July 20, 1965 J. E. MARTIN 3,196,443

CIRCULARLY POLARIZED DIPOLE ANTENNA

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Fig. 1

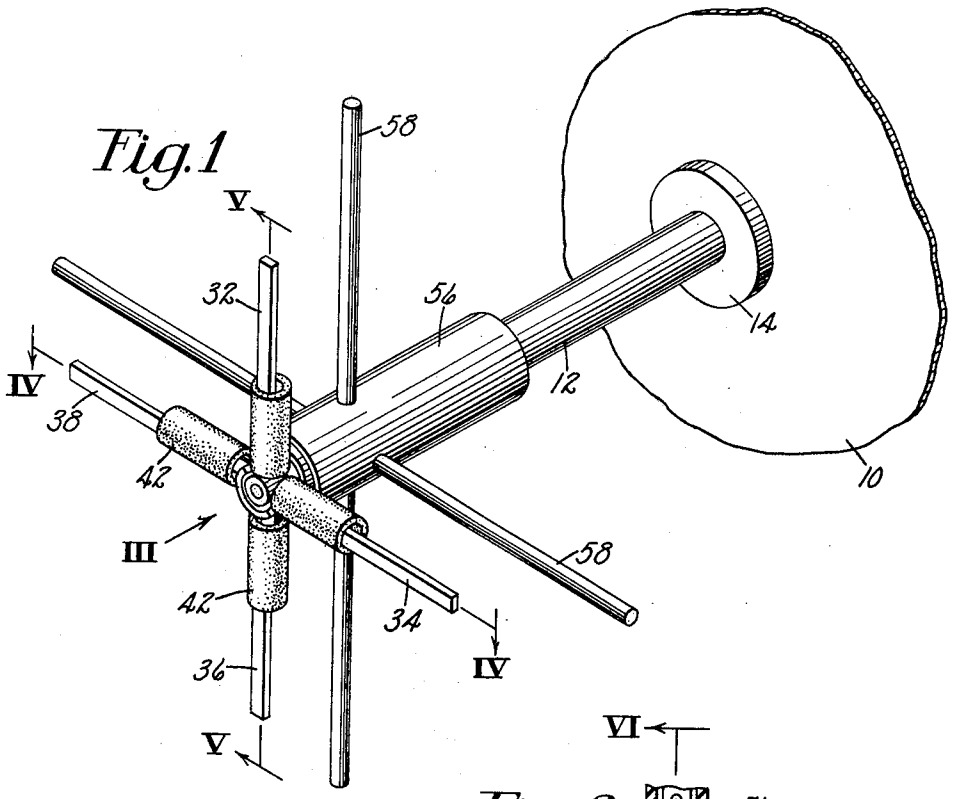


Fig. 2

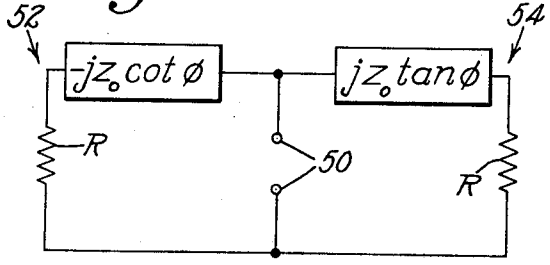
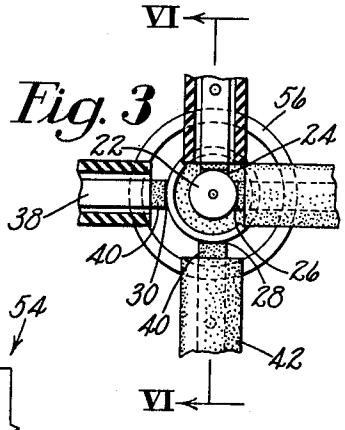


Fig. 3



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Fig. 4

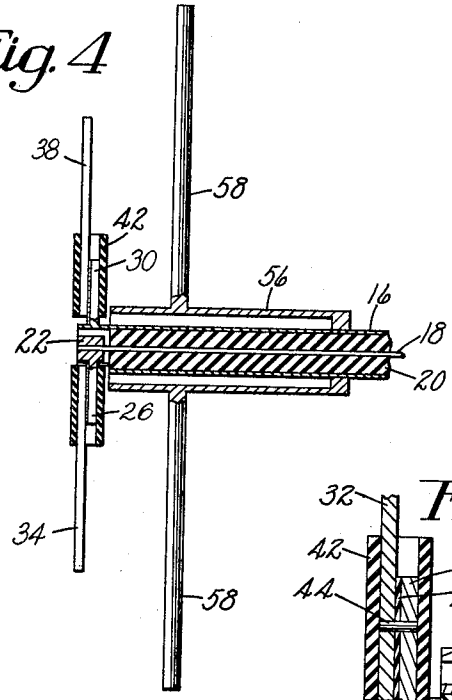


Fig. 6

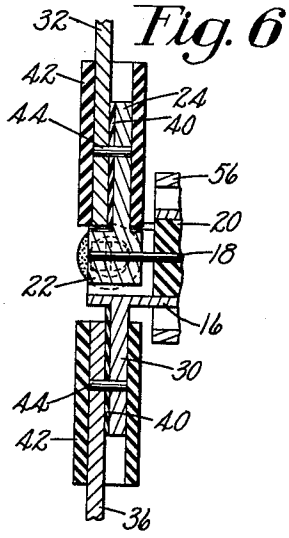
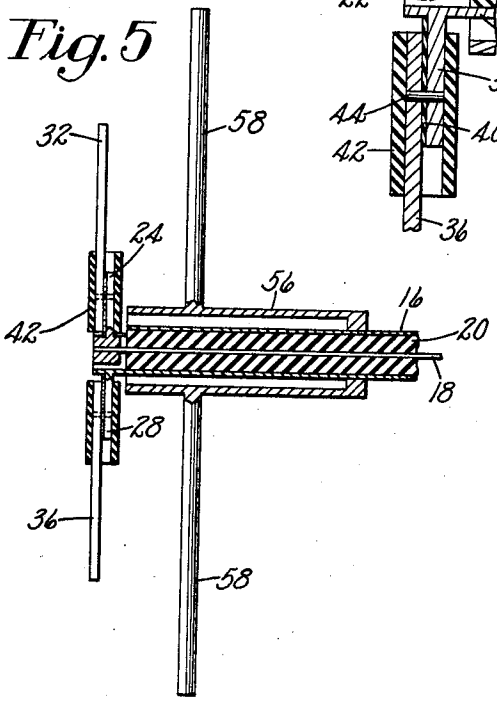


Fig. 5



United States Patent Office 3,196,443 Patented July 20, 1965

3,196,443

CIRCULARLY POLARIZED DIPOLE ANTENNA

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Filed Aug. 28, 1962, Ser. No. 220,001
2 Claims. (Cl. 343—797)

This invention relates in general to antennas for use with electromagnetic wave energy and in particular to an antenna comprising two pairs of orthogonally related dipoles and adapted to radiate and receive circularly polarized electromagnetic energy.

Antenna systems are presently known which employ two pairs of orthogonally related dipoles and which achieve a circularly polarized field. However, such antenna systems have employed external means, e.g., transmission line sections, for exciting radiating currents on the crossed dipoles in phase quadrature which phase relationship of 90 electrical degrees provides the necessary condition for circularly polarized pattern. The matching and phasing means of such feeding systems, such as line sections, transformers and skirts, presents a difficult problem with respect to coaxial mounting and the avoidance of spurious induced currents which might adversely affect the pattern. Also, of course, it is essential to circular polarization for the dipole currents to be equal, this equality implying that the length of the two dipoles be essentially equal.

Accordingly, it is an object of the present invention to provide an antenna comprising orthogonally related dipoles which may be fed from a common central feed point at the end of a transmission line for the radiation of a circularly polarized field in which such mechanical problems are minimized.

To this end and in accordance with a feature of the invention, an antenna is provided comprising two pairs of orthogonally related dipoles each comprising oppositely directed arms in which a portion of each dipole adjacent to the central points of feed (herein termed the "base portion") comprises a section of transmission line which, while constituting a portion of the dipole itself, provides a suitable series impedance for achieving the desired phase quadrature when the dipoles are fed at their base from the end of a transmission line.

Another object of the present invention is to provide an antenna having a broadly directive substantially cardioid radiation pattern, such a pattern being particularly useful in such applications as require directive systems, for example, as telemetry and communication with space vehicles.

Other features and advantages of the invention will best be understood from the following description taken in connection with the accompanying drawings in which:

FIG. 1 is an angular view of an antenna, embodying the present invention;

FIG. 2 is a functional schematic of the antenna;

FIG. 3 is an enlarged view partly in section of a portion of the antenna looking along the arrow III of FIG. 1;

FIG. 4 is a section taken generally on line IV—IV of FIG. 1;

FIG. 5 is a section taken generally on the line V—V of FIG. 1; and

FIG. 6 is a section of a portion of the antenna taken along the line VI—VI of FIG. 3.

Referring to the drawings, the antenna is shown as supported from a housing 10 which may, for example, be a trailing surface of a vehicle, the support comprising a coaxial transmission line 12 extending through a gasket 14 fixed to the housing 10. The transmission line 12 comprises (see FIG. 4) an outer conductor 16 and an inner conductor 18 separated by insulating material 20. At the

outer end of the coaxial line a portion of the insulating material 20 is removed and an annular stud 22 is welded to the center conductor 18 while the corresponding length of the outer conductor is cut away in a 180° sector. To the stud 22 are silver soldered in orthogonal relation two stubs 24 and 26 (FIG. 3) while two other stubs 28 and 30 are similarly secured to the remaining portion of the tip of the conductor 16 the stubs thus extending radially at 90° intervals from a common centrally located feed point at said end of the coaxial line. To the four stubs 24, 26, 28 and 30 are fastened four arms 32, 34, 36 and 38, respectively, separated in each case from the stubs by a thin layer of insulation 40, the fastening means comprising insulating sleeves 42. The arms 32 and 36 with the stubs 24 and 28 constitute one pair of dipoles while the arms 34 and 38 and the stubs 26 and 30 constitute a second pair of dipoles orthogonally related to the first pair.

In one pair of dipoles comprising the arms 32 and 36, the arms and stubs are connected by rivets 44, while in the other pair of dipoles comprising the arms 34 and 38, no such connection is made.

The stubs and the base portions of the arms which coextend with the stubs will be seen to constitute transmission line sections adapted to provide reactive-line impedances to the flow of dipole current when the dipole is fed by the coaxial line. As shown in FIG. 2, the load presented to the feed points 50, corresponding to the point of connection of the inner ends of the stubs to the coaxial line, comprises two parallel circuits 52, 54, one for each dipole. In each circuit, the radiation resistance R is in series with a reactance which is the net effective reactance of the two line sections of the corresponding dipole.

According to the present invention the line sections of the two orthogonally related dipoles provide in series with the radiation resistance of the dipoles, reactances which as between the two dipoles are of opposite signs, the reactance in one being an inductive reactance $+jX$ while the reactance in the other dipole is a capacitive reactance $-jX$, the two reactances being equal at the operating frequency so that the net load at the load points 50, that is, the antenna input impedance, is purely resistive. Preferably, this resistive load will be matched to the characteristic impedance of the coaxial line.

Further to achieve the proper phasing of the antenna currents to produce a circularly polarized field, the effective reactance in each dipole is made equal to the radiation resistance R.

The appropriate values of reactance can be provided by suitable establishment of the parameters of the transmission line sections by appropriate design in accordance with well-known transmission line theory. Transmission line sections when open circuited provide a series reactance $X=-jZ_0 \cot \phi$ and when short circuited a series reactance $X=jZ_0 \tan \phi$ where Z_0 is the characteristic impedance of the line and ϕ the electrical length of the section. Further herein, the net series reactance of the two open circuited sections in one dipole is $X_0=-jZ_{0E} \cot \phi$ and the net series reactance X_s of the short circuited sections in the other is $jZ_{0E} \tan \phi$ where Z_{0E} is defined as the effective characteristic impedance of the line combination and ϕ is the electrical length of each section.

The current flowing in the two pairs of dipoles in a given phase for a voltage of the same phase is:

For the inductive dipole:

$$\vec{I}_s=\frac{\vec{V}}{R+jX}$$

For the capacitive dipole:

$$\vec{I}_0=\frac{\vec{V}}{R-jX}$$

The phase of

$$\vec{I}_s = \tan^{-1} - \frac{X}{R}$$

while the phase of

$$\vec{I}_o = \tan^{-1} + \frac{X}{R}$$

Assuming that X is made equal to R by suitable adjustment of the parameters Z_o and ϕ, the phase of

$$\vec{I}_s = \tan^{-1}(-1) = -45°$$

while the phase of

$$\vec{I}_o = \tan^{-1}(+1) = +45°$$

so that the current are in quadrature. At the same time, the ratio of the absolute values of the currents

$$\frac{I_s}{I_o} = \frac{\sqrt{R^2+X^2}}{\sqrt{R^2+X^2}} = 1$$

while the reactive components of current are equal and in opposite phase and cancel so that the transmission sees a purely resistive impedance.

Accordingly, the conditions requiste to the radiation of a circularly polarized field are present under the recited conditions.

A balun **56** is provided at the end of the coaxial line **12** to eliminate unbalancing currents flowing on the outside of the coaxial line. It is, of course, not necessary where the antenna is fed by a balanced line. To provide a broadly directive radiation pattern, a pair of directors **58** are attached to the balun **56** and located about 0.1γ from

the driven elements. With the aforedescribed director, the radiation pattern assumes substantially the shape of a cardioid of revolution.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent of the United States is:

1. In an antenna, a rigid coaxial transmission line, four stubs extending radially at 90° intervals from a common central feed point at an end of said line, two of said stubs being connected to each conductor of said line, four radially disposed conductive arms of equal length longer than the stubs, each arm being carried by a stub and extending parallel thereto from its base and separated therefrom by a thin layer of insulation, thereby forming two pairs of orthogonally related dipoles with a transmission line section at the base of each arm electrically in series between the arm and a conductor of the coaxial line and means for electrically connecting the stubs and arms of one dipole at a point spaced from the base thereof whereby at a given operating frequency the input impedence of one dipole across the inner ends of the stubs thereof has a reactive component equal to and of opposite sign to the corresponding input impedance of the other dipole.

2. Apparatus as in claim **1** and additionally comprising sleeves of insulating material snugly encompassing the arms and stubs.

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HERMAN KARL SAALBACH, *Primary Examiner.*