EP 0051671

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 3: H01Q 1/38, 1/48	A1	(11) International Publication Number: WO 81/03398 (43) International Publication Date: 26 November 1981 (26.11.81)

(21) International Application Number: PCT/US81/00628

(22) International Filing Date: 12 May 1981 (12.05.81)

(31) Priority Application Number: 149,548

(32) Priority Date: 13 May 1980 (13.05.80)

(33) Priority Country: US

(81) Designated States: DE, FR (European patent), GB, JP.

Published
With international search report

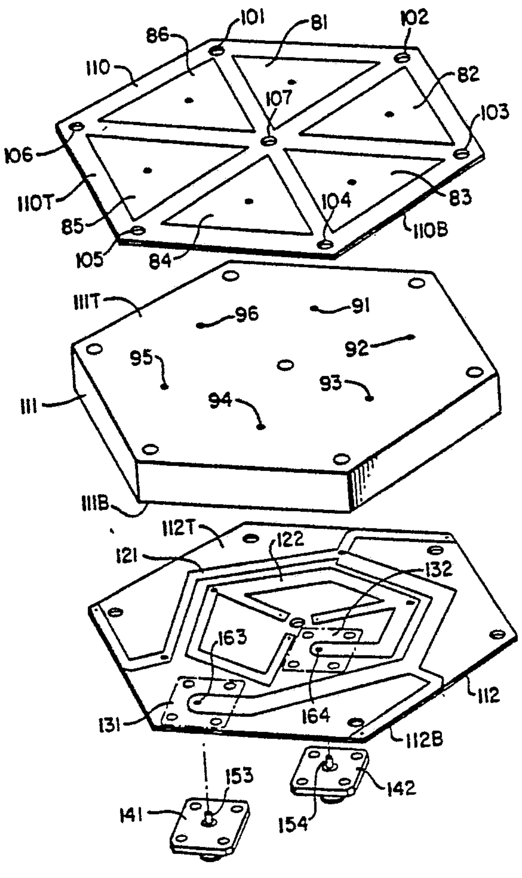
(71) Applicant; and
(72) Inventor: FINKEN, Kenneth, R. [US/US]; 2392 Brookside Drive, Indialantic, FL 32903 (US).

(74) Agents: WANDS, Charles, E.; Suite 600, 1919 Pennsylvania Avenue, N.W. Washington DC 20006 (US) et al.

(54) Title: CIRCULARLY POLARIZED HEMISPHERIC COVERAGE FLUSH ANTENNA

(57) Abstract

An antenna configuration capable of providing either shaped conical or uniform hemispheric coverage to circularly polarized signals from a very thin or flush mounted radiation structure. For this purpose, the antenna is configured of an array of (N = three or more) radiation elements (11-14) fed in phase rotation (i.e. 360°/N phase difference between elements) to provide circular polarization. These elements may be short asymmetrically top loaded stubs, unbalanced slots, "L" type stubs, "U" shaped slots or other types of unbalanced elements which provide null free coverage in a hemisphere. The shape of these elements and their position in the array control the desired shaping of the antenna pattern. The antenna elements are provided on a first printed circuit board (15) that is spaced apart by a thin dielectric spacer (20) from an impedance matching/phasing network such as from 90° and 180° hybrid networks formed on a second printed circuit board (21). The ratio of zenith (or nadir) to horizon signal is controlled by the location of vertical feed wires that extend from the hybrid-containing circuit board through the spacer to the radiation elements, and the degree of unbalance of the radiation elements themselves. Assembly of the components of each antenna structure is accomplished by mounting screws that extend from one printed circuit board through the thin dielectric spacer to the other board. The resulting thin structure permits conformal mounting to curved surfaces such as an aircraft fuselage; if desired, however, the antenna may be mounted in a recess below the surface of the aircraft to thereby provide a completely flush mounting arrangement.



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CIRCULARLY POLARIZED HEMISPHERIC COVERAGE FLUSH ANTENNA

FIELD OF THE INVENTION

The present invention relates generally to radio antennas and, more particularly, to an extremely compact airborne antenna for providing shaped conical or uniform hemispheric coverage to circularly polarized signals.

BACKGROUND OF THE INVENTION

In airborne communication environments, such as aircraft or satellite based systems, radio signal transmission/reception capability over a substantial terrestrial area is required. For example, in a satellite, the extent of terrestrial coverage is of shaped conical configuration substantially bounded by lines tangential to the surface of the earth and intersecting the satellite. For lower altitude aircraft radio coverage extends hemisperically from the aircraft to the horizon. Antennas located near the surface of the earth which communicate with high flying aircraft or satellites of undetermined location also require hemispherical coverage. In any of these environments, a requirement for intended hemispherical radio coverage is a signal transmission scheme that makes available more signal at elevation angles near the horizon because of the greater distance and transmission loss. In addition, and it is especially true for antennas mounted on high performance aircraft, the physical size and shape of the antenna impact directly on its utility in the environment. Ideally, the antenna should not only provide full hemispheric coverage with the desired increase in gain at near horizon elevation angles, but should also be rugged, light weight and be of low drag configuration, and thereby readily acceptable for mounting on high performance aircraft.

Prior art approaches to provide hemispherical antenna coverage have included turnstile and crossed-slot structures, as well as a combination of those two configurations,as exemplified by the multi-element structure detailed in the U. S. Patent to Griffee, et al., 3,811,127. As described in this patent, while a crossed-slot antenna presents a minimum height profile when mounted to the fuselage of the aircraft, in order to be satisfactorily broadband, it becomes too large in horizontal displacement for fuselage mounting. The turnstile approach suffers from maximum vertical height limitations, thereby making it too large for satisfactory mounting on modern jet aircraft.

The patentees' approach is to combine the turnstile and crossed-slot configuration in an effort to achieve broadband operation and still make the size of the antenna compatible with aircraft mounting limitations. However, the Griffee, et al. configuration must still be fairly large in order to obtain the broadband performance intended and the patentees do not contemplate adjustability or control of the shape of the radiation pattern.

Of course, reduced-size antenna structures, per se, such as those of microstrip configuration, have been proposed for airborne applications. Examples of such antennas are described in the U.S. patents to Kaloi, 4,125,838 and 4,151, 530 and the U.S. patent to Van Atta, et al., 3,680,142. However, none of these structures provides a broad antenna pattern required for hemispherical coverage; nor do they provide control over the radiation pattern shape, in particular the ratio of zenith-to-horizon signal.

SUMMARY OF THE INVENTION

In accordance with the present invention there has been developed a new and improved antenna configuration that is capable of providing either shaped conical or uniform hemispheric coverage to circularly polarized signals from a very thin or flush mounted radiation structure. For this purpose, the antenna is configured of an array of (N = three or more) radiation elements fed in phase rotation (i.e. 360°/N phase difference between elements) to provide circular polarization. These elements may be short asymmetrically top loaded stubs, unbalanced slots, "L" type stubs, "U" shaped slots or other types of unbalanced elements which provide null free coverage in a hemisphere. The shape of these elements and their position in the array control the desired shaping of the antenna pattern.

In accordance with a first embodiment of the invention operating over two frequency bands, four printed circuit-formed antenna elements are provided on a first printed circuit board that is spaced apart via a thin dielectric spacer from 90° and 180° hybrid networks formed on a second printed circuit board. The ratio of zenith (or nadir) to horizon signal is controlled by the location of vertical feed wires that extend from the hybrid-containing circuit board through the spacer to the radiation elements, and the degree of unbalance of the radiation elements themselves.

In a second embodiment, two sets (for two respective frequencies) of three radiation elements are provided on a first printed circuit board, the individual elements of each set being asymmetrical top loaded elements. Impedance matching and phase delay lines at each frequency are incorporated on the second printed circuit board, from which vertical wires extend through a dielectric spacer to the elements on the first printed circuit board.

Assembly of the components of each antenna structure is accomplished by mounting screws that extend from one printed circuit board through the thin dielectric spacer to the other board. The resulting thin structure permits conformal mounting to curved surfaces such as an aircraft fuselage; if desired, however, the antenna may be mounted in a recess below the surface of the aircraft to thereby provide a completely flush mounting arrangement.

Advantageously, with this type of antenna configuration, by way of which pattern shaping is readily and easily controlled, the signal response of the antenna affords several db more gain at near horizon elevation angles than more conventional antennas having a zenith or nadir directed beam, and still provides adequate coverage at zenith or nadir.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 depicts an embodiment of a four element circularly polarized hemispheric coverage antenna having L-shaped stubs;

Figure 2 depicts an embodiment of a four element circularly polarized hemispheric coverage antenna having asymmetrical top-loaded elements;

Figure 3 depicts an embodiment of a circularly polarized hemispheric coverage antenna having three asymmetrical top-loaded elements for two operating frequencies; and

Figure 4 is an exploded view of the antenna of Figure 3.

DETAILED DESCRIPTION

Referring now to Figure 1 of the drawings there is shown a first embodiment of the invention configured of a pair of square-shaped printed circuit boards 15 and 21 disposed on opposite surfaces (top and bottom as viewed in Fig. 1) of a thin square dielectric spacer element 20. Printed circuit board 15 contains a set of four separated L-shaped areas 11-14 of metallic film (e.g. copper) arranged at the corners of the board with the long and short legs of each "L" shape colinear with respective edges of the corner. Mounting holes 41-44 extend through board 15 as well as spacer 20 and lower printed circuit board 21 for receiving suitable mounting screws by way of which the two boards 15 and 21 are held together with spacer 21 sandwiched between the boards in the antenna's assembled configuration.

Lower printed circuit board 21 contains 90° and 180° hybrids printed on its surface that faces the bottom of dielectric spacer 20 from which feed wires extend through spacer 20 and to connection holes 31-34 in upper printed circuit board 15. As shown in Figure 1 these connection holes or points of electrical connection of the vertical feed wires to the antenna elements near one end of the antenna elements effectively form an L-shaped stub. With this unbalanced antenna configuration and the feeding of the four antenna elements being fed in phase rotation from the hybrid networks printed on lower printed circuit board 21, the combined elemental array of Figure 1 produces a circularly polarized signal with hemispheric coverage.

For the L-shaped stub arrangement shown in Figure 1, the shape of the radiation profile is such that maximum sensitivity or strength occurs in the zenith direction and is minimum in the horizontal direction. By changing the geometrical location of contact holes 31-34 on elements 11-14, and the shape of the elements, the profile of the signal radiation/response characteristic of the array can be easily changed. For example, by moving the location at which the vertical feed wires contact each element to a location more geometrically centrally located on each element, thereby forming a T-shaped element, the antenna profile is altered towards a maximum signal sensitivity/strength in the horizontal plane and minimum at the zenith or nadir.

It should be observed that each antenna element individually does not exhibit the proper polarization characteristics (which in fact, change sense of circular polarization throughout the hemisphere). However, when combined in an array configuration, such as that described above, the cross-polarized components are cancelled to a large degree, and the desired sense of circular polarization is predominant over the entire hemisphere.

The four L-shaped elements 11-14 are doubly tuned impedance matched to operate over two frequency bands, and 90° and 180° hybrids are used to provide the proper phase of excitation over these two frequency ranges. These 90° and 180° hybrid feed networks are required for dual frequency operation, where the two frequencies of interest are separated by a significant amount, thereby ensuring a broadband feed network. Still, it is to be observed that a separate impedance matching network which doubly tunes the individual elements is the controlling factor for dual frequency operation. For narrowband single frequency operation, a simple delay line may be employed as the impedance matching feed network. Thus, rather than use these hybrids, other signal coupling networks may be employed so as to provide the intended excitation to provide the desired antenna coverage profile. Also, in place of the L-shaped elements of Figure 1, elements of different shapes and arrangements may be employed, such as those illustrated in Figures 2 and 3, to be described below.

The antenna configuration shown in Figure 2, like that of Figure 1, contains an array of four antenna elements. In this embodiment, however, the array is formed of asymmetrical top-loaded elements 51-54 disposed at the corners of a top or upper printed circuit board 60. The antenna of Figure 2 also includes a thin dielectric spacer 70 and a lower circuit board 71 containing suitable impedance matching/phasing networks, as described above. Again, where a doubly tuned impedance matched embodiment operating over two frequency bands is desired, the circuit on board 71 may consist of 90° and 180° hybrids. The upper and lower printed circuit boards and spacer are assembled together by suitable screws passing through holes 71-74 in each of the boards and spacer. The feed wires from the signal coupling network on lower printed circuit board 71 pass through spacer 70 and board 60 to be electrically connected to asymmetrical elements 51-54 at corner locations 61-64, as shown, so that the desired circularly polarized hemispherical coverage is provided from a four element array of asymmetrical top-loaded elements.

A three element, two frequency embodiment of the invention utilizing three asymmetrical top-loaded elements at each operating frequency is shown in its assembled form in Figure 3 and in the exploded view of Figure 4. It should be noted that exploded views of the embodiments of Figures 1 and 2 have not been shown in order to simplify the drawings and description. The embodiment of Figure 3 was chosen as an expedient to illustrate a version of the invention involving two sets of radiation elements, the simpler layouts of Figures 1 and 2 being readily apparent to one skilled in the art, especially having the benefit of the dual frequency version of Figure 3.

Referring now to Figures 3 and 4, like the previously described embodiments of Figures 1 and 2, the three element array employs respective upper and lower printed circuit boards 110 and 112 between which a thin dielectric spacer 111 is sandwiched in the antenna's assembled configuration. The bottom 110B of board 110 rests on the top 111T of spacer 111, while the top 112T abuts against the bottom 111B of spacer 111. On the top or upper surface of board 110 there are disposed (e.g. plated or deposited) two sets of three triangular shaped (top loaded) antenna elements 81-86, through each of which extends a respective feed wire contact hole 91-96. The contact holes 91-96 extend through spacer 111 to points of projection for feed wires from the printed circuit impedance matching and phase delay network made up of sections 121 and 122 on surface 112T of printed circuit board 112. A plurality of holes 101-107 are further provided in boards 110, 112 and spacer 111 for receiving connection screws for assembly of the antenna package. Finally at areas 131 and 132 on the bottom surface 112B of board 112 a pair of connectors 141 and 142 are fastened. Connector 141 has a coaxial feed center lead 153 for extending through board 112 to electrically contact network 121 at junction point 163. Similarly, connector 142 has a coaxial feed center lead 154 for extending through board 112 to electrically contact network 122 at junction point 164.

In lieu of connectors 141 and 142, however, a diplexer (with one connector) could be incorporated for electrical coupling to the lower printed circuit board 112.

As is the case with the embodiments of the invention shown in Figures 1 and 2, control of the shape of the antenna radiation/sensitivity profile is easily accomplished simply by locating the position of the feed wires from networks 121 and 122 to the points of contact on elements 81-86, so that the radio of zenith (or nadir) to horizon signal is controlled in all cases by the location of the vertical feed wire and the degree of imbalance of the radiation element on the printed circuit board.

As will be appreciated from the foregoing description of exemplary embodiments of the invention, the compact hemispherical coverage antenna of the present invention is particularly valuable for fixed (non-steerable) earth to satellite or aircraft communications where strong signal is required at elevation angles near the horizon because of the greater distance and transmission loss, yet the invention still provides coverage throughout an entire hemisphere. The thin profile or flush mounting structure offers low drag for high performance aircraft, and the printed circuit construction yields a rugged, light weight, low cost antenna.

While I have shown and described several embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible to numerous changes and modifications as known to a person skilled in the art, and I therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are obvious to one of ordinary skill in the art.

WHAT IS CLAIMED IS:

1. An antenna comprising:

a plurality of radiation elements disposed in a prescribed geometrical configuration;

an impedance matching and signal coupling network to be electrically connected to said radiation elements; and

means for controlling the antenna coverage profile produced by said radiation elements including conductor means electrically connecting prescribed portions of said network to selected locations on said radiation elements.

2. An antenna according to Claim 1, further comprising a thin layer of insulating material on opposite sides of which said radiation elements and said network are respectively disposed.

3. An antenna according to Claim 2, wherein said radiation elements are formed of thin layers of conductive material disposed atop one side of said thin layer of insulating material.

4. An antenna according to Claim 2, wherein said network is formed of printed circuit configuration.

5. An antenna according to Claim 3, wherein said network is formed of printed circuit configuration, said conductor means including feed wires extending from said network through said layer of insulating material to selected locations on said thin layers of conductive material.

6. An antenna according to Claim 1, wherein said radiation elements are configured as top-loaded stubs.

7. An antenna according to Claim 1, wherein said radiation elements are configured to provide unbalanced slots.

8. An antenna according to Claim 1, wherein said impedance matching network comprises 90° and 180° hybrids, and that said antenna is doubly tuned impedance matched over two frequency bands.

9. An antenna according to Claim 1, wherein said radiation elements are formed of a pair of sets of three top-loaded elements.

10. An antenna according to Claim 9, wherein said impedance matching network is formed of a pair of networks from the respective

ones of which respective conductor means extend to prescribed locations on the elements of the sets of said pair.

11. An antenna according to Claim 1, wherein said radiation elements are comprised of one selected from the grup consisting of L-shaped stubs, U-shaped slots, asymmetrically top-loaded stubs and unbalanced slots.

12. An antenna according to Claim 1, wherein said conductor means include a respective feed wire for each radiation element to a respective portion of said network.

13. A method of controlling the antenna coverage profile for circularly polarized signals radiated or received by an array of unbalanced antenna elements comprising the steps of:

disposing said elements in a prescribed geometrical configuration;

providing an impedance matching and phase delay network through which signals are to be coupled with respect to said antenna elements; and

electrically connecting prescribed portions of said network to selected locations on respective ones of said elements.

14. A method according to Claim 13, wherein said elements are comprised of one selected from the group consisting of L-shaped stubs, U-shaped slots, asymmetrically top-loaded stubs and unbalanced slots.

15. A method according to Claim 13, wherein said elements are formed of plural sets of a plurality of asymmetrically top loaded elements each.

16. A method according to Claim 13, wherein said disposing step comprises arranging, as said elements, thin layers of conductive material in a preselected geometrical configuration on one side of a thin dielectric substrate.

17. A method according to Claim 16, wherein said network providing step comprises disposing said network on a side of said thin dielectric substrate opposite said one side thereof.

18. A method according to Claim 17, wherein said electrically connecting step comprises interconnecting respective conductors from said network through said substrate to said selected locations on respective ones of said elements.

FIG. 1.

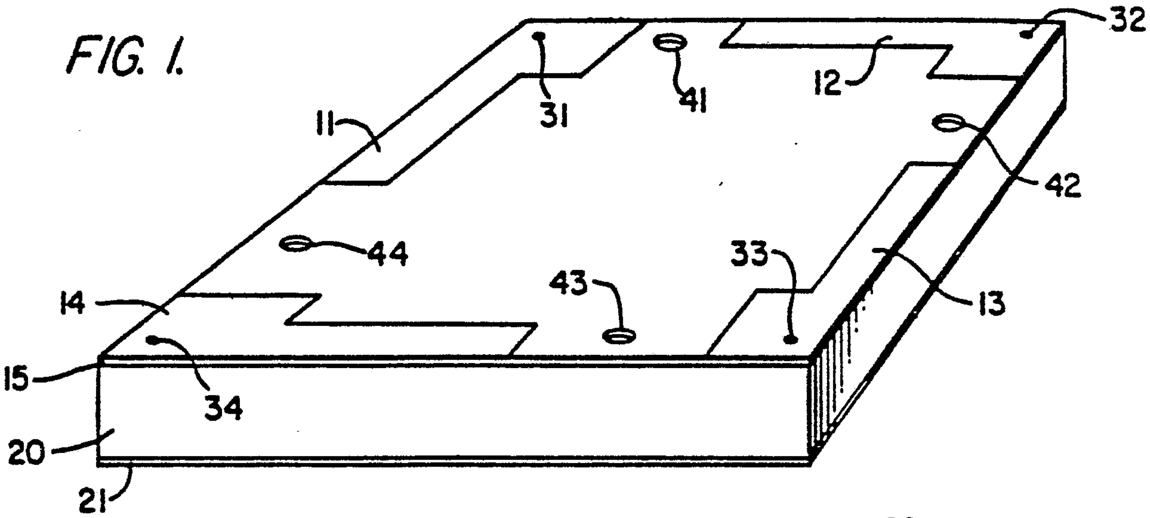


FIG. 2.

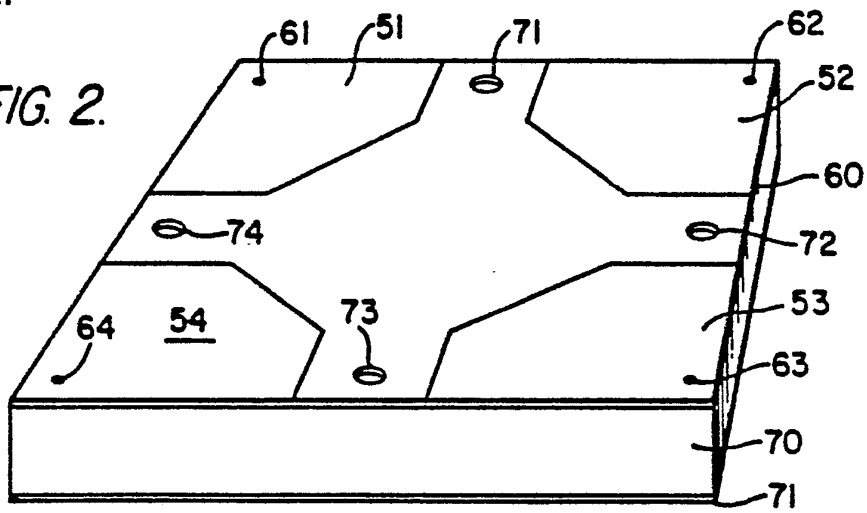
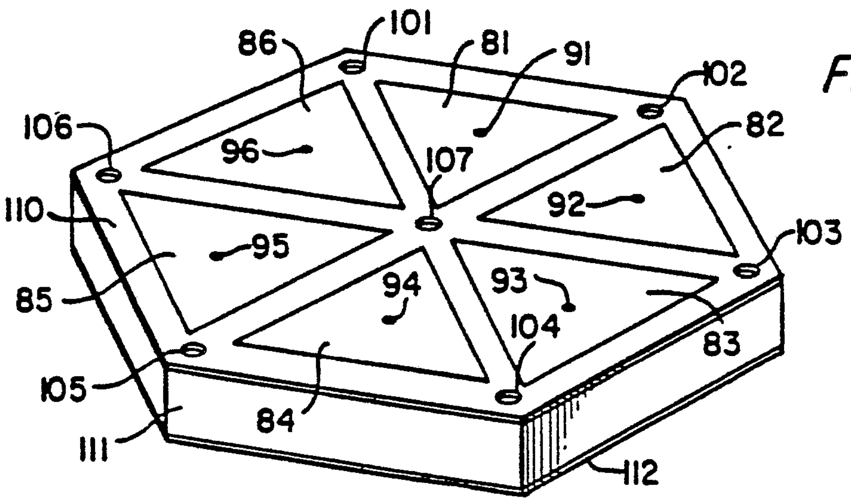


FIG. 3.



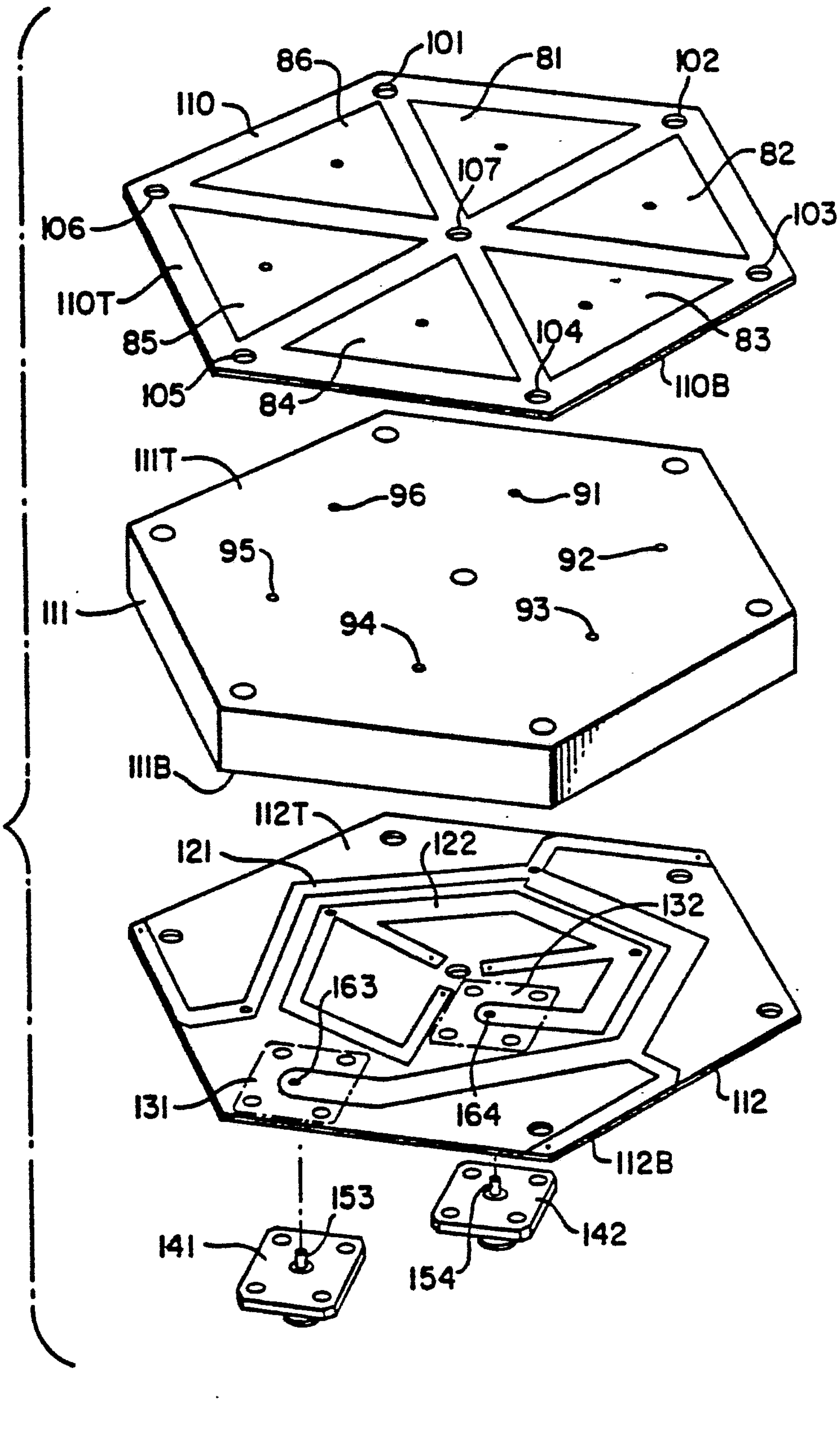

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FIG. 4.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US81/00628

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.3 H01Q 1/38, H01Q 1/48

U.S. CL. 343/700MS, 846

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	343/700MS, 705, 708, 797, 846, 854

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 4,042,935, Published 16 August 1977, Ajioka et al	1-5, 10, 12-13, 16-18
A	US, A, 4,157,548, Published 5 June 1979, Kaloi	6-9, 11, 14-15
A	US, A, 3,718,935, Published 27 February 1973, Ranghelli et al	1-5, 10, 12-13, 16-18

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"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
7/29/81	05 AUG 1981

International Searching Authority [1]	Signature of Authorized Officer [20]
ISA/US	David K. Moore (signature) David K. Moore

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