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11-6-73 OR 3,771,160 SR

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Laverick

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[54] **RADIO AERIAL**

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[30] **Foreign Application Priority Data**

Aug. 4, 1970 Great Britain 37,684/70

[52] **U.S. Cl.** **343/756,** 343/781, 343/837, 343/909

[51] **Int. Cl.** **H01q 19/00**

[58] **Field of Search** 343/756, 772, 909, 343/781, 837

[56] **References Cited**

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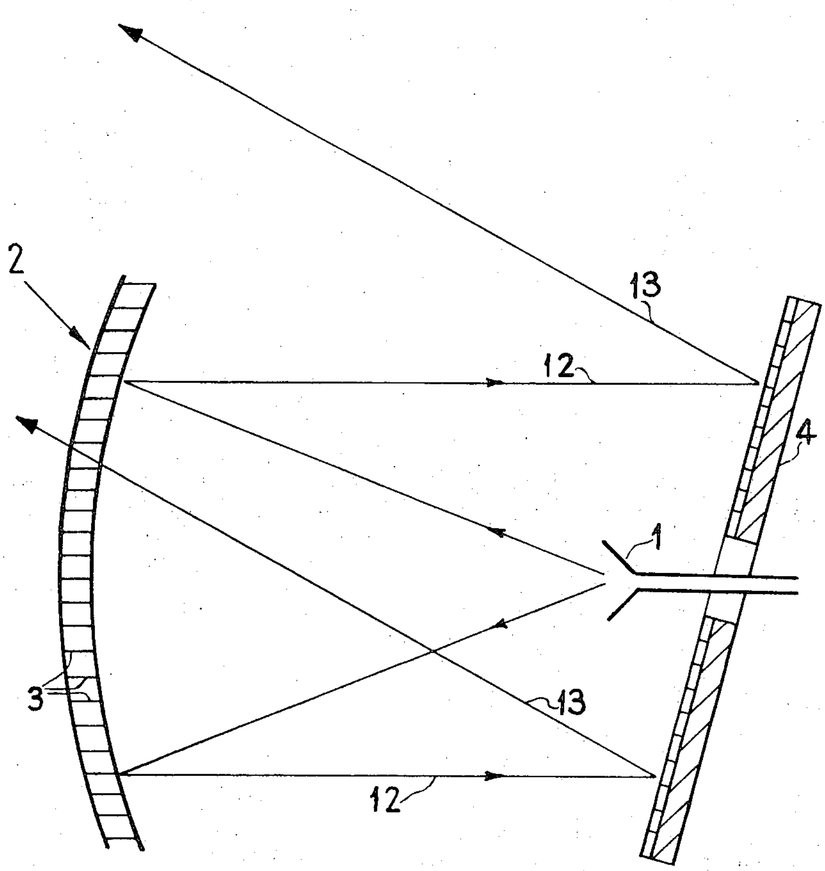
[57] **ABSTRACT**

A cassegrain aerial having a primary feed, an auxiliary reflector which transmits or reflects according to the plane of polarisation of energy incident on it from the primary feed, and a main, twist reflector which receives energy reflected from the auxiliary reflector, rotates its plane through 90° and re-reflects it into free space through the intervening auxiliary reflector. The main, twist reflector consists of a sheet reflector in front of which two, parallel, wire grids are arranged, the wires extending at 45° to the plane of the incident wave and being arranged so that 90° rotation of the polarisation plane is effected at at least two frequencies.

5 Claims, 3 Drawing Figures



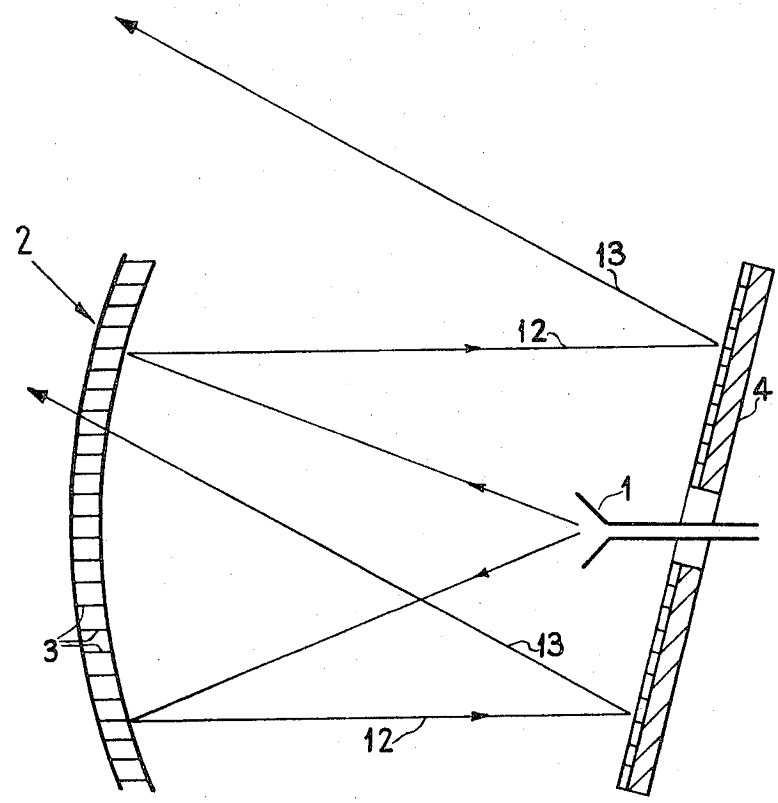


Fig. 1

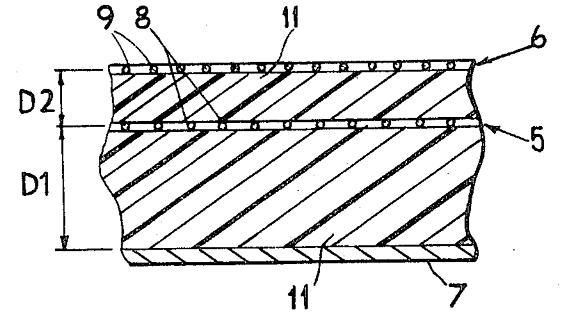


Fig. 2

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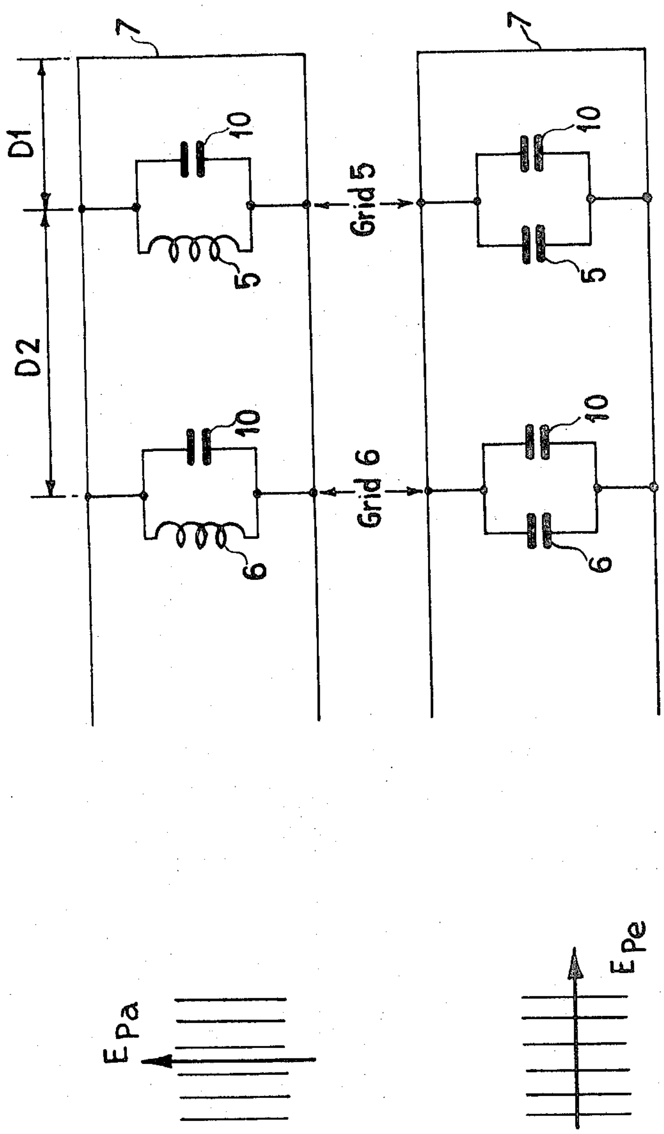

Fig. 3

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RADIO AERIAL

This invention relates to radio aerials and particularly to such aerials which employ plane polarised radio waves for producing selective reflection and transmission at certain surfaces.

Examples of such aerials are described in U.S. Pat. Nos. 2,736,895 and 2,867,801 as well as Great Britain Pat. No. 898,933 although it is to be understood that the present invention is not limited by the constructional arrangements described in those specifications.

The ability to produce a rotational shift of the plane of polarisation of a plane polarised wave is of value in conjunction with a surface which reflects or transmits according to the angle of the plane of polarisation of a wave incident upon the surface. However, a disadvantage of known arrangements of this kind is that they are restricted to operation at a single frequency.

An object of the present invention is to provide means in a radio aerial for producing a rotational shift of the plane of polarisation of an incident plane polarised wave for at least two frequencies of incident wave.

According to one aspect of the present invention, in a radio aerial including a reflector assembly for producing a rotational shift of the plane of polarisation of an incident plane polarised wave, the assembly comprises a plurality of conductive grids arranged in front of a reflector, the admittance of the individual grids, and the spacing between the grids and between the grids and the reflector, being such that, at each of a plurality of operating frequencies, the respective admittances of the assembly to mutually perpendicular components of a predetermined plane polarised wave incident upon the assembly are of relatively inverse magnitude and opposite sign.

There may be two grids each comprising an array of parallel conductors extending in a direction which is arranged to be at approximately 45° to the plane of polarisation of the incident wave.

One of the two grids may be spaced from the reflector approximately a quarter wavelength in respect of a first predetermined frequency and the second grid positioned in the region of a short circuit position with respect to the input admittance presented to an incident wave of that first frequency.

The reflector assembly may comprise, in conjunction, a plane metal reflector, a layer of dielectric foam material, a first grid of parallel wires, a second layer of dielectric foam material and a second grid of parallel wires, the wires of each grid being glued to a respective dielectric skin which is glued to the adjacent foam layer.

According to a second aspect of the invention, a cassegrain radar aerial comprises a localised source of a plane polarised wave, the source being directed at an auxiliary reflector comprising an array of conductors extending in a direction parallel to the electric plane of said polarised wave, and a twist reflector assembly including a plane reflector, a first grid of parallel conductors spaced a quarter wavelength from the plane reflector in respect of a first predetermined frequency, and a second grid of parallel conductors situated in the region of a short circuit position with respect to the input admittance, at said first predetermined frequency, presented, in operation, to a plane polarised wave reflected from said auxiliary reflector and incident upon the twist reflector assembly, the conductors of the two grids extending in a direction which is at 45° to the plane of polarisation of the wave incident at said twist reflector assembly, and the individual admittances of the two grids being such that a plane polarised wave, of said first or a second predetermined frequency, originating from said localised source and reflected by said auxiliary reflector to be incident at said twist reflector assembly, is reflected by the twist reflector assembly with a 90° rotational shift of the plane of polarisation for transmission through said auxiliary reflector.

A radio aerial for operation at two frequencies and in accordance with the invention will now be described, by way of example, with reference to the accompanying drawings, of which:

FIG. 1 is a diagrammatic view of a section of the aerial in a plane containing the aerial axis;

FIG. 2 is a part sectional view of a detail, a 'twist' reflector assembly, of FIG. 1, and

FIG. 3 shows equivalent circuits for the twist reflector assembly of FIG. 2 in respect of orthogonal components of an incident wave.

Referring now to FIG. 1, the aerial construction is, broadly, as follows. A feed horn 1 is directed at a parabolic reflector 2 and is positioned at the focus of the reflector 2 so that the wave reflected by the reflector 2 is a parallel beam. The wave emitted by the feed horn 1 is plane polarised, the electric (E) vector being perpendicular to the plane of the paper.

The parabolic reflector 2 functions also as a transparent window in accordance with the angle of the plane of polarisation of a wave incident upon it. It is constructed of a number of parallel conducting strips 3 shown in end view in FIG. 1. At least the leading edge of each strip 3 is shaped to conform to the paraboloidal surface of the reflector 2 as a whole. The strips 3 are embedded in a dielectric medium, for example a fibreglass honeycomb, and a dielectric skin glued to the front and back faces may be used to increase the rigidity of the structure.

Parallel wires may be used instead of the strips 3. In either case the spacing of the conductors must be sufficiently small to give a high reflection coefficient at the highest operating frequency and their thickness (diameter) must be sufficiently small to give high transmission of energy polarised perpendicular to them.

The E vector of the wave emitted by the feed horn 1 is polarised perpendicular to the plane of the paper, and, as can be seen in FIG. 1, this is in alignment with the direction of the strips 3. Nearly complete reflection therefore results and a parallel beam is reflected to a 'twist' reflector assembly 4. As its name implies this 'twist' reflector assembly is required to twist the plane of polarisation of the wave incident upon it. A 90° twist of this plane causes the wave reflected by the twist reflector 4 to be polarised in a plane parallel to the plane of the paper and thus transverse to the strips 3 of the reflector 2. Substantially complete transmission of the wave by the 'reflector' 2 then occurs.

In order to steer the ultimately transmitted beam, the twist reflector 4 is pivotally mounted about an axis (not shown) perpendicular to the plane of the paper. It will be apparent that the angular sweep of the beam is twice the angular displacement of the twist reflector 4.

The construction and operation of the twist reflector 4 will now be described.

FIG. 2, which is not to scale, shows two copper wire grids 5 and 6 mounted in front of a continuous aluminium back plate 7. The distances D1 and D2 between the plane 7 the grid 5 and the grid 6 are determined as will be explained. The spacing of the individual wires 8 and 9 of the grids must be sufficiently small to permit satisfactory reflection while at the same time this spacing in conjunction with the wire diameter is chosen to produce a desired grid impedance.

Each grid 5 and 6 is formed by sticking the wires to a skin. The skins are then glued to low-density dielectric foam sheets 11 which maintain the spacings D1 and D2. The rear foam sheet 11 is also glued to the aluminium plate 7.

The operation of the twist reflector 4 depends upon the production of a differential phase shift between different components of an incident plane polarised wave. In the present embodiment it is convenient to consider orthogonal components parallel and perpendicular to the wires 8 and 9 of the grids 5 and 6. The grids are accordingly arranged with the wires 8 and 9 at 45° to the plane of polarisation of an incident wave.

Referring to FIG. 3, the upper circuit shows the transmission line equivalent of the twist reflector 4 as presented to the parallel component of the E field of the incident wave. The lower circuit shows the corresponding equivalent transmission line for the perpendicular component. The diagrams at the left indicate the field component in relation to the grid wires.

For the parallel component the grids 5 and 6 constitute inductive shunts across the line, while for the perpendicular components the grids 5 and 6 constitute capacitive shunts. In both cases the grids are shunted by a small capacitance 10 resulting from the dielectric skin on which the wires are mounted. This error capacitance is compensated by a corresponding small increase in the grid inductance beyond the calculated value.

According to the present design approach, the grid 5 is first positioned to provide operation at one frequency, that is, it is positioned a quarter wavelengh, at that frequency, in front of the back plate 7 with the wires 8 of the grid arranged at 45° to the plane of polarisation of the incident wave.

As explained in Great Britain No. 700,868 the positioning of a grid one quarter of a wavelength away from a conducting plane and arranged to receive a plane polarised wave in a plane at 45° to the wires of the grid, causes a 180° differential phase shift between the parallel and perpendicular components of the (E) wave. This is because the parallel component is reflected from the grid with a 180° phase shift while the perpendicular component does not 'see' the grid and is reflected from the back plate with a tital shift of 360° due to path length and back plate reflection. The resulting differential phase shift is 180°.

If a differential phase shift of 180° is imposed between the parallel and perpendicular components on reflection, then the desired 90° polarisation plane twist is achieved. It can be shown that this is a general requirement and can be expressed as $Y_{pa} = {}^{-1}/Y_{pe}$ where Y_{pa} and Y_{pe} are the admittances presented to the parallel and perpendicular components respectively. Thus the 'parallel' and 'perpendicular' admittances have relatively inverse magnitudes and opposite signs.

The grid 6 is then positioned at the first (or another) short circuit plane (at the first chosen frequency) in the path to the grid 5 and back plate 7 so that, being in parallel with a short circuit, i.e., an infinite admittance, the admittance of the grid 6 has no effect at this chosen frequency. There is then complete freedom to adjust the diameter and spacing of the wires 9 of the grid 6 to achieve, at various lower frequencies, the necessary inverse parallel and perpendicular admittance relation previously mentioned in conjunction with the first grid.

The manner in which the admittance of a wire grid depends upon the diameter, spacing and frequency is well known and is described in Volume No.10 of the M.I.T. Radiation Laboratory Series, 'Waveguide Handbook' edited by N.Marcuvitz.

In addition, the position of the second grid 6 can be varied to some extent, at the higher frequency without unduly affecting the higher frequency condition. This is because, as can be seen by reference to a Smith Chart, for a limited distance on either side of the infinite admittance (short circuit) plane the admittance remains sufficiently large to swamp the transferred admittance of the second grid 6.

By these means, variation from a third harmonic relation is obtainable within the range between 2 and 5 to 1.

In considering the extension of the operating frequencies for which a twist reflector may be designed, a particular frequency relationship that lends itself to realisation is a succession of third harmonics, each of the last, thus λ_1; $3\lambda_1$; $9\lambda_1$; $27\lambda_1$; etc.

This extension of the number of operating frequencies can be obtained with a single grid design the single grid having a large inductance at the highest frequency and spaced a quarter wavelength, at the lowest frequency, from a conducting ground plane. Thus at each design frequency the grid would have a large inductance and it would be spaced an odd multiple of quarter wavelengths from the ground plane. The structure would therefore twist reflect. However, at the high frequencies the design would have a narrow bandwidth.

On the other hand, the form of dual frequency design in which first one grid is positioned for the high frequency and then a second grid is added for the low frequency, can have a wide bandwidth for both low and high frequencies. It is applicable when the two frequencies are in odd harmonic relation, i.e.

$$\lambda_2 = 3\lambda_1,\ 5\lambda_1,\ 7\lambda_1,\ \text{etc.}$$

The original design described above was based on the first of these frequency pairs.

Ratio ranges corresponding to the 2 to 5 variation of the third harmonic relation, exist for other pairs in the above odd harmonic series, for example for the pairs 1:7; 1:9 etc., although the greater the pair ratio the smaller the possible variation of the ratio.

It can be seen therefore that the design can be extended to operate at several frequencies provided that their ratios are favourable.

In a design for a multi-frequency twist-reflector first a pair of grids is positioned, according to the above design, to operate at the highest two frequencies, then a third grid is added, in the region of a short circuit plane, which operates at the next lower frequency but has no effect on the upper two frequencies. Further grids may be added similarly.

This design provides operating frequencies in the ratio 1:3:9:27 etc.

Again the flexibility in the choice of grid inductances allows the exact ratios of the frequencies to be adjusted.

I claim:-

1. In a single feed radio aerial including a reflector assembly for producing a rotational shift of the plane of polarisation of a wave incident upon said reflector assembly, said reflector assembly comprising a plane reflector member, a plurality of grids, each grid comprising a plurality of parallel conductors in a plane parallel to said plane reflector member for intercepting a wave incident upon said plane reflector member, said grids having individual admittances and spacings from said reflector member for providing that, at each one of a plurality of distinct operating frequencies, the respective admittances of said reflector assembly, to components of said wave parallel to said conductors and perpendicular to said conductors, are of relatively inverse magnitude and opposite sign.

2. A radio aerial according to claim 1, wherein there are two of said grids, each of the two grids comprising a planar array of parallel conductors extending in a direction which is at an angle of 45° degrees to said plane of polarisation of said wave.

3. A radio aerial according to claim 2, wherein one of said two grids is spaced from said reflector member by a quarter wavelength in respect of a first predetermined frequency and the other of said two grids is positioned in the region of a short circuit position with respect to the input admittance of said assembly as presented to an incident wave of said first predetermined frequency.

4. A radio aerial according to claim 2, wherein said reflector assembly comprises, in order, a plane metal reflector member, a first layer of dielectric foam material, a first grid assembly comprising a first dielectric skin member and a plurality of parallel wires glued to said first dielectric skin member, a second layer of dielectric foam material, and a second grid assembly comprising a second dielectric skin member and a plurality of parallel wires glued to said second dielectric skin member, said plane metal reflector member, said layers of dielectric foam material and said grid assemblies being glued together to form a unitary assembly.

5. A cassegrain radar aerial according to claim 1, and comprising a localised source of a plane polarised wave, an auxiliary reflector at which said localised source is directed, said auxiliary reflector comprising an array of parallel conductors extending parallel to the electric component of a plane polarised wave received from said localised source, said reflector assembly being directed toward said auxiliary reflector for rotating the plane of polarisation of a wave derived from said source by reflection from said auxiliary reflector, and for reflecting the wave so derived to said auxiliary reflector for transmission therethrough.

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