July 28, 1959 O. M. WOODWARD, JR 2,897,496

CORNER REFLECTOR ANTENNA

Filed Jan. 12, 1955 2 Sheets-Sheet 1

Fig.1a.

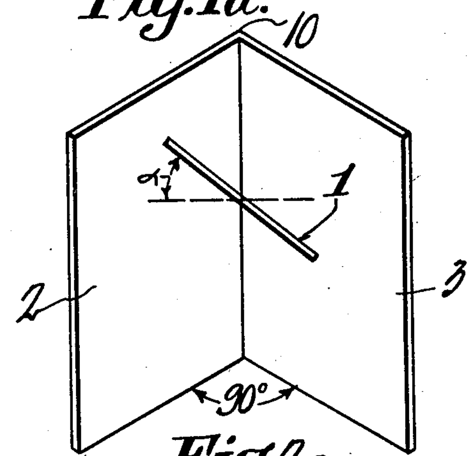

Fig.1b.

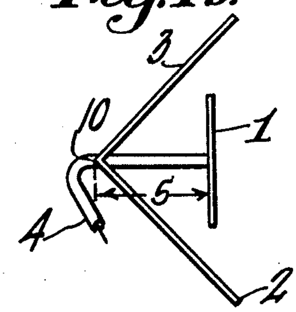

Fig.2a.

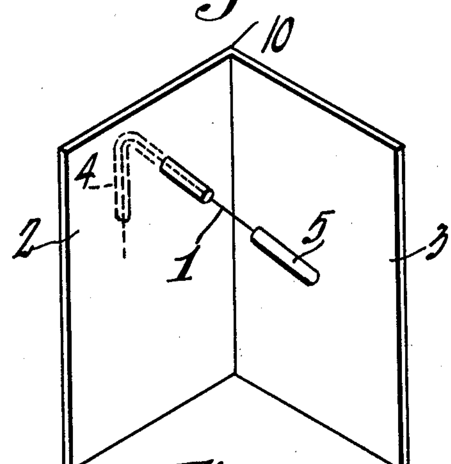

Fig.2b

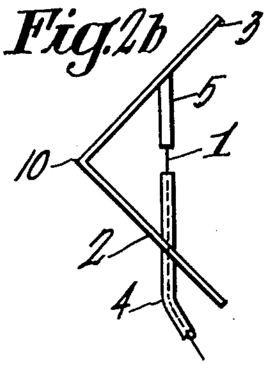

Fig.3a.

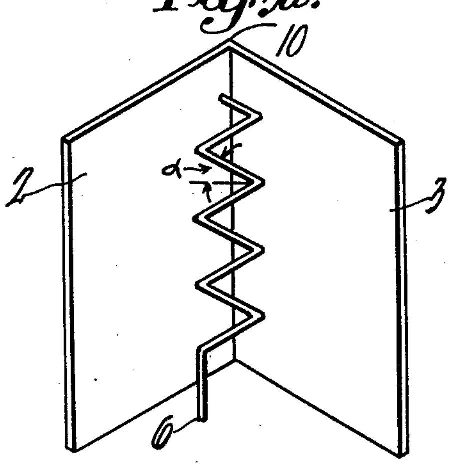

Fig.3b

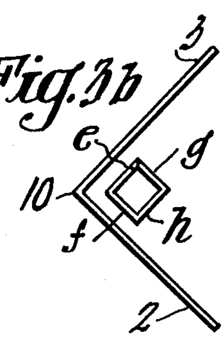

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Fig.4

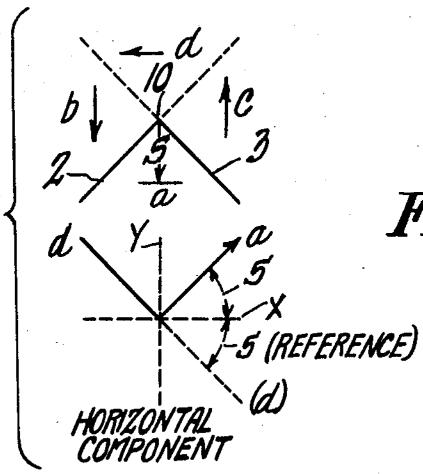


Fig.5

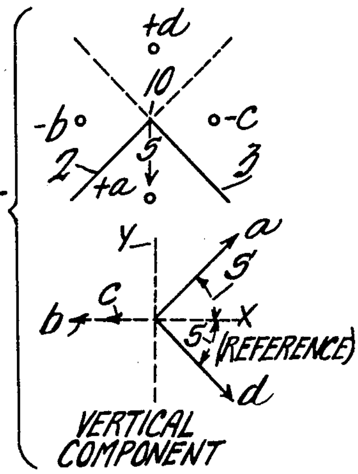


Fig.6.

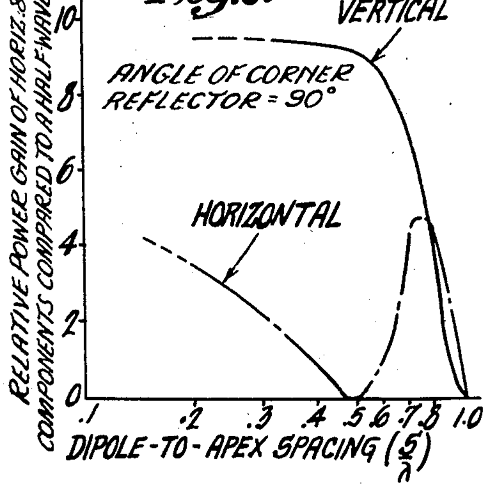


Fig.7

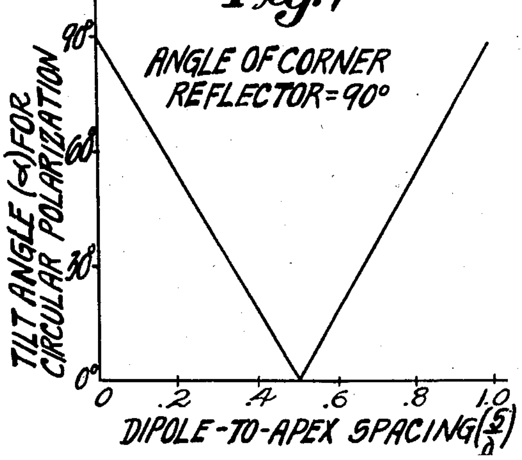
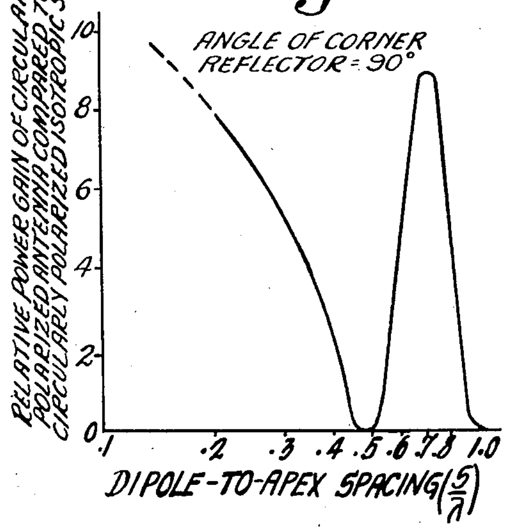


Fig.8.



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CORNER REFLECTOR ANTENNA

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Application January 12, 1955, Serial No. 481,392

8 Claims. (Cl. 343—818)

This invention relates to radio antennas and, particularly, to a corner reflector antenna for propagation of electromagnetic waves with a continuously variable plane of polarization.

Corner reflector antennas have been developed for the propagation of sharply defined directive radio fields. By mounting a radiating element adjacent the corner of a pair of intersecting reflecting surfaces, with the element arranged parallel to the line of intersection between the surfaces, an efficient directive antenna is obtained.

While such antennas produce directive radiation patterns, recent developments in the field of directive radio wave propagation have indicated that the use of circularly polarized radio waves is, in various applications, highly desirable. For example, experience in airport-to-airplane communication has indicated a need for more reliable means of communication. Such communication should be free from random polarization changes caused by the banking of the aircraft and from amplitude variations due to ground reflections. By the use of a circularly polarized antenna at the ground station, signal transmission is greatly stabilized and greater freedom is possible as to the location of an antenna on the aircraft.

It is an object of the invention to radiate or receive in a novel manner directive electromagnetic waves having a varying plane of polarization.

Another object of the invention is to provide a new and simple means of propagating or receiving a circularly polarized radio field with a single dipole antenna.

It is a further object of the invention to efficiently propagate or receive a sharply defined directive circularly polarized radio field by means of a corner reflector antenna.

The above objects of the invention are accomplished by mounting a single radiating element within the angle formed by a pair of intersecting planar surfaces. In order to obtain a circularly polarized radio field from the antenna, the radiating element is rotated thru an angle in a plane parallel to the intersection of the surfaces and perpendicular to the bisector plane of the angle formed by the pair of intersecting surfaces so as to be positioned at a predetermined tilt angle of a value between but not including zero and ninety degrees with respect to the bisector plane.

A more detailed description of the invention follows with reference to the accompanying drawing in which like parts are given like reference numerals and in which:

Figs. 1(*a*) and 1(*b*) are front and top views respectively of a corner reflector antenna constructed in accordance with the invention;

Figs. 2(*a*) and 2(*b*) are front and top views respectively of the corner reflector antenna of Figs. 1(*a*) and 1(*b*) showing a coaxial feed line arrangement in which the balun is included as a part of the antenna;

Figs. 3(*a*) and 3(*b*) are front and top views respectively of a corner reflector antenna constructed in accordance with the invention including a square helix as the radiating element;

Fig. 4 is an image analysis of a horizontal component of the radio field radiated from the corner reflector antenna of the invention;

Fig. 5 is an image analysis of the vertical component of the radio wave radiated from a corner reflector antenna of the invention;

Figs. 6, 7 and 8, which are graphic presentations, are given as a partial explanation of the operation of a corner reflector antenna constructed in accordance with the invention.

Referring to Figs. 1(*a*) and 1(*b*), a single dipole radiator **1**, which may be a half wave dipole, is located at a distance S from the apex **10** and along the perpendicular bisector of a corner reflector, the corner reflector comprising a pair of flat wave reflecting surfaces **2** and **3**. The sufaces **2** and **3** are made of electrically conductive sheets which are arranged to intersect at an angle, for example, 90°, the vertex of the angle being located at the intersection or apex **10** of the surfaces **2** and **3**. The single dipole **1** is rotated thru an angle in a plane parallel to the intersection and perpendicular to the bisector plane of the angle formed by the pair of intersecting surfaces so as to be positioned at a tilt angle α between but not including zero and ninety degrees with respect to the bisector plane. A feed line which may, for example, be a coaxial conductor **4** is made to pass thru a point in the apex **10** formed by the intersecting reflecting surfaces **2** and **3**, and is connected to the dipole **1** at its midpoint. The conductor **4** can be connected or coupled to a transmitter or receiver, not shown, by any of the methods well-known in the art.

By positioning the dipole **1** at a certain spacing S from the apex **10** of the intersecting reflecting surfaces **2** and **3**, the dipole tilt angle α may be adjusted to produce equal forward field gains for the vertical and horizontal components of the radio field radiating from the antenna.

In explaining the electrical operation of the antenna, the dipole current may be resolved into horizontal and vertical components and analyzed by the theory of images. Referring to Figs. 4 and 5, Fig. 4 shows an image analysis of the horizontal component of a corner reflector antenna according to the invention. Assuming that the horizontal component is being received at a distant point broadside to the corner reflector, the following analysis may be given. During the electrical operation of the antenna, assuming an angle of intersection of the reflecting surfaces **2** and **3** of 90° and, also, assuming the metal sheets to be infinite in extent, current fed to the dipole **1** in quadrant (*a*) will produce corresponding images in quadrants (*b*), (*c*), and (*d*). The current present in the image quadrants, as shown in Fig. 4, assume the same direction from left to right around the apex **10** of the corner reflector. It may be seen that, as the distant point under consideration is broadside to the corner reflector, the current present in the images of quadrants (*b*) and (*c*) may be passed by in that the distant point will be located at the null ends of these images. Therefore, only the image in quadrant (*d*) need be considered in addition to the vector of the corner reflector in quadrant (*a*). Assuming the apex **10** of the corner reflector to be a reference point, the field vector of the electrical radio wave propagation from the dipole in quadrant (*a*) will be at an angle, in respect to the reference X, equal to S divided by the wavelength times three hundred and sixty degrees. The image in quadrant (*d*), however, with respect to the apex **10** of the corner reflector or reference point will lag behind the reference point at the same angle. This field vector is shown as a dotted line (*d*). However, the current in quadrant (*d*) will flow in the opposite direction to that in quadrant (*a*). Therefore, the field vector of image (*d*) must be shown as being of opposite polarity as shown by the solid line (*d*) of Fig. 4. It is to be noted that the sum of the field vectors (*a*) and (*d*) will lie along the Y axis for the particular example given.

Reference is now made to Fig. 5 for an explanation of the vertical component of the radio wave radiated from the corner reflector antenna constructed in accordance with the invention. The polarity of the images in quadrants (*b*) and (*c*) are negative with respect to the reference point or apex **10** of the corner reflector. As shown in the field vector analysis, they will add along the negative X or reference axis. As in the case of the field vector analysis of the horizontal component, the field vector of the energy radiated from quadrant (*a*) will appear, at a distant point broadside to the antenna, at an angle to the reference point equal to S divided by the wavelength times three hundred and sixty degrees. The field vector of the image appearing in quadrant (*d*), however, will lag behind the reference point at the same angle and is of the same positive polarity as the current flow in quadrant (*a*) of the corner reflector. The resulting field vector is shown in Fig. 5 as extending at an angle with respect to the X axis equivalent to the spacing S. It is noted that the sum of the field vectors (*a*), (*b*), (*c*) and (*d*) will lie along the X axis. As pointed out above, the sum of these field vectors in respect to the horizontal component of the radio wave will lie along the Y axis. Hence, a quadrature relationship exists between the horizontal and vertical components which is an essential aspect in the propagation or reception of circularly polarized radio waves.

Although the method of explaining the operation of an antenna such as the subject corner reflector antenna by the theory of images is only rigorously correct for infinite reflector sheets, the method does enable an approximation to be obtained for finite sheet reflectors. The power gain, relative to a half wavelength dipole is plotted in Fig. 6 for both the horizontal and vertical components versus the spacing of the dipole **1** from the apex **10** of the corner reflector. The curves shown were obtained by the mutual impedance method. An examination of the curves will show that no operation can be obtained for spacing values S near one-half wavelength and one wavelength at the operating frequency. Based on the curves of Fig. 6, the correct tilt angle α of the dipole **1** to produce circular polarization is plotted in Fig. 7 versus the dipole-to-apex spacing. The resulting relative power gain of the circularly polarized antenna is given in Fig. 8. It is seen that correct operation of the antenna may be obtained for values of spacing S in the region of one-quarter wavelength and three-quarter wavelength at the operating frequency.

The extent to which the reflecting surfaces **2** and **3** may be reduced in size and still retain essentially circularly polarized radiation can be determined experimentally. However, a test model with each half of the corner reflector approximately two wavelengths by three wavelengths in size at the operating frequency was found to produce radiation having an axial ratio of less than 1 db.

The above discussion has referred to a 90° corner reflector. A similar explanation, however, could be given for corner reflectors having angles of 45°, 22.5° and so forth. The angle at which the reflecting surfaces **2** and **3** are made to intersect may be obtained experimentally in view of the particular application of the antenna. However, it has been found, that in the case of a 60° angle of the corner reflector, no quadrature relationship will exist. Hence, an angle of 60° and its multiples cannot be used.

The corner reflector antenna of Fig. 1 requires a balun for the dipole **1**, if fed with a coaxial line **4**. A simpler alternative, however, is shown in Figs. 2(*a*) and 2(*b*) in which the balun is included as part of the antenna. As shown in Figs. 2(*a*) and 2(*b*), the outer conductor of a coaxial line **4** joins with and extends through one of the reflecting surfaces **2** of the corner reflector at the required tilt angle α. The inner conductor of the coaxial line **4** joins with a dummy continuation **5** of the outer conductor of coaxial line **4**, the continuation being connected to the opposite reflecting surface **3**. Hence, a balanced dipole **1** fed at its midpoint is obtained.

In order to obtain greater directivity in the vertical plane, the embodiment shown in Figs. 3(*a*) and 3(*b*) may be used. A square helix antenna **6** is positioned in the corner reflector comprising two reflecting surfaces **2** and **3** so that the legs (*e*) and (*f*) form a phase reversing one-half wavelength transformer with the surfaces **2** and **3**. Sections (*h*) and (*g*) which are inclined at the required tilt angle α form the radiators to produce circular polarization. Succeeding helix turns will then be in phase, resulting in greater directivity in the vertical plane.

By the proper determination of the tilt angle α of a radiating element, the spacing of a radiating element from the apex **10** of the corner reflector, and the particular angle at which the reflecting surfaces intersect, a corner reflector antenna is obtained which will propagate a sharply defined directive circularly polarized radio field. The particular dimensions used, as discussed in connection with Figs. 6, 7 and 8, may be readily determined by the exercise of reasonable engineering skill and will be determined in accordance with the particular application and situation in which the corner reflector antenna is to be utilized. The corner reflector antenna of the invention may be used either to propagate or receive radio waves.

Having described my invention, I claim:

1. A corner reflector antenna comprising a pair of reflecting surfaces arranged to intersect at an angle having a vertex located at said intersection of said surfaces and a bisector plane, a radiating element positioned within said angle at a given distance from said vertex in a plane perpendicular to said bisector plane of said angle and at a given angle other than zero and ninety degrees with respect to said bisector plane, whereby said antenna is effective to radiate and to receive a directive circularly polarized radio field.

2. A corner reflector antenna comprising a pair of reflecting surfaces arranged to intersect at an angle having a vertex located at said intersection of said surfaces and a bisector plane, a radiating element positioned within said angle a given distance from said vertex in a plane which is parallel to said vertex and perpendicular to said bisector plane of said angle at a tilt angle other than zero and ninety degrees with respect to said bisector plane.

3. A corner reflector antenna comprising a pair of flat reflecting surfaces arranged to intersect at an angle having a vertex located at said intersection of said surfaces and a bisector plane, a single dipole radiator positioned within said angle in a further plane parallel to said vertex and perpendicular to said bisector plane of said angle, said radiator being positioned within said angle a given distance from said vertex and at a given tilt angle in said further plane other than zero and ninety degrees with respect to said bisector plane, whereby said antenna is effective to radiate or receive a directive circularly polarized radio field.

4. A corner reflector antenna as claimed in claim 3 and wherein said pair of reflecting surfaces are arranged to intersect at an angle of ninety degrees.

5. A corner reflector antenna comprising a pair of reflecting surfaces arranged to intersect at an angle having a bisector plane, a radiating element positioned within said angle a given distance from said intersection of said angle a given distance from said intersection of said surfaces in a further plane parallel to said intersection and perpendicular to said bisector plane of said angle, said

element being rotated thru an angle in said further plane to be positioned at a tilt angle other than zero and ninety degrees with respect to said bisector plane, whereby said antenna is effective to radiate or receive a directive circularly polarized radio field.

6. A corner reflector antenna comprising a pair of reflecting surfaces arranged to intersect at an angle having a vertex located at said intersection of said surfaces and a bisector plane, a coaxial line having an inner and an outer conductor and adapted to carry a signal to or from said antenna extending thru one of said surfaces and into said angle, a dummy continuation of said outer conductor connected to the other of said surfaces within said angle, said outer conductor being connected to said one surface and said inner conductor being connected to said dummy continuation to form a balanced dipole fed at its midpoint and positioned within said angle a given distance from said vertex in a plane parallel to said vertex and perpendicular to said bisector plane of said angle, said coaxial line extending thru said one surface at a point on said one surface relative to the position of said dummy continuation on said other surface to cause said dipole formed by the connection of said inner conductor to said dummy continuation to be positioned at a given tilt angle other than zero and ninety degrees with respect to said bisector plane.

7. A corner reflector antenna comprising a pair of reflecting surfaces arranged to intersect at an angle having

a vertex located at said intersection of said surfaces and a bisector plane, a square helix radiating element positioned within said angle at a given distance from said vertex with the axis of said element in said bisector plane of said angle and in a plane parallel to said vertex, said element including radiating sections positioned a given tilt angle other than zero and ninety degrees with respect to said bisector plane, whereby said antenna is effective to radiate or receive a directive circularly polarized radio field.

8. A corner reflector antenna comprising a pair of reflecting surfaces arranged to intersect at an angle having a bisector plane, a single dipole radiator positioned within said angle a given distance from the intersection of said surfaces along said bisector plane in a further plane parallel to the intersection and perpendicular to said bisector plane of said angle, said radiator being rotated thru an angle in said further plane to be positioned at a tilt angle other than zero and ninety degrees with respect to said disector plane, whereby said antenna is effective to radiate and to receive a directive circularly polarized radio field.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,897,496 July 28, 1959

Oakley M. Woodward, Jr.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 73, strike out "angle a given distance from said intersection of said"; column 6, line 19, for "disector" read -- bisector --.

Signed and sealed this 26th day of January 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents