United States Patent [19]

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[11] **3,813,674**

[45] **May 28, 1974**

[54] **CAVITY BACKED DIPOLE-SLOT ANTENNA FOR CIRCULAR POLARIZATION**

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[22] Filed: **Jan. 4, 1973**

[21] Appl. No.: **321,083**

[30] **Foreign Application Priority Data**

Jan. 5, 1972 Great Britain 393/72

[52] **U.S. Cl.** **343/730,** 343/789, 343/803, 343/854

[51] **Int. Cl.** **H01q 1/28,** H01q 13/18

[58] **Field of Search** .... 343/727, 767, 769, 789, 343/803, 854; 333/84 M

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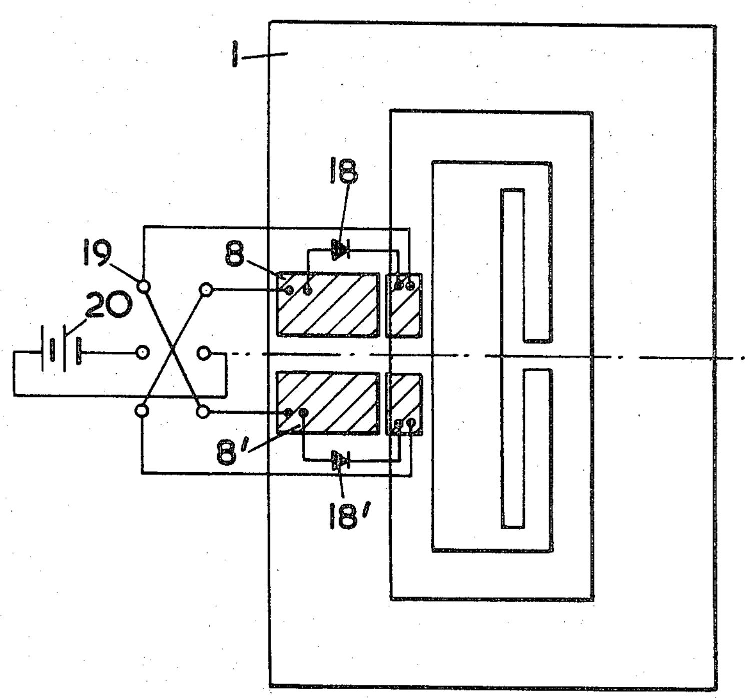
[57] **ABSTRACT**

Aerial for receiving or transmitting circularly polarized electromagnetic radiation includes a dipole mounted substantially within the aperture of a slot and means for coupling the slot to the dipole asymmetrically. It may also include an electromagnetic cavity adjacent the coupled dipole and slot. In one embodiment the dipole is formed on one side of an insulating substrate and a narrow conductor is formed on the other side substantially opposite the dipole, with part of the dipole, the substrate, and the conductor together forming a stripline feed which may have a matching network formed by a further part of the dipole, the substrate, and the conductor.

6 Claims, 4 Drawing Figures



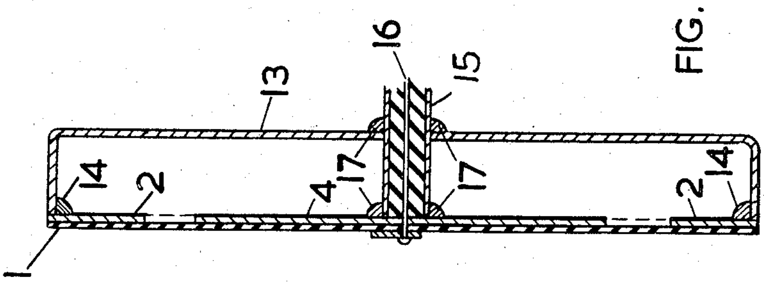


FIG. 2.

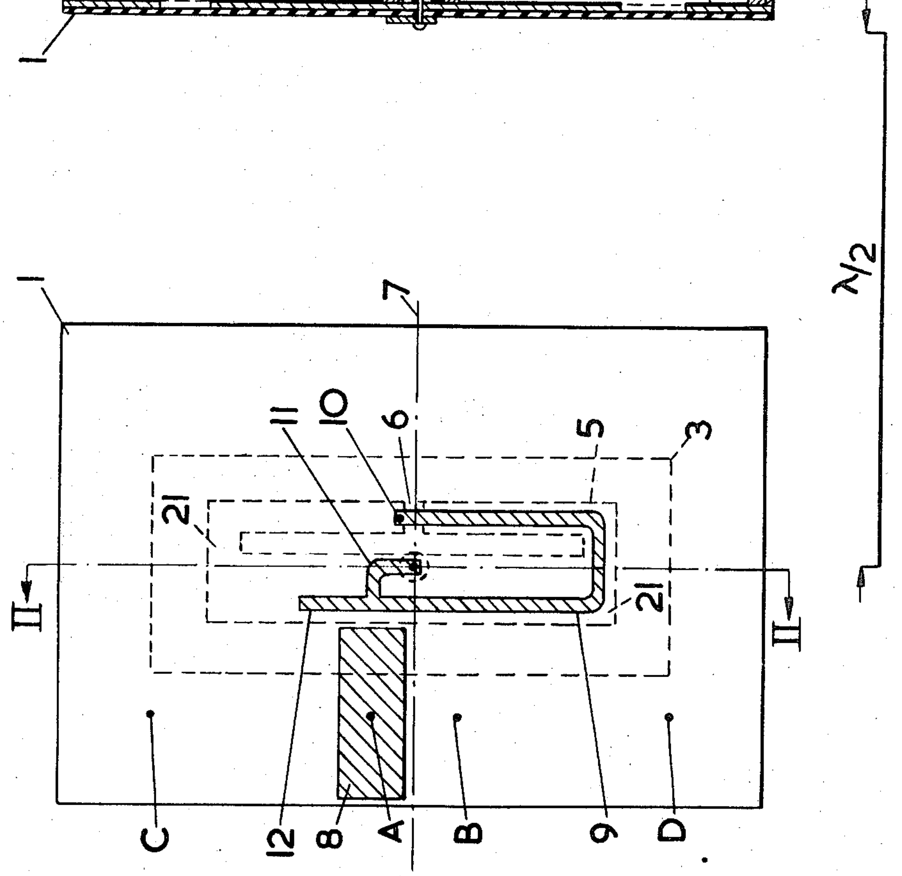


FIG. 1.

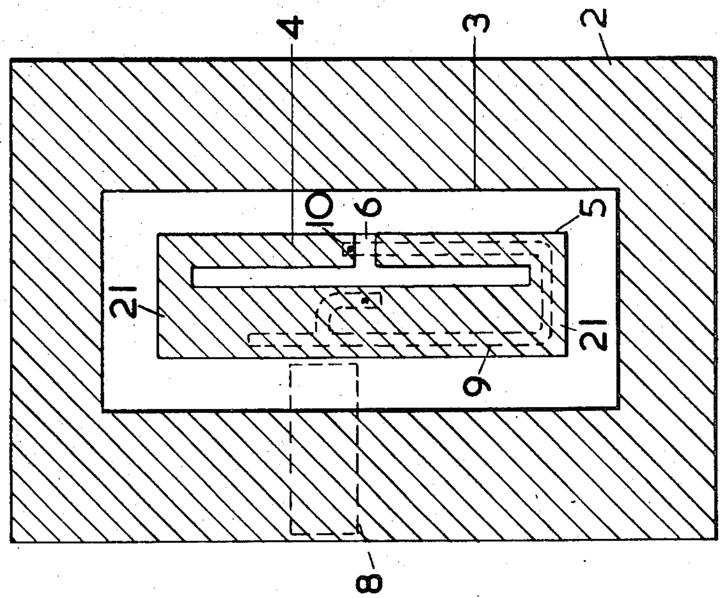


FIG. 3

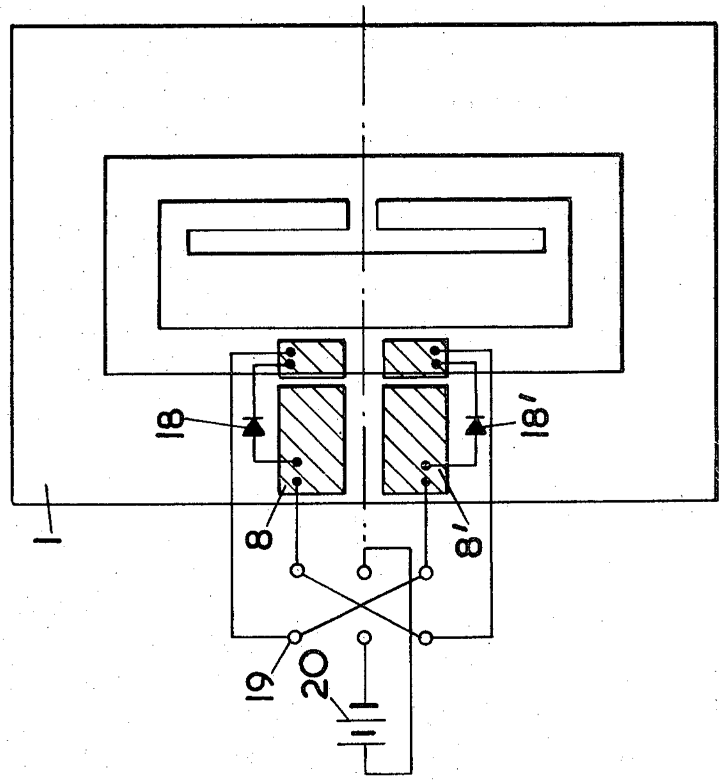


FIG. 4.

CAVITY BACKED DIPOLE-SLOT ANTENNA FOR CIRCULAR POLARIZATION

BACKGROUND OF THE INVENTION

This invention relates to aerials and in particular to aerials for transmitting and receiving circularly polarized electromagnetic radiation.

Known satellite communication systems have comprised low-powered transmitters sited in a satellite co-operating with large mechanically steerable highly directive aerials at an earth transmitter receiver station. Recent developments of higher-power transmitters for satellites have led to the possibility of employing smaller aerials or aerial arrays at the receiver. A desirable satellite communication system employs a transmitter/receiver in, and a suitable aerial mounted on, an aircraft. It has been suggested that the use of circularly polarized electromagnetic radiation to convey the information in such communication systems is advantageous since the Faraday rotation of such radiation in its passage between transmitter and receiver does not affect the response of a suitable receiving aerial to it. Furthermore, such a receiving aerial, being responsive only to a particular hand of circularly polarized radiation, can inherently distinguish between that radiation received directly from a transmitter and the same radiation received after reflection from the sea, because in the latter case the hand of the polarization is reversed.

There is therefore a requirement for an aerial; suitable for mounting, preferably flush-mounting, in an aircraft; which has a capability of transmitting or receiving circularly polarized signals in conjunction with suitable transmitters or receivers; which is effective over as wide a range of directions as possible; and, which is convenient and comparatively simple for use in arrays.

It is an object of this invention to provide an aerial which can be made to meet the requirement outlined above.

SUMMARY OF THE INVENTION

According to the present invention an aerial for receiving or transmitting circularly polarized electromagnetic radiation includes a dipole mounted substantially within the aperture of a slot and means for coupling the slot to the dipole asymmetrically. The aerial may also include an electromagnetic cavity adjacent the coupled dipole and slot. The dipole may be folded and a consequently comparatively shallow electromagnetic cavity used. The dipole may be formed on one side of an insulating substrate and a narrow conductor formed on the other side substantially opposite the dipole, part of the dipole the substrate and the conductor together forming a stripline feed which may have a matching network formed by a further part of the dipole the substrate and the conductor. Those parts of the dipole which also form part of the stripline feed and matching network may be wider than the remainder of the dipole.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the invention will now be described by way of example only, and with reference to the accompanying drawings of which:

FIG. 1 is a plan view of an L-Band or UHF aerial,

FIG. 2 is a section through the aerial of FIG. 1 along the line II—II in the direction indicated by the arrows,

FIG. 3 is a view of the underside of part of the aerial of FIG. 1, and,

FIG. 4 is a diagram of a modification of the aerial of FIGS. 1 to 3 with a switching circuit appendant thereto.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In describing the drawings elements common to two or more drawings have been given common reference numbers. FIGS. 1 to 3 inclusive are scale drawings all drawn to the same scale. The scale shown beneath FIGS. 1 and 2 which equals $\lambda/2$ where λ is the wavelength of the signal to be transmitted or received, indicates the relative size of the aerial. Suitably scaled the aerial is capable of operating at L-Band (of the order of 1,600 MHz) or Ultra High Frequency (UHF) frequencies.

In the drawings a rectangular insulating low loss substrate 1 for example of glass-fibre, has a conductor 2, having a rectangular slot defined by an edge 3 of the conductor 2 cut centrally therein, printed on one side of the substrate 1. Printed on the same side of the substrate 1 centrally within and insulatedly separated from the conductor 2 is a folded dipole formed of a conductor 4 defined by an edge 5 of the conductor 4. There is a small gap 6 at the center of the dipole. The dipole occupies a rectangular area, the longer and shorter sides of which are parallel to the longer and shorter sides of the slot respectively. The shorter sides of the dipole will be referred to hereinafter as the ends 21 of the dipole. The conductor 4 is symmetrical about a line of symmetry 7 parallel to and equispaced from the ends 21. The parts of the dipole on either side of the gap 6 are narrower than the rest of the dipole. On the reverse side of the substrate 1 is printed a rectangular conductor 8 and a narrow strip of conductor 9. One end of the narrow strip 9 overlays the gap 6 in the dipole and is electrically connected to the dipole adjacent the gap 6, by a lead 10 passing through the substrate 1. The remainder of the strip 9 overlays and follows the shape of a little more than half of the complete conductor 4 forming the dipole. The strip 9, the substrate 1 and the conductor 4 form a stripline feed whose end remote from the gap 6 of the dipole terminates in a matching network. The matching network comprises a series arm 11 and a parallel arm 12. The series arm 11 is formed of a branch of the conductor 9 part of which is parallel to the conductor 9 and projects over the line of symmetry 7. The parallel arm 12 is formed of a collinear extension of the conductor 9. The conductor 8 is a capacitive coupling strip for coupling the slot and the dipole. It is positioned with its shorter edge parallel to the conductor 9 adjacent the matching network and overlaying the edge 3. Its center is at A, a little more than half the length of its shorter side from the line of symmetry 7.

A conductor 13 of unlidded-box-like construction having open end dimensions substantially corresponding to those of the substrate 1 and a depth of 0.08 λ, where λ is the wavelength of the radiation to be transmitted or received, is electrically and mechanically connected to the conductor 2 at the edges of its open end as indicated at 14 and forms a cavity. A co-axial signal cable from a transmitter and/or receiver (not shown), having an outer conductor 15 and an inner conductor 16 insulatedly separated therefrom, passes through a hole provided in the closed end of the conductor 13 to a point adjacent the series arm 11 of the matching network. The outer conductor 15 is electrically connected to the conductor 13 and to the middle of the wider arm of the dipole as indicated at 17. The inner conductor 16 passes insulatedly through the folded arm of the dipole and the substrate 1 and is electrically connected to the end of the series arm 11 of the matching network.

The aerial of FIGS. 1 to 3 is mounted in an aircraft (not shown) with that surface of the substrate 1, having the conductors 8 and 9 printed thereon, flush with and insulated from an outer surface of the aircraft at a suitable point for example on the rear fuselage. The aerial is orientated so that the dipole is in the vertical plane when the aircraft is in normal cruising flight. The conductor 2 and the cavity box are electrically bonded to the aircraft outer skin. In a transmitting mode an L-Band or UHF signal as appropriate is applied via the co-axial signal cable to the stripline feed which matches the signal source to the dipole. The dipole is excited and transmits linearly polarized radiation. The dipole is also capacitively coupled via the conductor 8 to the slot which also transmits linearly polarized radiation. The dimensions of the dipole and the slot and the conductor 8 and their relative positions are such that the radiations from the slot and the dipole are polarized in orthogonal planes and in phase quadrature. The resultant radiation is nominally circularly polarized with a given hand and is propagated with an acceptable ellipticity-ratio and relative radiated power over a wide range of angles. The actual range of angles will depend on the site chosen for mounting the aerial.

Circularly polarized radiation at L-Band or UHF frequency as appropriate incident on the surface of the aerial can be considered as comprising a combination of two waves in quadrature with each other, linearly polarized in two orthogonal planes. In a receiving mode the slot responds to one of these waves and the dipole responds to the other; if the coupling strip 8 is suitably proportioned and positioned, these responses will combine to form a resultant signal on the cable 15 with a comparatively high sensitivity to circularly polarized waves having a given hand of circular polarization over a wide range of angles and outside this range it still has useful sensitivity to circularly polarized incident radiation.

If the dipole was not coupled to the slot by means of the coupling strip 8, a signal applied to the dipole would tend to induce equal in phase currents parallel to the longer edges of the slots. Such balanced currents would not provide any useful net effect. The conductor 8 is therefore positioned to one side of the line of symmetry 7 to introduce a small capacitance between one edge of the slot and one arm of the dipole. This causes the currents induced parallel to the longer edges of the slot in the conductor 2 to be unbalanced. In-phase currents will therefore flow around the two ends of the slot causing it to radiate or respond to radiation with a polarization in a plane orthogonal to and, in the case shown, in phase quadrature with that of the dipole.

The slot is most sensitive to radiation polarized in a plane parallel to the shorter sides of the slot, referred to hereinafter as horizontally polarized radiation, while the dipole is most sensitive to radiation polarized in a plane parallel to the longer sides of the slot, referred to hereinafter as vertically polarized radiation. If the conductor 8 is positioned with its center at the points C or D shown in FIG. 1, that is near the ends 21 of the dipole, the radiation or response of the slot is dominant and the aerial radiates mostly or responds best to horizontally polarized radiation. If the coupling is suitably reduced by reducing the dimensions of the conductor 8 positioned at C or D then the response of the slot is reduced and eventually the aerial radiates equally or responds equally well to horizontally polarized radiation and to vertically polarized radiation. However, the phase difference between the horizontally polarized radiation and the vertically polarized radiation is then either 0° or 180° and the resultant radiation transmitted most efficiently, or best responded to, by the aerial is linearly polarized in a plane normal to the surface of the aerial and inclined at 45° to the longer edges of the slot.

No useful result is obtained if the center of the coupling conductor 8 is positioned on the line of symmetry 7, but if the coupling conductor 8 is positioned with its center at B, on the other side of the line of symmetry 7 from A and equispaced from it, the operation of the aerial is similar to that when the conductor 8 is positioned at A except that the circularly polarized radiation transmitted or responded to is of the opposite hand.

The latter feature can be utilised in an aerial in which for example it is desired to transmit or receive circularly polarized radiation of right hand (say) and in another state to transmit or receive circularly polarized radiation of left hand. This technique can be used to communicate with satellites equipped with aerials of either hand by means of a single aerial. This form of aerial is shown schematically in FIG. 4. The dimensions and assembly of the various components of the aerial are identical with those of the aerial described hereinabove with reference to FIGS. 1 to 3, except that two coupling conductors 8 and 8′ are printed on to the substrate 1. The conductor 8 is positioned with its center at A (FIG. 1) and the conductor 8′ is positioned with its center at B (FIG. 1). Each of the conductors 8 and 8′ has the same overall dimensions as the conductor 8 of FIG. 1 but each is divided into two conductive areas insulatedly separated from each other. The two parts of each of the conductors 8 and 8′ are bridged by RF switching diodes 18 and 18′ respectively. A two-pole changeover switch 19 is connected to a direct current voltage source 20 and to the diodes 18 and 18′ such that in one position it reverse biases the diode 18 and forward biases the diode 18′, whereas in the other position it forward biases the diode 18 and reverse biases the diode 18′.

When the diode connected across the two parts of either of the two conductors 8 or 8′ is forward biased the two parts are electrically connected and the dipole and the slot are capacitively coupled by that conductor. When the diode across the two parts of either of the two conductors 8 or 8′ is reverse biased the two parts are electrically insulated from each other and the capacitive coupling between the dipole and the slot provided by that conductor is made negligible.

It has been explained that the circularly polarized radiation responded to or radiated by the aerial when the conductor 8 is placed at the position A differs only in hand from that when the conductor **8** is placed at the position B. Operation of the switch **19** thus causes circularly polarized radiation of either hand to be transmitted or received by the aerial when appropriately connected to a transmitter or receiver (not shown).

Inspite of the small dimensions of the aerials described hereinabove their receiver gain is of the order of plus 5db with respect to the gain of a theoretical detector capable of an isotropic response to circularly polarized radiation. The aerials may be mounted in arrays comprising two or more such aerials in a conventional manner to increase the gain. The aerials in such an array may also be variably phased with respect to each other in order that they might be electrically steered, again in a conventional manner.

It will be appreciated by those skilled in the art that many variations and modifications of the aerials described above are possible. The aerials need not be flush mounted with the fuselage of the aircraft but could be mounted externally with the back of the cavity electrically and mechanically secured to the fuselage. Only a small hole is then required in the fuselage to allow the co-axial signal cable to be connected to the aerial. The low profile of the aerial should not cause any aerodynamic problems although a radome may be desirable to protect the conductors of the aerial from weathering.

I claim:

1. An aerial for receiving or transmitting circularly polarized electromagnetic radiation comprising an insulating substrate on one side of which is formed a dipole, said dipole being mounted substantially within the aperture of a slot antenna, means for coupling the slot antenna to the dipole asymmetrically with respect to a line of symmetry of the dipole, an electromagnetic cavity adjacent the coupled dipole and slot antenna, and a narrow conductor formed on the other side of said substrate substantially opposite the dipole and disposed such that part of the dipole, the substrate, and the conductor together form a stripline feed, said means for coupling the slot antenna to the dipole asymmetrically

comprising another conductor formed on the same side of the substrate as the narrow conductor but insulatedly separated from it and positioned over the dipole and the slot antenna so as to couple them together capacitively.

2. An aerial for receiving or transmitting circularly polarized electromagnetic radiation including a dipole mounted substantially within the aperture of a slot antenna, an electromagnetic cavity adjacent the coupled dipole and slot and having a depth of less than $\lambda/10$, where λ is the wavelength of the radiation, means for coupling the slot antenna to the dipole asymmetrically with respect to a line of symmetry of the dipole for determining the relative phase and amplitude of the responses of the slot antenna and the dipole to the radiation, and means connected to the dipole for feeding alternating electrical signals at the frequency of the radiation to the dipole and thus via the coupling means to excite the slot antenna.

3. An aerial as claimed in claim **2**, and wherein the dipole is a folded dipole.

4. An aerial as claimed in claim **2** and further including an insulating substrate on one side of which is formed the dipole, and a narrow conductor formed on the other side of said substrate substantially opposite the dipole, disposed such that part of the dipole the substrate and the conductor together form a stripline feed.

5. An aerial as claimed in claim **2** wherein the means for coupling the slot to the dipole asymmetrically with respect to a line of symmetry of the dipole is another conductor formed on the same side of the substrate as the narrow conductor but insulatedly separated from it and positioned over the dipole and the slot so as to couple them together capacitively.

6. An aerial as claimed in claim **2** wherein the means for coupling includes an electronic switch device for controlling the phase between the responses of the slot and the dipole to the radiation afforded by said means for coupling.

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