

Feb. 28, 1956

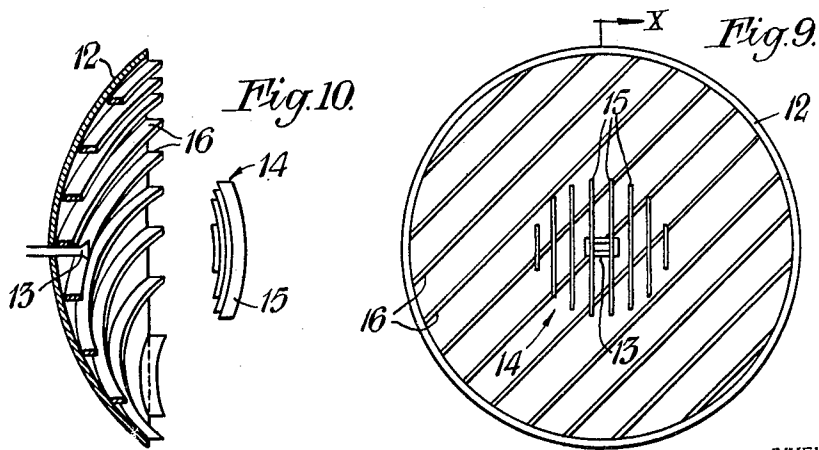
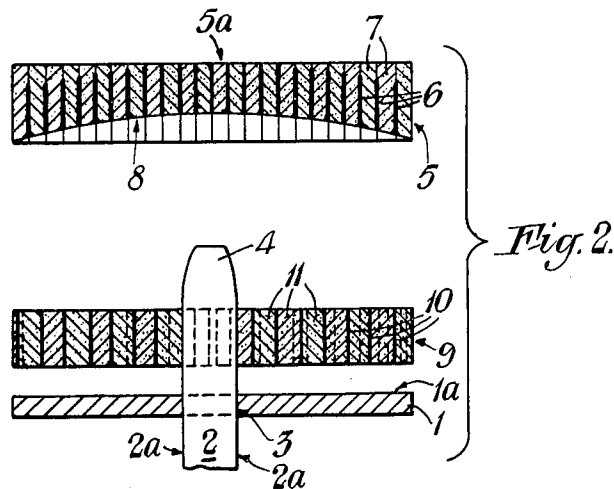
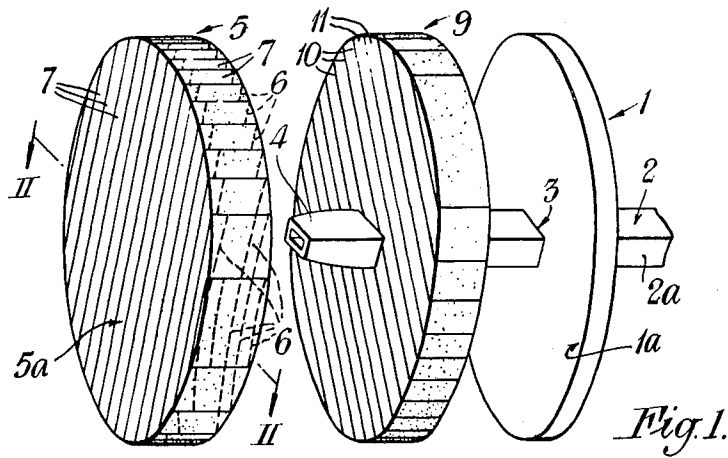
C. A. COCHRANE

2,736,895

HIGH FREQUENCY RADIO AERIALS

Filed Feb. 15, 1952

2 Sheets-Sheet 1



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HIGH FREQUENCY RADIO AERIALS

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2 Sheets-Sheet 2

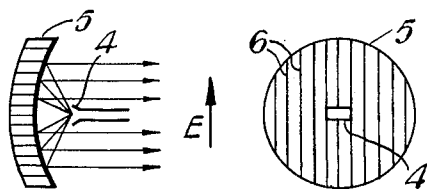


Fig. 3.

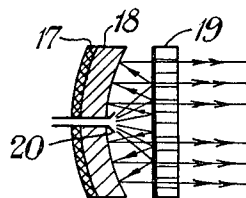


Fig. 11.

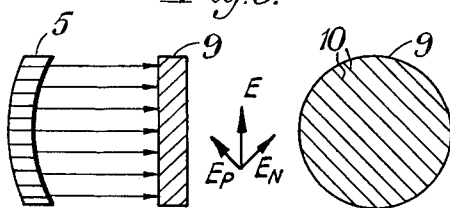


Fig. 4.

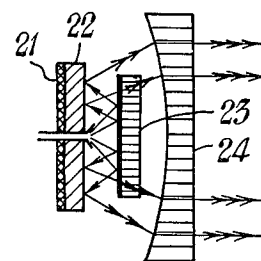


Fig. 12.

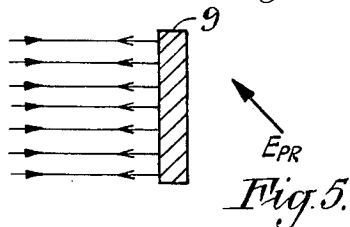


Fig. 5.

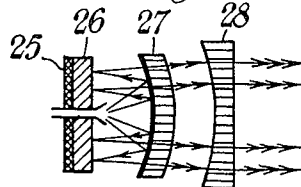


Fig. 13.

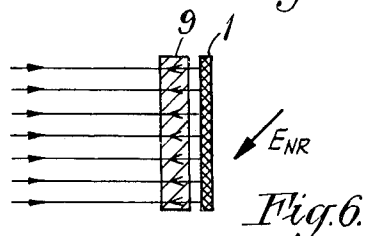


Fig. 6.

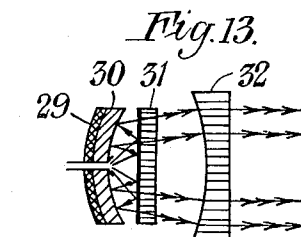


Fig. 14.

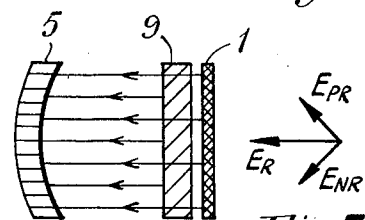


Fig. 7.

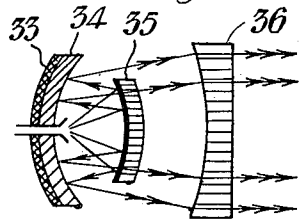


Fig. 15.

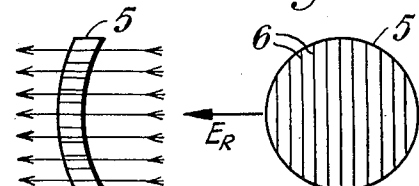


Fig. 8.

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HIGH FREQUENCY RADIO AERIALS

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Application February 15, 1952, Serial No. 271,679

Claims priority, application Great Britain February 16, 1951

10 Claims. (Cl. 343—756)

This invention relates to high frequency radio aerials.

The use of a mirror, e. g. a paraboloidal mirror, as a reflector and focusing element in high frequency radio aerials is well-known but some difficulty is experienced in feeding the high frequency energy to such mirrors. In the simplest arrangement, the primary source of radiation, for example, a waveguide horn, is disposed in front of the mirror on the axis of the emergent beam at or near to the focal point of the mirror. In such a system the primary feed constitutes an obstacle in the path of the radiated beam and may cause undesirable distortions in the radiation pattern from the aerial. In another arrangement, which overcomes this difficulty to some extent, the mirror employed has a part thereof cut away so that the radiated beam lies entirely to one side of the horizontal plane containing the focal point of the mirror, in which case the primary radiating source, being disposed at or near the focal point, is located outside the path of the beam. In yet a further known arrangement, the feed to the aerial is effected from the rear of the mirror by means of a primary source located at the centre of the mirror, a small auxiliary reflector being disposed in front of the main mirror to direct the energy radiated from the primary source back to the main mirror from which it is again reflected to constitute the emergent beam.

None of these known arrangements has proved entirely satisfactory and it is the object of the present invention, therefore, to provide an improved aerial arrangement which is such that any aerial elements located in the path of the emergent beam shall have a minimum effect on the beam itself.

According to the invention, in a high frequency radio aerial of the type in which radiation from a primary source is directed by an auxiliary reflector back on to a main reflector adapted to emit the radiation into free space, the auxiliary reflector being disposed at least partially in the path of the emergent beam from the main reflector, the primary source is arranged to radiate energy polarised in a given plane, the auxiliary reflector is arranged so that it will reflect incident energy which is polarised in the given plane but will transmit substantially all such energy which is polarised in a plane at right-angles to the given plane, and means is associated with the main reflector which will rotate through substantially 90° the plane of polarisation of any radiation reflected thereto by the auxiliary reflector.

The invention will be understood from the following description of some ways in which it may be carried into effect, reference being made to the accompanying somewhat diagrammatic drawings, in which:

Fig. 1 is a perspective view of one form of radio aerial according to this invention;

Fig. 2 is a section taken on the plane indicated by the line II—II of Fig. 1;

Figs. 3 to 8 are diagrams drawn to a smaller scale illustrating the manner in which the aerial of Figs. 1 and 2 is adapted to function;

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Fig. 9 is a front elevation of another form of aerial according to this invention;

Fig. 10 is a section taken on the line X—X of Fig. 9; and

Figs. 11 to 15 are diagrams each illustrating one of a number of further different forms of aerials according to this invention.

Referring first to Figs. 1 and 2, the high frequency radio aerial illustrated comprises a plane main reflector 1, shown as a circular metal plate, and a waveguide 2 of rectangular cross-section extending axially through an aperture 3 at the centre of the reflector 1. The waveguide terminates, at a distance in front of the reflector 1, in a horn 4 which is arranged to radiate high frequency energy, fed thereto through the waveguide 2, towards an auxiliary mirror 5, the plane front face 5a of which is disposed parallel with the reflecting surface 1a of the main reflector 1. The mirror 5 is composed of a considerable number of flat strips 6 of an electrically conducting material, such for example as metal foil or a coherent layer of metal particles, which are arranged side-by-side in parallel relationship and are spaced from each other by interposed strips 7 of a solid dielectric material, such as, for example, an expanded polyvinyl chloride polymerisation product. The strips 6 are of uniform width and have their longer edges suitably curved (as shown in broken lines for three only of the strips in Fig. 1) so that those edges disposed nearer to the horn 4 are all contained in a paraboloidal surface 8 (see Fig. 2). The strips 7 of dielectric material have their front longitudinal edges all contained in the face 5a and may be either of varying widths (as shown) so that their rear longitudinal edges are also all contained in the paraboloidal surface 8, or all of the same constant width so that their rear edges are all contained in a plane containing the rear edge of the mirror 5. The strips 7 are all of the same thickness which is such that the spacing between adjacent strips 6 is somewhat less than half a wave-length of the high frequency energy being fed through the waveguide 2. The wider faces of all the conducting strips 6 are located in planes parallel with the planes containing the shorter or side walls 2a of the waveguide 2, from which it follows that the longitudinal edges of the strips 6 which are located in the paraboloidal surface 8 all lie parallel to the direction of polarization of the electric vector of the radiation from the horn 4.

Threaded on the waveguide 2 between the main reflector 1 and the horn 4 is a "quarter-wave plate" 9 which consists of a circular disc built up from layers 10 of an electrically conducting material, e. g. metal foil, interleaved with layers 11 of a dielectric material, for example, an expanded polyvinyl chloride polymerisation product. The layers 10 are set edgewise to the circular faces and parallel with each other, being spaced apart by a distance which is less than half a wave-length of the high frequency energy supplied through the waveguide 2. Moreover, the orientation of the quarterwave plate 9 is such that the planes containing the wider faces of the layers 10 form dihedral angles of 45° with the planes containing the wider faces of the strips 6. The thickness of the quarter-wave plate is sufficient to ensure that all or substantially all, the radiation which is incident upon a flat face of the plate and which has the electric vector polarized parallel to the layers 10 will be reflected, and the front face of the plate 9 is spaced from the reflecting surface 1a of the main reflector 1 by a distance equal to a quarter of a wave-length in air of the high frequency energy supplied through the waveguide 2 or to any odd multiple of this length.

In the use of the aerial described, high frequency energy of the appropriate wave-length is fed to the aerial through

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the waveguide 2 and is radiated by the horn 4 towards the paraboloidal surface 8 of the auxiliary mirror 5, this radiation being polarized so that the direction of the electric vector of the radiation is parallel with the planes containing the wider faces of the conducting strips 6. Owing to the spacing of these, all, or substantially all, of the incident radiation is reflected back towards the quarter-wave plate 9, the reflected radiation being concentrated into a parallel beam due to the collimating action of the auxiliary mirror 5. When this reflected radiation meets the front surface of the quarter-wave plate 9, the direction of its electric vector is at 45° to the edges of the conducting layers 10. Owing to the spacing of these layers, that wave component polarized parallel to the layers 10 is reflected forwards to the auxiliary mirror 5. However, that wave component polarized perpendicularly to the layers 10 passes between these layers to the reflecting surface 1a and is there re-reflected to pass once again between the conducting layers 10, this time towards the auxiliary mirror 5. Owing to the fact that this wave component has travelled half a wave-length, or an odd multiple of a half wave-length, farther than the wave component which is polarized parallel to the conducting layers 10, the polarization of the re-reflected wave component which has traversed the plate 9 has now been rotated through 180° . Hence, the high frequency energy composed of the two re-reflected components travelling towards the auxiliary mirror 5 has had its plane of polarization rotated through 90° with respect to that of the high frequency energy radiated from the horn 4. Since the direction of polarization of the electric vector of the re-reflected radiation is now perpendicular to the planes containing the wider faces of the conducting strips 6 of the auxiliary mirror 5, the re-reflected radiation will pass straight through the mirror 5 which will have little or no effect upon the beam emerging from the mirror.

The steps in the functioning of the aerial described with reference to Figs. 1 and 2 may briefly be explained by considering the diagrams of Figs. 3 to 8. In each of these diagrams, a body having one edge shown by a heavy black line and bearing horizontal cross-hatching represents an aerial element which is opaque, and therefore reflecting, to high frequency radiation incident upon the face represented by the heavy black line when this radiation is polarized so that the direction of the electric vector is contained in a given plane but which is transparent to incident radiation which is polarized so that the electric vector is contained in a plane at right-angles to the given plane. Similarly, in these diagrams, a body represented with oblique cross-hatching is an aerial element which introduces a rotation of the plane of polarization of high frequency energy incident thereon through 90° . A body represented in the diagrams with double cross-hatching is an aerial element which will totally reflect high frequency radiation of any polarization incident thereon.

In the diagram of Fig. 3 there is shown the horn 4 of Fig. 1 radiating high frequency energy against the reflecting face of the auxiliary mirror 5 of Fig. 1. At the right-hand side of Fig. 3 the face view of the mirror 5 is shown in relation to the position of the horn 4 (represented by a rectangle), the vertical lines indicating the conducting strips 6 of Fig. 1. The arrow E indicates the direction of polarization of the electric vector of the radiation which is directed by the horn 4 against the mirror 5 and is re-reflected therefrom in the form of a parallel beam, this beam having the same plane of polarization and being indicated by the lines fitted with solid arrow heads.

Fig. 4 also shows the mirror 5 and in addition the quarter-wave plate 9 of Fig. 1, this being shown in face view at the right-hand side of the figure where the inclined lines represent the edges of the conducting layers

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10. This figure represents the stage when the beam reflected from the mirror 5 has just reached the front face of the plate 9, and the arrows E_P and E_N respectively represent the wave components polarized parallel with and normal to the conducting layers 10 of the plate 9.

From Fig. 5 it can be seen that the wave component polarized parallel with the conducting layers 10 is re-reflected as indicated by the open arrow-heads, towards the auxiliary mirror 5, the direction of polarization of the electric vector of this wave component being indicated by the arrow E_{PR} and not having been changed in relation to that shown at E_P .

In Fig. 6 the quarter-wave plate 9 is again shown but here backed by the main reflector 1 of Fig. 1. The wave component which has its electric vector polarized perpendicularly to the conducting layers 10 of the quarter-wave plate 9 has here passed through the quarter-wave plate, been re-reflected by the main reflector 1 and again passed through the quarter-wave plate towards the auxiliary mirror 5. The arrow E_{NR} indicates the direction of polarization of the electric vector of this re-reflected wave component and it will be seen that its direction has been rotated through 180° in relation to that of the vector E_N of Fig. 4.

In Fig. 7 there are shown the auxiliary mirror 5, quarter-wave plate 9 and main reflector 1, with the two re-reflected wave-components represented by the horizontal lines carrying open arrow heads. As will be seen, the re-combining of the wave components having the polarizations indicated by E_{PR} and E_{NR} will produce a beam in which the high frequency energy is polarized with its electric vector in the direction E_R , that is at 90° to the initial direction of polarization shown at E in Fig. 3.

Fig. 8 shows that the beam thus constituted passes freely through the auxiliary mirror 5, the direction of polarization of its electric vector being now perpendicular to the planes containing the wider faces of the conducting strips 6 of the mirror 5.

It will be understood that the main reflector 1 may, if desired, be placed in close contact with the rear face of the quarter-wave plate 9, the depth of the conducting layers 10 of the latter then being equal to a quarter wave-length of the high frequency energy or an odd multiple thereof. Moreover, although for the purposes of this example the main reflector has been described as a metal plate, any other suitable known reflecting surface may be utilised in its place such, for example, as a set of parallel rods, a set of parallel plates or a slotted plate reflector.

Figs. 9 and 10 show an alternative form of an aerial according to this invention in which the main reflector is a paraboloidal mirror 12, again shown as a metal plate but capable of functioning when constructed from parallel rods, parallel plates or a slotted metal plate. The primary radiating source is a waveguide 13 located in an aperture at the centre of the mirror and arranged to radiate high frequency energy in the direction of the focal point of the mirror, this radiation being polarized in a given plane which, in the example illustrated, is the plane of the paper. Located in front of the main mirror, with its centre on the axis thereof, is an auxiliary mirror 14 which is constructed in such a manner that it will reflect back to the main mirror substantially all of the energy received from the primary source but will transmit any energy incident thereon which is polarized in a plane at right-angles to that in which the energy from the primary source 13 is polarized.

At or near to the surface of the main mirror 12 there is provided means which will rotate the plane of polarization of the radiation incident thereon through 90° in the course of re-reflecting this radiation to produce the desired emergent beam.

It will be appreciated that due to the change in the

polarization of the radiation reflected by the main mirror 12, that portion of this radiation which falls upon the auxiliary mirror 14 will be transmitted through this mirror with substantially no loss. In consequence, the energy is distributed substantially as uniformly across the full cross-sectional area of the emergent beam as if the auxiliary mirror were not present.

The auxiliary mirror is arranged to produce the desired result by constructing it from a set of equi-distant parallel metallic plates 15 spaced apart by a distance which is less than half a wave-length of the high frequency energy, their edges lying parallel with the direction of polarization of the electric vector of the radiation from the primary source 13. The polarization-changing means associated with the main mirror 12 comprises a series of equi-distant parallel metallic plates 16 spaced apart by a distance which is more than half a wave-length and less than one wave-length and disposed with their edges at 45° to the plane of polarization of the incident radiation, the depth of the plates 16 being such as to produce a phase shift of 90° between the wave component polarized parallel to the plate 16 and that polarized perpendicular to the plates. Consequently, the radiation directed to the main mirror 12 by the auxiliary mirror 14, will emerge, after passing between the plates 16, being reflected from the main mirror and again passing between the plates 16, with its plane of polarization rotated through 90°. In consequence, the re-reflected radiation will pass through the auxiliary reflector 14 which will have little or no effect upon the beam emerging from the mirror.

In the example illustrated in Figs. 9 and 10, the auxiliary mirror 14 is shown as a concave mirror so that in reflecting radiation from the primary source 13, it will also play some part in focussing the beam. It will be understood, however, as will be indicated below, that the auxiliary mirror 14 may also be a plane mirror such as is indicated at 1 in Fig. 1.

In an alternative arrangement, the elements of the aerial are constructed and arranged in the manner illustrated in Figs. 9 and 10 but with the difference that the spacing of the plates 16 is modified so that it is now less than half a wave-length of the high frequency energy radiated from the primary source 13. In this case, the distance from the free edges of the plates 16 to the reflecting surface of the main reflector 12 is made a quarter of the wave-length in air of the high frequency energy, or any odd multiple of this length, care being taken that the depth of the plates be sufficient to ensure that sensibly all the radiation polarized parallel with the plates will be reflected from the free edges thereof. In this form of the invention, the functioning of the aerial is substantially as is indicated by the diagrams of Figs. 3 to 8. It will be understood that the plates 16 may be replaced by any equivalent system, such as a system of parallel rods.

It is to be understood that although the applications of the invention described in relation to Figs. 1 to 10 are relatively simple, many other arrangements are possible. In Fig. 10, the surface of the auxiliary reflector 14 is shaped so that it forms part of the collimating system for the aerial. Additionally, a second set of parallel metallic plates may be provided at or at right-angles to those these plates being disposed at right-angles to those constituting the reflecting surface and being spaced apart by a distance greater than half a wave-length but less than a wave-length of the high frequency energy. The plates of this additional set may be so positioned and shaped as to act as a lens for the radiation reflected from the main mirror whereby they may be used as an additional focussing element or for producing a predetermined modification in an aqu-phase front such as is required for the so-called "cosecant squared" diagram. Alternatively, the auxiliary reflector may be formed from a series of parallel rods spaced apart by a distance less than half a wave-

length and this series of rods may cover the whole aperture of the main mirror. Again, the auxiliary mirror may be employed for producing scanning motion of the emergent beam without moving the main mirror or the primary radiating source.

The diagrams of Figs. 11 to 15 indicate various arrangements of the elements of aerials according to this invention, the conventional representations defined in relation to Figs. 3 to 8 being adhered to in these Figs. 11 to 15 also.

In Fig. 11 the main reflector 17 is of paraboloidal form and has associated with its reflecting face a quarter-wave plate 18 of the same character as that shown at 9 in Figs. 3 to 8. The auxiliary reflector 19 is a plane mirror which is opaque to the radiation emitted by the horn 20 but is transparent to the re-reflected radiation emerging from the main reflector 17. In this figure (as also Figs. 12 to 15) the radiation reflected from the auxiliary reflector is represented by lines each carrying a single open arrow head and the re-reflected radiation constituting the emergent beam from the main reflector is represented by lines each carrying two open arrow-heads.

Fig. 12 shows a plane main reflector 21 carrying a quarter-wave plate 22, and a plane auxiliary reflector 23, the production of a parallel-sided emergent beam being effected by means of a lens 24 constructed in the well-known manner. The re-reflected radiation which has passed through the lens is represented in each of Figs. 12 to 15 by lines each carrying three open arrow-heads.

Fig. 13 illustrates another form in which the main reflector 25 with its quarter-wave plate 26 is of plane form and the auxiliary reflector 27 is arranged to play some part in the collimating action of the aerial, the remainder of the collimating action being exerted by a lens 28.

In Fig. 14 there is shown an inverse arrangement in which the main reflector 29 (with its quarter-wave plate 30) is of concave form and the auxiliary mirror 31 is of plane form, part of the collimating action being performed by the main reflector 29 and the remainder thereof by the lens 32.

Fig. 15 shows yet another form in which the main reflector 33 with its quarter-wave plate 34 and the auxiliary mirror 35 are of concave form and each reflector or mirror plays some part in the collimating action of the aerial, the final production of the parallel-sided emergent beam being effected with the aid of the lens 36.

In the foregoing specification the aerials according to the invention have been described solely in relation to the radiation of energy from the aerial but it will be understood that each aerial may also be used for the reception of energy.

What I claim is:

1. A high frequency radio aerial comprising a primary source emitting radiation polarized in a given plane, an auxiliary reflector arranged to be illuminated by said radiation and constructed to reflect substantially the whole of the incident radiation polarized in said given plane but to permit free passage of substantially all radiation incident thereon which has its plane of polarization at substantially 90° to said given plane, and a main reflector arranged to be illuminated by radiation reflected from said auxiliary reflector and constructed to re-reflect said reflected radiation as an emergent beam polarized in a plane substantially at 90° to said given plane and illuminating at least part of said auxiliary reflector.
2. An aerial according to claim 1, wherein at least one of said reflectors is shaped to perform a collimating function.
3. An aerial according to claim 1, including a collimating lens disposed in the path of the beam.
4. An aerial according to claim 1, wherein the beam

is collimated by means of at least one of said reflectors in conjunction with a lens.

5. An aerial according to claim 1, wherein the auxiliary reflector comprises a set of electrically conducting layers disposed parallel with the direction of the polarization of the electric vector of the radiation emitted by the primary source and spaced apart by a distance less than half a wavelength of said radiation.

6. An aerial according to claim 1, wherein the main reflector comprises a totally reflecting surface faced with a set of electrically conducting layers disposed at 45° to the direction of the polarization of the electric vector of the radiation emitted by the primary source and parallel with the direction of propagation of said radiation, the spacing between the layers being less than half a wavelength of said radiation.

7. An aerial according to claim 1, wherein the main reflector comprises a totally reflecting surface faced with a set of electrically conducting layers disposed at 45° to the direction of the polarization of the electric vector of the radiation emitted by the primary source and parallel with the direction of propagation of said radiation, the spacing between the layers being more than half a wavelength but less than one wave-length of said radiation.

8. A high frequency radio aerial producing an emergent beam from high frequency energy radiated from a primary source with the aid of a main reflector arranged to emit the beam and an auxiliary reflector located in the path of the radiation from the primary source and at least partially in the path of the beam, wherein the radiation from said primary source is polarized in a given plane, said auxiliary reflector is constructed to reflect to said main reflector incident radiation polarized in said plane but to permit free passage of any incident radiation polarized in a plane at right-angles to said plane, and said main reflector is constructed to rotate the polarization of radiation incident on said reflector through 90° in the course of its reflection as said beam by said reflector.

9. A high frequency radio aerial comprising a receiver for radiation, a main reflector adapted to collect high frequency energy from free space and an auxiliary reflector arranged to re-reflect onto said receiver radiation reflected from said main reflector, said auxiliary reflector being disposed at least partially in the path of said incident energy, in which the auxiliary reflector is constructed so that it will permit free passage to said main reflector of incident energy which is polarized in a given plane but will reflect substantially all energy incident thereon which is polarized in a plane at right-angles to said given plane, and means is associated with the main reflector which will rotate through substantially 90° the plane of polarization of any radiation polarized in said given plane which is incident on said main reflector.

10. A high frequency radio aerial comprising an auxiliary reflector constructed to reflect substantially the whole of incident energy polarized in a given plane but to permit free passage of substantially the whole of incident energy polarized in a plane at substantially 90° to said given plane, a primary source of radiation illuminating said auxiliary reflector with energy polarized in said given plane, a main reflector arranged to re-reflect energy reflected by said auxiliary reflector as an emergent beam illuminating at least part of said auxiliary reflector, and means associated with said main reflector which rotates through substantially 90° the plane of polarization of any energy reflected thereto by said auxiliary reflector.

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