June 2, 1953 F. J. LUNDBURG ET AL 2,640,930

ANTENNA ASSEMBLY

Filed Jan. 12, 1950 3 Sheets-Sheet 1

Fig. 1.

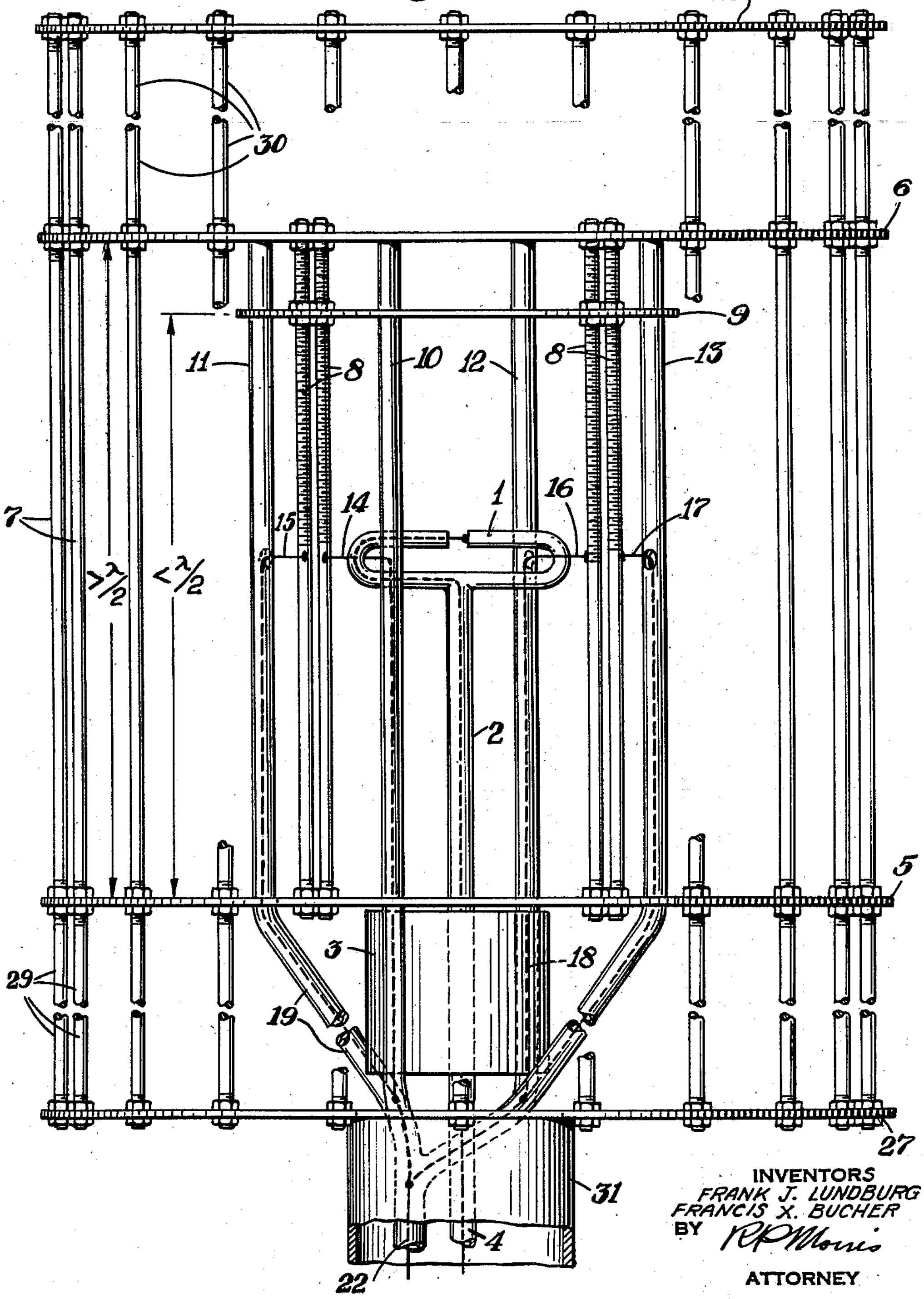



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Fig. 2.

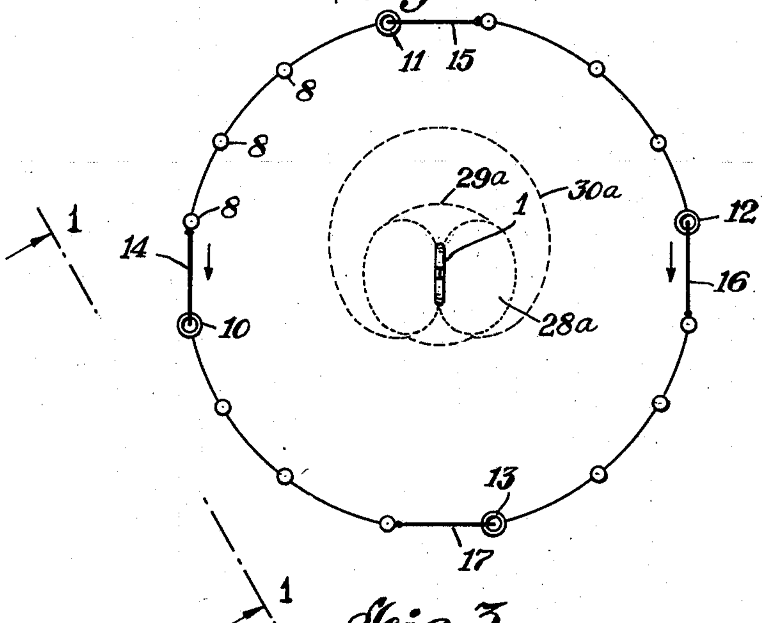


Fig. 3.

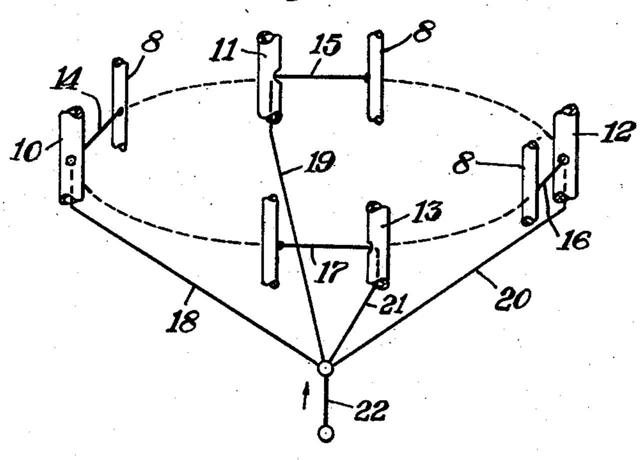


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Fig. 4.

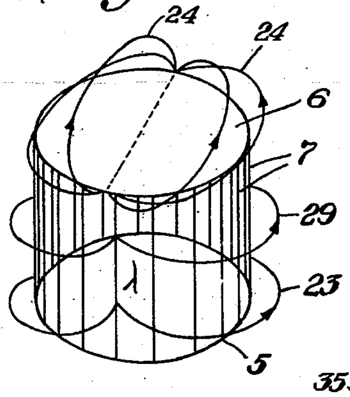



Fig. 7.

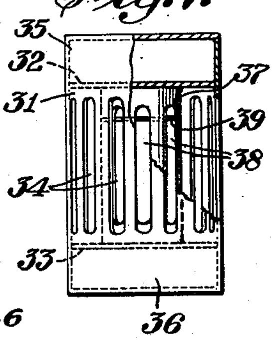



Fig. 5.

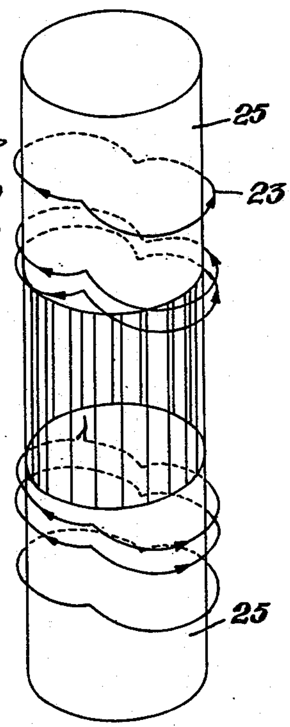
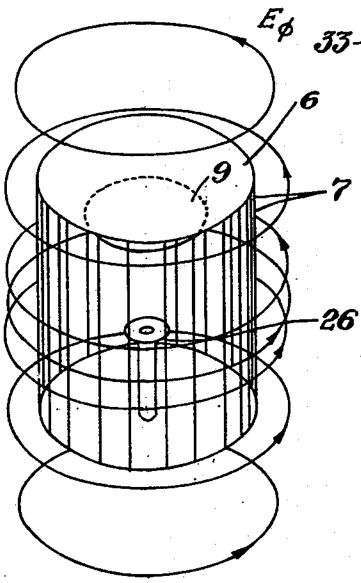



Fig. 6.





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# UNITED STATES PATENT OFFICE

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## ANTENNA ASSEMBLY

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15 Claims. (Cl. 250—33.51)

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This invention relates to antennas and more particularly to an antenna assembly designed for providing an omnidirectional and rotating figure-of-eight pattern.

Various systems have been proposed for providing omnidirectional radio beacons. In general these systems may comprise a directive antenna producing a normal figure-of-eight pattern and an omnidirectional antenna or radiator, the energy of which combined with the directive figure-of-eight pattern will produce a unidirective pattern of generally cardiodal form. If then the pattern is caused to rotate at a given rate the null point of the cardiod may be detected and the direction line obtained thereby which may serve to guide craft along a given course toward or away from the beacon. In order that a continuous indication be provided it is necessary that rotation of the directive pattern be at a fairly high rate. Thus at the normal frequencies used for navigation purposes the directive antenna structure is too large to be readily rotatable at the required speed.

Furthermore, in most antenna systems designed for a single polarization, horizontal polarization for example, there exists an accompanying radiation polarized at right angles thereto which may cause errors in the directive pattern produced in the receiving arrangement. To avoid the difficulty of rotating large structures resort has been made to goniometers wherein a coil is rotated in the field of energy produced by two right angular fixed antenna systems so that an effective rotation of figure-of-eight radiation pattern is provided. However, in such a case there is present still certain errors introduced by this expedient.

It is an object of our invention to provide an antenna assembly for omnidirectional beacon use wherein the rotated directive pattern is produced by the rotation of a small antenna such as a dipole antenna unit.

This dipole is made of small dimensions relative to a half wave length at the operating frequency, so that it may be easily rotated and associated therewith, and is provided with a radiating structure to provide the desired omnidirectional pattern and resonator structure to furnish the desired impedance characteristics of the system and to purify the polarization.

According to a feature of our invention a radio assembly is provided comprising a dipole antenna of small length relative to a half wave length of the operating frequency, a resonator effectively open to radiation about the periphery

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of the dipole and enclosing the antenna and an omnidirectional antenna mounted symmetrically about the dipole radiator. The resonator is in the form of a cage made of conductive plates which may be interconnected by vertical rods or may be interconnected by a conductive sheet provided with vertical slots around its periphery. The omnidirectional radiator comprises radiating elements arranged symmetrically about the dipole and cophasally energized and may be positioned between adjacent rods or conductive portions of the cage. The resonator structure itself may produce polarization errors of its own and to avoid these extensions may be provided, as continuous conductive sheets or as cage structures of similar construction to the first one named, in the form of additional sections added either above, or above and below the cage, further to reduce polarization errors. The resonator structure may not completely compensate the capacitive reactance of the short dipole so there may be provided within the first cage a second cage structure comprising a plurality of spaced rods or a cylinder with a plurality of spaced slots about said dipole mounted on a diameter smaller than the first cage. On the rods of this smaller cage is arranged a conductive plate which may be adjusted to provide an inner resonator of inductive reactance adjustable to the desired value to compensate the capacitive reactance of the short dipole.

While we have set forth the principal objects and features of our invention, a better understanding of the invention and more detailed disclosure of the objects and features thereof may be had from the particular description thereof made with reference to the accompanying drawing, in which:

Fig. 1 is an illustration of the physical construction of an entire assembly incorporating the features of our invention as viewed along lines 1—1 of Fig. 2, with certain of the elements omitted for clarity of illustration;

Fig. 2 is a diagram more clearly illustrating the antenna construction itself with respect to its functional operation;

Fig. 3 is a diagram illustrating the manner of feeding the omnidirectional antennas of the assembly;

Figs. 4, 5, and 6 are diagrammatic showings illustrating how polarization errors arise and are compensated; and

Fig. 7 illustrates a modified physical construction of the antenna assembly.

Referring to Fig. 1, a folded dipole unit 1 is illustrated which may be fed by some form of feeding arrangement shown at 2 and may be coupled through a rotary coupler 3 to coaxial feed line 4. Adjacent the base of the coupler 2 is provided a first conductive plate 5 and spaced there-above a second conductor plate 6. The plates 5 and 6 are interconnected by a plurality of rods 7, which form effectively a resonator structure which may be considered as a radiator excited by dipole antenna 1. Preferably the spacing between plates 5 and 6 is made slightly greater than $\lambda/2$ at the center frequency. Rods 7 are spaced sufficiently close to one another around the periphery to provide an effective vertical polarization screen or filter so that only the horizontally polarized energy passes. Each two adjacent rods 7 form effectively the boundaries of a short section of wave guide which act as the ultimate radiators. As it is longer than a half wave length it will freely pass radiated energy in the $TE_{10}$ mode. By its resonator action the resonator effectively provides an impedance match with the outer atmosphere or ether.

Since antenna 1 is short with respect to a wave length it will have a low radiation resistance and high capacitive reactance and hence would be inefficient. The resonator formed by plates 5 and 6 and rods 7 does not fully overcome these deficiencies. In order to load this antenna properly to achieve the desired compensation a second or inner cage is provided by a plurality of rods 8, arranged on a smaller diameter and concentric with circle of rods 7, extending between plates 5 and 6. A movably adjustable plate 9 is provided mounted on rods 8. This plate may be adjusted to provide the desired resonance loading for the dipole 1 to compensate the capacitive reactance and obtain the desired radiation efficiency. Plate 9 and rods 8 together with plate 5 form a second resonator about dipole 1. When plate 9 is properly adjusted to compensate the capacitive reactance of dipole 1, the spacing between plates 9 and 5 will be less than $\lambda/2$ at the mid-operating frequency so that the resonator action will be inductive. Here again the space between adjacent rods 8 and plates 9 and 5 bounds effectively a short section of wave guide. This wave guide will have a filtering action tending to reduce the amount of energy radiated from the resonator but since the length of wave guide is very short as determined by diameter of rods 8 this effect will be negligible. After adjustment of this resonator structure there may still be a slight mismatch between the entire antenna assembly and transmission line 4. In this case a matching impedance may be bridged on the line and may be housed for example within the rotary coupler 3. Certain of the rods 8 may be made in the form of hollow conductors as indicated at 10, 11, 12 and 13. These may serve as coaxial transmission lines for feeding respective antenna units 14, 15, 16 and 17, Figs. 2 and 3, which may be mounted between the respective hollow conductors and the next adjacent rods 8. Separate feed lines 18, 19, 20 and 21 may be provided each of substantially equal length to supply to these antenna units energy in cophasal relation coming in over a common feed line 22.

The structure so far described will provide a rotatable figure-of-eight and omnidirectional pattern which will be generally horizontally polarized. However, due to the resonator action itself a certain amount of vertical polarization may be radiated from the structure due to the radiation about the upper and lower ends of the resonator cage. An understanding of how this vertical polarization arises and how it may be compensated may be had by reference to the diagrammatic illustrations of Figs. 4, 5 and 6.



Turning first to Fig. 4, the radiation coming from the resonator formed by plates 5 and 6 and rods 7, will be in the general form shown by lines 23 and lines 24 of Fig. 4. It will be seen that the radiation lines of electric force which close around the portion of the resonator defined by rods 7 are purely horizontally polarized. However, some of the energy lines as shown at 24 will close over the ends of the resonator structure and these lines since they are in the vertical plane or have components in this plane will produce accompanying vertical polarization components. It has been found that by adding extensions to the main resonator cage as indicated at 25 of Fig. 5 this accompanying vertically polarized energy can be reduced to an inconsequential value. It is believed that this is caused as illustrated in Fig. 5 by forming such an extension so that additional lines of force tend to terminate around the cylindrical resonator. Since the radiation from the antenna is very large this energy will be greatly attenuated as it travels up or down the extensions so that any line of force on the end plates will produce negligible vertically polarized components.

Fig. 6 illustrates the effect of the lines of electric field from the omnidirectional loop 26 shown generalized instead of by separate conductors 14—17 as in Figs. 1–3. So long as the loop elements are made so short that energy fed thereto is substantially constant throughout the length of these radiators substantially pure horizontal polarized energy will be radiated therefrom. As long as the conditions described obtain with respect to the omnidirectional radiator this radiator may be mounted anywhere about the dipole either within the resonator cages or outside thereof. Should there exist any vertically polarized components in the omnidirectional radiator it is desirable further that this radiator be mounted within the cage resonator structure so that such components may be effectively filtered out.

Turning back to Fig. 1, these extensions are illustrated as plates 27 and 28 interconnected with plates 5 and 6 respectively by means of rods 29 and 30. The entire antenna assembly may be mounted directly on the ground or on any suitable support as indicated at 31.

While Fig. 1 gives an idea of a structure in accordance with our invention, a better understanding of the feeding of antenna units 14, 15, 16 and 17 may be had by reference to Figs. 2 and 3. In these figures it will be noted that the inner conductors and transmission lines 18, 19, 20 and 21 extend up through rods 10, 11, 12 and 13 and out through openings therein across to the next adjacent rods 8 of the assembly. In this manner the feeding can be accomplished relatively simple. The pattern from the dipole 1 is indicated generally at 28*a*, Fig. 2, while the omnidirectional pattern from elements 14, 15, 16 and 17 is indicated at 29*a*. These two patterns combined provide a cardiod pattern and illustrated at 30*a*. By simple rotation of dipole 1 the cardiod pattern may be rotated at any desired rate.

In an actual model of the antenna designed for operation in the 700 to 800 megacycle range dipole antenna 1 was made substantially a tenth of a wave length long and was designed for coupling to a motor for rotation at 1800 R. P. M. The inner cage was made of a diameter in the order of one half wave length at the center frequency and the spacing between rods 7, 22, 25 and 26 was made in the order of one tenth wave length. It will be recognized that only the dipole unit itself need be rotated, the remaining part of the structure being fixed. This arrangement was found to provide a substantial impedance match between the dipole unit and a 50 ohm line feeding the dipole; the normal radiation resistance of the dipole without the load resonator cage being in the order of 2-3 ohms. This antenna was found to operate between 730-785 megacycles with no greater than a 2:1 mismatch of impedance.

A similar structure designed for operating in the very high frequency range between 112 and 118 megacycles and rotated at 1800 R. P. M. has been found to provide satisfactory operating results showing an improvement of several hundred per cent over that provided by the conventional antenna structures used for the omni-range beacons.

In Fig. 7 is shown a modification of the antenna wherein the outer edge structure comprises a cylindrical sheet 31, terminated at its ends by plates 32, 33. A plurality of slots 34 are provided in the surface of sheet 31. These slots should be dimensioned in accordance with the openings between the rods as described in connection with Fig. 1. Extensions 35 and 36 may be provided above and below the resonator cage structure, these extensions being shown as extended cylindrical sheet portions. No slots need be provided in these extensions as their purpose will be fulfilled as well without them. In fact the extensions shown in Fig. 1 could as well be continuous sheets, but the rod construction is more convenient there. Moreover, the open construction provides a lighter weight structure less subject to wind pressures.

An inner cage structure is shown at 37 which may also be in the form of a cylindrical sheet provided with slots 38. The adjustable wall portion may be in the form of a shorting plunger 39 which may be adjusted to render the desired portions of slots 38 effective. The dipole radiator within cage 37 may be the same as in Fig. 1, and the omni-directional antenna may be formed by conductors bridged across certain of slots 38 and fed as in Fig. 1. It will be clear that if desired any combination of the rod construction of Fig. 1 and the sheet construction of Fig. 7 may be used.

While we have described above a particular example of our invention, it will be readily recognized that many changes may be made therein without departing from the spirit of our invention. For example, various types of omnidirectional radiators may be used with this system, it being merely necessary that proper horizontal polarization be maintained and that the omnidirectional antenna is not mounted in such a position as to make undesirable variations in the directive radiation pattern. Furthermore, the various wave lengths mentioned are not to be considered to be limitations of our invention and the principles thereof are applicable to any wave length. Moreover, a wide variation may be provided in the length of the dipole radiator, it being borne in mind that the efficiency of the antenna system and its radiation resistance is to be adjusted by means of a resonator having dimensions suitable to provide the necessary loading. Since a short dipole radiator has a larger capacity reactance, the resonator structure will generally be predominantly inductive to compensate the capacitive reactance and reduce the impedance to a real impedance. Any residual mismatch can be taken care of by any known type of impedance matching device. Also the dipole need not be of the folded type but may be of any desired construction.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention.

We claim:

1. A radio antenna assembly comprising a radiating dipole antenna of small length relative to half a wave length at the operating frequency to provide a directive figure-of-eight pattern, a resonator effectively open to radiation about one periphery thereof effectively enclosing said antenna, and an omnidirectional antenna mounted symmetrically about said dipole antenna.

2. A radio antenna assembly according to claim 1, wherein said resonator comprises a pair of plates having conductive surfaces, spaced on opposite sides of said dipole, and a plurality of conductive rods perpendicular to the plane of polarization of said dipole, spaced around the dipole and connected to said plates, and said omnidirectional antenna comprises radiating elements symmetrically spaced around said dipole and connected for cophasal energization.

3. A radio antenna assembly according to claim 1, wherein said resonator comprises a pair of plates having conductive surfaces, spaced on opposite sides of said dipole, and a cylinder with a plurality of spaced slots perpendicular to the plane of polarization of said dipole, spaced around the dipole and connected to said plates, and said omnidirectional antenna comprises radiating elements symmetrically spaced around said dipole and connected for cophasal energization.

4. A radio antenna assembly according to claim 1, further comprising an extension at one end of said resonator for attenuating any component radiation energy polarized perpendicularly to the plane of polarization of said radiator.

5. A radio antenna according to claim 4, further comprising an extension at the other end of said resonator for attenuating said perpendicular polarized component.

6. A radio antenna assembly comprising a dipole radiator having an overall length short with respect to a quarter wave length at the operating frequency, a pair of conductive plates spaced apart on opposite sides of and substantially concentric with the center of said dipole, conductive means interconnecting said plates and providing regularly spaced conductive openings extending substantially perpendicularly to said plates, said plates and conductive means forming a resonator cage substantially matching the impedance of said antenna to the radiation space at said operating frequency, a plurality of radiators at regularly spaced intervals extending between adjacent one of said conductive means, and means for cophasally exciting said radiators.

7. A radio antenna assembly according to claim 6, wherein said conductive means comprises a

cylinder provided with a plurality of spaced slots therein.

8. A radio antenna assembly according to claim 6, wherein said conductive means comprises a plurality of spaced rods, arranged in a circular pattern and spaced apart to provide said conductive openings.

9. An antenna assembly for providing a rotatable unidirectional radiation pattern comprising a rotatable dipole antenna to provide a directive radiation pattern, a resonator comprising a pair of plates and a set of rods interconnecting said plates forming a resonator for impedance loading of said dipole, a plurality of antenna elements, symmetrically mounted about said resonator structure and said dipole to provide an omnidirectional radiation pattern, and means for supplying radio frequency energy to said dipole and said antenna element.

10. An antenna assembly comprising a first cage structure including four plates mounted in parallel planes and spaced apart along a given axis, and a plurality of rods regularly spaced apart at spacings small with respect to a half wave length and arranged on a circle of a given diameter concentric with said axis, said rods extending between adjacent ones of said plates and being fastened thereto; a second cage structure within said first cage structure mounted between the center two of said four plates, said second cage structure comprising a plurality of rods mounted between said plates on a periphery of diameter less than said diameter, and a movable plate mounted on said rods for adjustable positioning therealong, a dipole radiator rotatably mounted on one of said two plates within said second cage structure, energizing means for supplying radio frequency energy to said dipole radiator, four radiator elements mounted between adjacent rods of said second cage structure and regularly spaced from one another, one end of each radiator being connected to respective of said rods, the rods adjacent similar ends of said radiators being made hollow, energizing conductors within said hollow rods and connected to the respective other ends of said radiators, and a common feeding conductor coupled to the free ends of said conductors, to supply energy to said radiator elements cophasally.

11. An antenna assembly according to claim 10, further comprising an extension on at least the upper end of said first cage structure for attenuating any component radiation energy polarized perpendicularly to the plane of polarization of said radiator.

12. A radio antenna assembly for radiating horizontally polarised waves comprising a substantially cylindrical radiant energy emitting resonator for radiating energy substantially horizontally polarised and an extension at one end of said resonator for attenuating any vertically polarised component radiation energy from said resonator, said extension having substantially the same cross-sectional dimensions as said resonator and being electrically connected thereto.



13. A radio antenna according to claim 12, further comprising an extension at the other end of said resonator of substantially the same cross-sectional configuration for further attenuating said perpendicularly polarised components.

14. A radio antenna assembly comprising a directive radiator of small dimensions relative to a half wavelength for radiating a figure-of-eight pattern of plane polarized energy, a resonator effectively open to radiation about one periphery thereof effectively enclosing said directive radiator and forming effectively a polarization filter about said open periphery, an extension at one end of said resonator for attenuating any component radiation energy polarized perpendicularly to the plane of polarization of said radiator, and an inner resonator open to radiation about its periphery and adjustable to compensate the inherent capacitive reactance of said radiator.

15. A radio antenna assembly comprising a directive radiator of small dimensions relative to a half wavelength for radiating a figure-of-eight pattern of plane polarized energy, a resonator effectively open to radiation about one periphery thereof effectively enclosing said directive radiator and forming effectively a polarization filter about said open periphery, an extension at one end of said resonator for attenuating any component radiation energy polarized perpendicularly to the plane of polarization of said directive radiator, and an omnidirectional radiator for radiating energy plane polarized in the same plane as said directive radiator, said omnidirectional radiator comprising short radiating elements mounted symmetrically about said directive radiator.

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