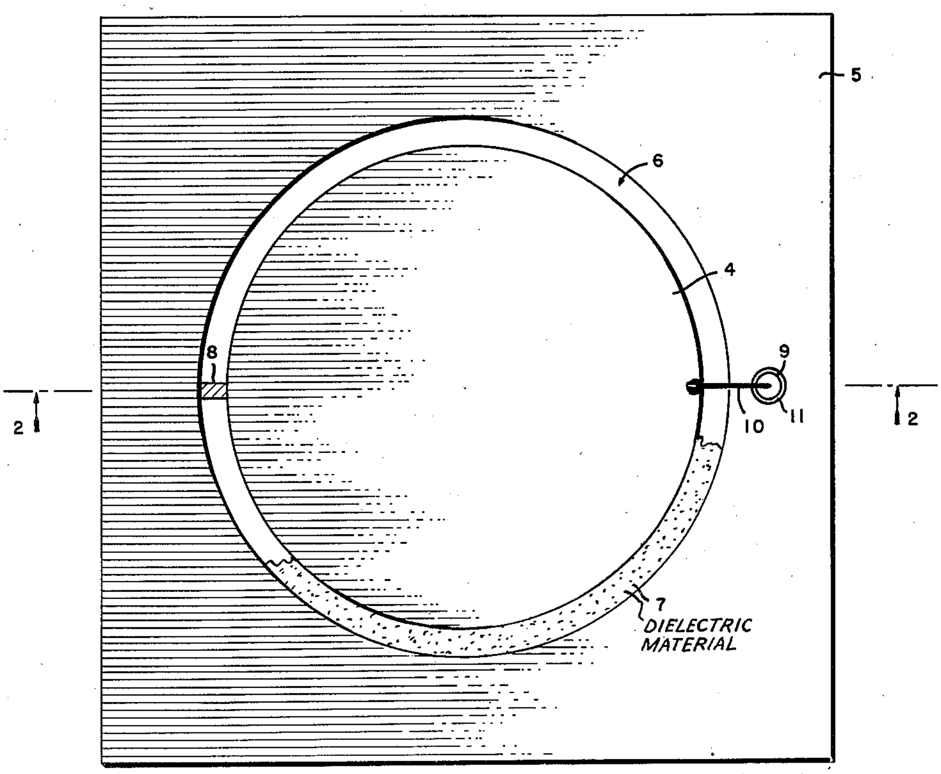


Fig. 2.

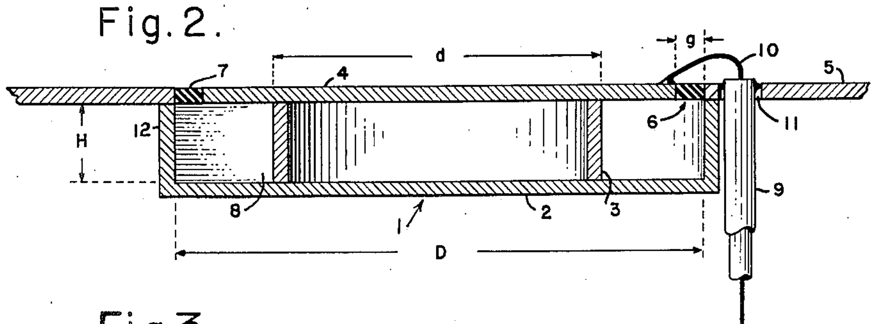
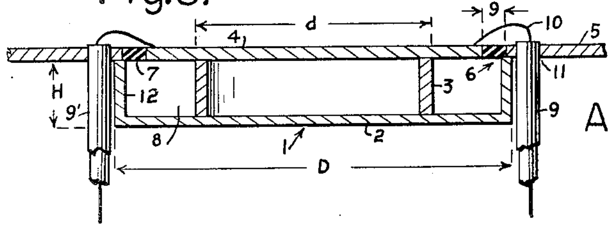


Fig. 3.



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Patented May 16, 1950 **2,508,085**

UNITED STATES PATENT OFFICE

2,508,085

ANTENNA

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Application June 19, 1946, Serial No. 677,655

13 Claims. (Cl. 250—33)

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This invention relates to new and useful improvements in antennas and particularly in mobile transmitting and receiving antennas for use on automobiles, buses, trains, aircraft and the like.

In the art of radio transmission where at least one station is mobile it is the general practice to employ vertically polarized radio frequency waves, since they have good field strength near to the ground.

A simple and widely used antenna for such waves is a vertical flexible whip antenna. This antenna has several serious shortcomings. In order to function efficiently it must be near to a quarter wave length long, a length at which it is resonant and has a narrow pass band. The pass band can be broadened by increasing the thickness of the radiating element but it then may cease to be a whip antenna and may present too rigid and hazardous a projection from a moving vehicle. The band width of an ordinary quarter wave whip antenna is of the order of ten per cent (.10) and, even if compensating circuits are used, this can only be increased to approximately twenty-five per cent (.25).

If the length of a whip antenna is reduced below a quarter wave length, then its radiation resistance will become materially lowered and its input impedance will include capacitive reactance. The expedient of tuning out this reactance with a coil will further decrease the efficiency of the antenna, and its already small band width.

Tilting a vertical whip antenna away from its perpendicular position, so as to lower the height of its tip, will diminish both its band width and radiation resistance.

At the relatively high frequency of 156 mc. a quarter wave length whip would be all of 16 inches long. A 16-inch protrusion from the top of a vehicle as high as a bus, or a truck, or a railroad car can be very troublesome. Such vehicles frequently are built nearly as high as the minimum head room tolerance legally permitted for bridges, tunnels, viaducts and terminals. Moreover, in certain areas such obtrusions would most likely encounter low hanging branches of trees.

Foldable mounting of a whip antenna to avoid overhead obstacles will make continued use of the associated radio equipment impossible. Furthermore, such a mounting, as well as one permitting the whip antenna to tilt when striking an object, will necessitate complicated and ex-

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pensive flexible feed line means and will add to servicing requirements.

A whip antenna attached to some part of a vehicle below the level of the roof, such as on a running board or bumper, will always be masked in some direction by the body of the vehicle.

Another possible objection to whip antennas is that they are conspicuous and easily identified and may, therefore, constitute an obvious clue to the presence of radio equipment in a vehicle and to the type of vehicle it is, for example, that it is a special police car.

The protrusion of a whip antenna is especially objectionable on an aircraft for the additional reasons that at ordinary high speeds it will produce substantial drag while at very high speeds its drag will attain such an inordinately large magnitude that it may either break off the antenna or damage the aircraft.

Among the objects of this invention are to provide a vertically polarized transmitting or receiving antenna which has a band width of 1.2 and substantially circular radiation patterns in horizontal planes, which antenna is very compact and therefore will, when installed on a vehicle, present no protrusion whatever.

With this object in view I provide a hollow conducting body, such as a metal cylinder, which is connected with, and is preferably carried by, a conducting surface. The body forms a transmission line with said surface which may be the roof of a vehicle, a wing of an airplane, etc.

In accordance with one feature of the invention, the transmission line is formed by a gap between the inner side of an edge of a hollow conducting body, such as a cylinder, which is completely within the vehicle, and the perimeter of a portion of a flat conducting surface constituted by part of a surface of the vehicle surrounded by said edge, the feeder being connected with the surface and the body near said gap.

According to another feature of the present invention, when the hollow conducting body is so proportioned that the area of an axial cross section of the enclosed space is of the order of one-third of one-thousandth of a wave length squared, then the antenna satisfies the above-mentioned objects.

Reference is made to my copending application U. S. Serial No. 669,758, filed May 15, 1946, although parts of its disclosure will be repeated for the convenience of the reader and to facilitate the understanding of the present invention.

Other objects, features and advantages of this invention will become apparent to those familiar with the art from the following description, and the appended claims and drawings in which:

Fig. 1 is a top plane view of the radiating element of one embodiment of the antenna;

Fig. 2 is a transverse cross sectional view of the antenna; and,

Figure 3 shows a section of a modification of the invention in the same relation as in Figure 2.

The antenna shown in the drawing consists of a cylindrical body element 1, which may be a metallic casting or spinning shaped like a pie plate. This element has a bottom disc 2, and a rim attached thereto, which bears the numeral 12. The cylinder is provided with a tube 3 which is mechanically attached to inside surface of bottom 2 at substantially its center. In practice tube 3 may be formed as an integral part of element 1, 2. Tube 3 may be of metal and as a result will be conductive. However, the inside may be non-conductive without preventing this device from functioning. The outer surface of tube 3 is part of the inner area of the hollow cylinder and should be conductive as there must be a low impedance axial connection between the inner sides of surfaces at the ends of cylinder 1, 2.

Tube 3 is of such length and is so arranged that a disc 4 carried by its upper end is parallel with bottom disc 2 and lies in the plane of a large plate 5 with which the rim of cylinder 1, 2 is in contact and to which it may be fastened. The disc and plate constitute in effect one "ground" plane for the cylinder. The rim of the cylinder 1, 2 is evenly separated by gap 6 from the edge of disc 4. Gap 6 may be an air gap, but preferably it is physically sealed by a dielectric substance 7. Gap 6 is short-circuited by a radial metal plate 8 within the cylinder extending radially from tube 3 to rim 1 with its edges contacting discs 2 and 4.

The structure 1—4 may be described as a hollow body or cylinder which has its ends closed by disc 2 and the disc 4 which is part of the ground plane, and has a gap 6 of about the same diameter as the cylinder which returns on itself.

The hollow cylinder, as well as the other elements, may be made of solid sheet metal (or an equivalent such as solid sheet plastic including a conductive layer) and, accordingly, the inner and outer areas, will comprise wall surfaces physically unbroken (except for gap 6 in cases where it is air insulated). However, this physical continuity is not necessary, and the device will operate satisfactorily if made of wire screen or of perforated sheet metal if the openings are not too large with respect to one wave length corresponding to the highest operating frequency, e. g. not larger than $^{6}/_{100}$ of a wave length.

The antenna is energized over a coaxial transmission line having an outer conductor 9 and inner conductor 10. Inner conductor 10 is connected to the edge of the disc 4 and the outer conductor 9 is connected to the side wall of cylinder 1, 2 and also to plate 5 in which a hole 11 is formed for its passage. These connections are made at points opposite each other across gap 6 and this part of the gap is at a place on the side of the hollow cylinder which is diametrically opposite the position of short-circuiting bar 8.

When the antenna is energized the edges of gap 6 constitute a balanced transmission line. The hollow body portion of this antenna (which may be further described as surrounding and enclosing a toroidal space adjacent to gap 6) has distributed inductive reactance which is shunted across the transmission line formed by gap 6. The magnitude of this distributed reactance depends primarily on the area of a transverse cross section, taken in the plane of plate 8, of the toroidal space on one side of tube 3. This is the space between the inner surfaces of element 1, 2, the outer surface of tube 3 and the inside surface of disc 4. If the inside radius of the hollow cylinder is designated as D, the outer radius of the tube 3 as d, and the distance between the inner surfaces of bottom 2 and disc 4 as H, then this cross sectional area may be calculated by using the formula $A=(D-d)xH$. Certain cylinders which have been made and tested and which have proper magnitudes of distributed reactance to perform in a preferred manner in accordance with this invention, have such dimensions that, when converted into wave lengths, the area derived by solving the equation is of the order of one-third of one-thousandth of a wave length squared. To specific antennas were tested; in one $A=.00324\ \lambda^2$, and in the second it was $.00326\ \lambda^2$.

Short-circuiting plate 8 causes nearly complete reflection of incident waves traveling along gap 6 around both sides of the hollow cylinder toward it. The interference between incident waves and reflected waves results in a standing wave distribution of voltage across gap 6.

One minimum of voltage across the gap occurs at shorting plate 8; two maxima of voltage occur at points on opposite sides of disc 4 each of which is about midway between plate 8 and the feed point. Under certain conditions, two additional voltage minima, which ordinarily are undesirable, may occur on gap 6. They will be between plate 8 and the feed point and are likely to be near to, and on each side of, the feed point. A condition which may cause this is that the gap is too long (the circumference of disc 4) in proportion to the cross sectional area A and that, therefore, the velocity of propagation along the gap is not great enough for the gap length.

When the only voltage minima are at the shorting plate and the feed point, the voltage differences across gap 6, though they vary in magnitude, are in the same phase, and currents moving to and from the respective edges of gap 6 at different positions along the gap move symmetrically together. It has been empirically ascertained in actual tests, and it can be further demonstrated in other ways, that this inphase condition of the RF voltages across gap 6 and the circular shape of the radiating portions will cause this element to act as a horizontally omni-directional radiator of vertically polarized energy, assuming, of course, that disc 4 is parallel to the ground.

When undesired additional voltage minima occur on gap 6 between the feed point and plate 8, the phases of the RF voltages near those minima shift rapidly. This alters the current distribution pattern and results in asymmetry of the horizontal radiation pattern. The hollow cylinder should preferably be so proportioned that the distances from plate 8 to the first voltage minima (or to imaginary positions of the first minima constructively existing beyond the feed point) in each direction around disc 4 are equal to (or greater than) one-half of the circumference of disc 4.

The desired standing wave condition can be obtained even when each half of gap 6 is greater than $\lambda/2$ in length by sufficiently increasing the velocity of propagation along the gap. It can be increased substantially beyond the speed of light under certain conditions. This is controlled in part, within certain limits, by the cross sectional area described above and by the capacity per unit length between the edges of the gap.

A cross sectional area A=.00324 λ^2 together with a gap which is a small fraction of a wave length wide, e. g. of the order of .045λ wide, and which has one of its edges formed by a thin metal edge of disc 4, results in a velocity of propagation along the gap about 20 percent greater than the velocity in free space. This permits the use of a cylinder whose circumference is proportionally increased so that each half circumference is in the neighborhood of twenty percent more than a half wave length. The physical enlargement of the hollow cylinder with respect to the operating wave length, which is effected at the same time that undesired voltage minima are averted, will make its input impedance low enough to match a 50-ohm coaxial line. Thus, in addition to being compact and vertically polarized (when properly positioned with respect to the earth) the device requires no input transformer, making it an ideal coupling between a 50-ohm cable and the radiation resistance of space. One example of satisfactory proportioning of the several parts of the antenna may be offered by suggesting the following dimensions: D=.485λ, d=.3027λ, H=.071λ, and the gap width, g=.0142λ. These dimensions are, unless otherwise specified, expressed in terms of a wave length corresponding to the middle frequency of the operating band of frequencies. In one embodiment which was tested the midfrequency used was 1345 megacycles (λ=8.78″) and in that embodiment D=4½″; d=2⅝″; H=⅝″; and g=⅛″.

It should be borne in mind that the controlling geometric characteristic for the hollow cylinder, if the gap be presumed to have a fixed amount of distributed capacitance per unit length, is the cross sectional area described above. For example, d may be made larger with respect to D, thus reducing the value of D−d, but by increasing H by an easily determined amount, A will remain substantially the same and the standing wave condition and input impedance will be substantially unchanged.

Moreover, the hollow cylinder may be shaped so that its toroidal cross section on each side of the central tube is of other shapes than rectangular. This cross section may be circular, elliptical or irregularly shaped. In the same manner, it is not essential that cross sections of the hollow cylinder, taken in planes perpendicular to the axis of tube 3 should be circular. The important factors are that A be generally of the order of one-third of a thousandth λ^2, and that the exact value of A can vary depending upon the capacitive characteristics of the gap. In this application, and in particular in the claims, the word "cylinder" is used in a broad sense to indicate all hollow structures which electrically conform with the requirements of the invention, though they are not necessarily geometric cylinders having circular transverse cross sections.

The antenna produces substantially circular radiation patterns in horizontal planes, i. e. planes perpendicular to the axis of tube 3, and figure-of-eght vertical patterns in planes passing through that axis. The band width of the antenna is of the order of 1.2. The band width is commonly defined as a ratio of the highest frequency to that of the lowest frequency transmitted.

Obviously the antenna described above may be employed at frequencies and for purposes other than those given above by way of exemplification.

The conductive ground plane 5 may be a metal sheet attached to the roof of a vehicle, or to the wing of an airplane, or may form an integral portion thereof. It does not necessarily have to be perfectly flat. As an analogous example, it is known that a ground plane of finite physical size, above a certain limit, will behave like an infinite reflective plane and affect the radiation patterns of any radiator associated with it. A physically infinite plane is unnecessary. Similarly, a physically substantially flat plane will, at ordinary wave lengths, behave like a perfectly flat ground plane. Therefore, the curved metal roof or other surface of a vehicle may serve as ground plane 5.

It is obvious that ground plane 5 will affect the vertical distribution pattern of the radiator. However, this is not a disadvantage. If the antenna is close to the earth, e. g. on the roof of a bus, the areas masked by the ground plane will be unimportant. Even if the antenna is not close to the earth, i. e. if it is in an airplane, the vertical masking is not a disadvantage. For in an aircraft installation the radiating element could be installed on the underside of the surface acting as a ground plane. The important patterns, those in horizontal planes, are not appreciably affected.

The non-conductive space inside the hollow cylinder need not necessarily be filled with air. Instead, other dielectrics may be used including dielectrics which are gases, liquids and solids. However, substances whose dielectric constants differ from that of air will increase the distributed capacity and reduce the velocity of propagation. The proportions of the hollow cylinder should, therefore, be somewhat altered. Other changes and adaptations will readily suggest themselves to those skilled in the art.

The element described in the present application as radial plate 8 need not in practice have this exact structure nor be of exactly zero impedance. The terms "short circuit" and "short-circuiting element" as used herein, both in the description and in the claims, are intended to include low impedance terminations, such as a short-circuiting wire across gap 6 or a similarly connected coil having low inductance. The short circuit or short-circuiting element must only be capable of producing a substantial percentage of reflection.

Moreover, it is also within the scope of this invention that another feed line 9′, Figure 3, be connected at the point designated for the location of and in lieu of the shorting element. The desired standing wave condition on the gap or slot can be produced with this two feed point arrangement just as well as by one in which there is a single feed point and a reflection point or low impedance point diametrically opposite to it. It has been found that usually a double feed affects the operating characteristics of the antenna by broadening the operating frequency band.

It is not essential that disc 4 should be mechanically separate and distinguishable from dielectric substance 7 which, in the embodiment shown in the drawing, fills gap 6. Instead, the whole open end of hollow cylinder 1, 2 may be closed with a single disc of dielectric material, such as certain plastics, modified in its center by a conductive element to be the electrical equivalent of disc 4. For example, a conductive plating, netting, coating, or paint could be placed on either surface of the single dielectric disc, over an area which would correspond to disc 4 in size and location. In fact a wire netting could be molded into the single dielectric disc to take the place of disc 4. Accordingly, it is intended herein, and in particular in the claims, that the word "disc," as used in this context, refers to an electrically effective disc and includes alternate physical structures such as the ones described above

What I claim is:

1. An antenna comprising a metal cylinder open at one and closed at the other end, said cylinder having a circular cross section of a diameter of about one-half of a wave length corresponding substantially to the center frequency of the operating band, a metal disc of smaller diameter, a metal tube having one end fastened to the closed end of the cylinder and the other end to the disc and holding the disc in the one plane with the edge of the open cylinder end, the circular gap between the edge and the disc being a fraction of a wave length wide, a lead-in line having one conductor connected with the disc and the other conductor with the cylinder at the gap, and a short circuit means across the gap at a point diametrically opposite the points of connection of the lead-in line.

2. The antenna according to claim 1, and in which the cross sectional area of the toroidal space within the cylinder taken in a plane containing the axis of said tube and on one side thereof is substantially one-third of one-thousandth of a wave length squared.

3. An antenna comprising a metal cylinder open at one and closed at the other end, said cylinder having a circular cross section, a metal disc, a metal tube having one end fastened to the inside surface of the closed end of the cylinder and the other end to the disc and holding the disc in one plane with the edge of the open cylinder end but spaced therefrom to form a circular gap between the edge and the disc, a lead-in line having one conductor connected with the disc and the other conductor with the cylinder near said gap, and a short circuit means across the gap at a point diametrically opposite the points of connection of the lead-in line.

4. An antenna comprising a metal cylinder $.07\lambda$ high, where λ corresponds substantially to the center frequency of the operating frequency band open at one and closed at the other end, said cylinder having a circular cross section of $.48\lambda$ diameter, a metal disc of $.4566\lambda$ diameter, a metal tube having an outer diameter of $.30\lambda$ having one end fastened to the inner surface of the closed end of the cylinder and the other end to the disc and holding the disc in one plane with the edge of the open cylinder end, the circular gap between the edge and the disc being $.0142\lambda$ wide, a concentric transmission line having its inner conductor connected with a point in the edge of the disc and its outer conductor connected with the cylinder near said gap at another point opposite to said first-mentioned point, a short circuit means across the gap at a place diametrically opposite to the points of connection of the concentric transmission line.

5. In an antenna, a hollow cylinder having closed ends and a gap formed in the closure of one end having the form of a closed loop, an internal connection between the ends near the axis of the cylinder, means for feeding the cylinder near the gap connected thereto near the gap, and a short circuit means across the gap, the distances between said short circuit at the gap and the points of feed at the gap in either direction along the gap being equal to or less than

$$\frac{\lambda}{2}$$

where λ, corresponding to the mean operating frequency is corrected for the velocity of propagation along the gap producing minima on the gap only at the short circuit and near to the connection of the feed means.

6. In an antenna, a hollow cylinder having closed ends and a gap formed in the closure of one end having the form of a closed loop, a connection between the ends near the axis of the cylinder, means for feeding the cylinder near the gap, and a short circuit means across the gap, the distances between said short circuit at the gap and the points of feed at the gap in either direction along the gap being equal to or less than

$$\frac{\lambda}{2}$$

where λ, corresponding to the mean operating frequency is corrected for the velocity of propagation along the gap producing voltage maxima on the gap between the short circuit and the feed point which are substantially midway between the short circuit and the feed point.

7. In an antenna, a hollow cylinder having closed ends and a gap formed in the closure of one end having the form of a closed loop, a connection between the ends near the axis of the cylinder, means for feeding the cylinder across the gap, and a short circuit means across the gap the distance along the gap from the short circuit to the feed point in either direction being less than the distance necessary to produce a voltage minimum on either side of the feed point.

8. In an antenna, a hollow conducting cylinder, a closure for one end of the cylinder, a closure for the other end of the cylinder extending beyond the side wall and having a gap which is substantially concentric with the cylinder and within the circumference of the cylindrical wall, means providing an internal connection forming a continuous wall between the closures near the axis of the cylinder, and means for feeding the cylinder across the gap.

9. In an antenna, a hollow conducting body having an edge, means providing a flat conducting surface extending in the same plane as said edge and connected thereto, and having a non-conductive gap formed in said surface adjacent to and within the boundary formed by the edge forming a transmission line which has the form of a circle, a feeder connected with the body and the surface at the transmission line, and low impedance radio frequency energy reflecting means connected across the line diametrically opposite the feed point.

10. In an antenna, a hollow conducting body having an edge, means providing a flat conducting surface extending in the same plane as said edge and connected thereto, and having a non-conductive gap formed in said surface adjacent to and within the boundary formed by the edge forming a transmission line which has the form of a circle, a feeder connected with the body and the surface at the transmission line, and a second feeder similarly connected across the line diametrically opposite the feed point.

11. An antenna having means providing a flat conductive surface having a non-conductive gap formed therein, having the form of a loop, a hol-

low conductive body having an outer wall conductively joined to said means on the outer side of the gap and an inner wall having two ends, one end conductively joined to the outer wall on its inner side and the other end conductively joined to the surface on the other side of the gap forming a chamber, with the edges of the material adjacent the gap forming a transmission line, and a feeder connected with the transmission line at points on opposite sides of said gap.

12. The antenna according to claim 11 in which the transmission line forms a circle.

13. The antenna according to claim 11 in which the transmission line forms a circle and in which short circuit means are connected across the transmission line substantially opposite the connection of the feeder.

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