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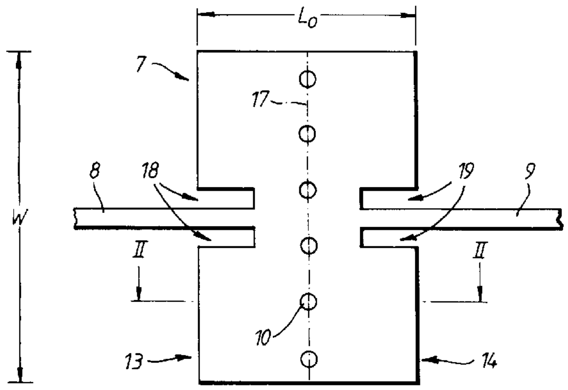
(54) Patch antenna.

(57) A patch antenna comprising a half-wavelength patch (7), an underlying ground plane (12) and an intervening dielectric substrate (11). A short-circuit (17) is formed between the patch (7) and the ground plane (12) by means of a row of plated-through holes (10) extending across the width (W) of the patch orthogonal to the resonant dimension (L_0). The short-circuit (17) effectively divides the patch into two independently controllable quarter-wavelength patch sections (15,16), which are fed at respective points remote from the short-circuit (17) by means of feed striplines (8,9). The beam produced by the antenna is steerable in a plane normal to the short-circuit and to the antenna by controlling the relative phase and/or the relative amplitude of the applied signals at the two feed points. A planar array of the antennas permits further adjustment of the beam shape.

Fig. 1.



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This invention relates to patch antennas.

The conventional half-wavelength rectangular patch antenna, having a single feed point, may be regarded as a lossy resonant cavity, which loses, i.e. radiates, energy mainly from the two edges of the patch which are separated by the nominal half-wavelength resonant dimension. The two radiating edges may be viewed as a two-element, in-phase, slot array yielding a radiation pattern which peaks at broadside in a direction normal to the plane of the patch and tapers to a level typically 10dB below the peak at 90° from the normal, the actual level being dependent upon the permittivity of the substrate carrying the patch.

Being a resonant structure, the two edges always radiate the applied signal with equal powers and with phase coherence. As a result the radiation pattern of the antenna always has a peak centred on a boresight which is normal to the plane of the patch, i.e. the antenna's beam axis is aligned with that boresight. Many antenna applications, however, demand a radiation pattern which is such that the beam axis is not centred on the normal boresight. It may even be that a null on the boresight is desired. Using conventional patch designs such radiation patterns can be achieved only by means of a phased array of patches and not by a single patch element.

It is an object of the present invention to provide a patch antenna having a radiation pattern which is not essentially centred on a boresight normal to the plane of the antenna.

According to one aspect of the invention, there is provided a patch antenna comprising two co-planar adjacent conductive patch sections, an underlying ground plane, adjacent edges of the patch sections being short-circuited to the ground plane, and feed means for feeding each patch section at a respective point remote from the adjacent edges, the beam axis of the antenna having a direction, in a plane normal to the short-circuited edges, which is dependent upon the relative phases of the signals at the feed points. Thus, it can be seen that the invention provides a patch antenna having a steerable beam capability.

In a preferred embodiment of the invention there is a single conductive patch divided into the two patch sections by a common short-circuit at the adjacent edges. This single conductive patch preferably has a resonant dimension normal to the common short-circuit and corresponding substantially to a half-wavelength at the operative frequency of the antenna.

Preferably there are two feed points, the feed means comprising respective feed striplines electrically coupled to the patch sections at the two feed points. The feed striplines may form continuous conductive layers with the patch sections at the feed points, there being a notch in each patch section in the vicinity of its feed stripline to provide impedance matching between the feed stripline and the patch section. The feed means may further comprise a common feed line to which the feed striplines are connected at a junction, the lengths of the two feed striplines determining the relative phases of the signals at the feed points. The feed striplines may present unequal impedance to the common feed line at the junction so that the signals have different magnitude at the feed points.

The single conductive patch and the ground plane are preferably separated by an intervening dielectric substrate, the common short-circuit comprising a row of plated-through holes formed in the substrate.

According to another aspect of the invention, an antenna comprises a planar array of patch antennas, each as aforesaid, the patch antennas being arranged so that their short-circuited edges lie substantially parallel to one another and the common feed lines being coupled to a single feed line for the antenna, the relative signal phases and amplitudes at adjacent patch sections in the array determining the overall radiation pattern of the antenna.

A patch antenna and an array incorporating the patch antenna, both in accordance with the invention, will now be described, by way of example only, with reference to the accompanying drawings, of which:

Figure 1 is a plan view of one patch antenna in accordance with the invention;

Figure 2 is a section on line II-II in Figure 1;

Figure 3 shows various feed arrangements suitable for use with the antenna; and

Figure 4 shows an antenna comprising an array of two patch antennas in accordance with the invention.

In the conventional half-wavelength patch antenna referred to above, at the centre line of the patch parallel to and equi-distant from the two radiating edges, the electric field strength within the patch falls to zero. This feature is exploited in the present invention as will now be explained with reference to Figures 1 and 2, which show one embodiment of an antenna in accordance with the invention.

As can be seen from the section drawing in Figure 2, the antenna comprises the basic structure of a conductive patch 7, a ground plane layer 12 and an intervening dielectric substrate 11. In the plan view of Figure 1 only the patch 7 is shown. It will be appreciated that the underlying ground plane 12 has a greater extent than the patch 7 in the normal manner. The antenna is suitably made of microstripline circuit board.

The resonant length L_o of the patch 7 corresponds nominally to a half-wavelength at the operative frequency of the antenna. Characteristic of the antenna is the provision of a short-circuit formed between the patch 7 and the ground plane layer 12 by means of a row of plated-through holes 10. As can be seen from Figure 1, the short-circuit formed by this row of holes 10 (and represented by the dotted line 17) extends parallel to and equi-distant from the two radiating edges 13,14 of the patch. The effect of introducing this short-circuit, which is along the aforementioned centre-line where the electric field within the patch falls to zero, is to effectively divide the patch into two quarter-wavelength patch sections 15,16 (Figure 2) and to make the two radiating edges 13,14 essentially independent of each other. As a result, each patch section 15,16 can be controlled independently in both the amplitude and the phase of its radiation. Although patch antennas having more than one feed point are known in the art, such antennas have previously been restricted to designs intended for radiating or emitting signals having independent, commonly orthogonal, polarisations.

The two patch sections 15,16 are fed at points remote from the short-circuit 17 by means of respective striplines 8, 9 (Figure 1) each of which forms a continuous conductive layer at the feed point. The radiating edges 13,14 of the patch include respective notches 18,19 in the vicinity of the feed striplines 8,9. The notches 18,19 provide impedance matching between the patch sections and the feed striplines. The depth of each notch, i.e. its extent in a direction normal to the radiating edge of the patch section, would normally be such that it presents an impedance equal to that of the feed stripline. A further factor in determining the notch depth is the width W of the patch. The width W determines the admittance of the radiating edges 13,14, which in turn, governs the variation in impedance along the patch length L_o. The width of the notch should be sufficient to minimise coupling between the patch section and the feed stripline. A gap, on either side of the feed stripline, equivalent to the thickness of the substrate 11 has been found to be sufficient.

The radiation pattern of the antenna is such that the beam axis lies in a plane normal to the short-circuit 17 and to the antenna. However, unlike the conventional half-wavelength patch antenna, the beam axis is not essentially aligned with a boresight in this plane and normal to the antenna. The angle between the beam axis and the boresight is determined by the relative phases and amplitudes of the signals applied to the two patch sections 15,16 by means of the feed striplines 8,9.

Figure 3 shows, by way of example only, three different feed arrangements for the antenna which produce different angles between the beam axis and the normal boresight. In all of these examples the two striplines 8,9 are connected together at a T-junction 20 to a common feed line 21. There is impedance matching at the T-junction 20, so that, if, for example, the striplines 8,9 have an impedance of 100 ohms each, the common feed line 21 will have an impedance of 50 ohms. In this case, the two patch sections 15,16 will be fed with signals of equal amplitude, but with a relative phase dependent on any difference in the lengths of the two striplines 8,9.

In Figure 3(a), the striplines 8,9 have equal lengths so that the two patch sections are fed with signals of the same phase. As a result, the edges 13,14 radiate in anti-phase to produce a null in the radiation pattern on the boresight.

In Figure 3(b), the T-junction 20 is 'offset' by a quarter-wavelength ($\lambda_o/4$) in the substrate from the central position shown in Figure 3(a), the effect being that there is a difference in the length of the striplines 8,9 which corresponds to a half-wavelength in the substrate at the operative frequency. The patch sections are thus fed with signals which differ in phase by 180°, resulting in a radiation pattern having a peak centred on the boresight. Thus, the beam axis is aligned with the boresight using this feed arrangement.

Figure 3(c) represents an intermediate position between the extremes of Figures 3(a) and 3(b), in which the offset X of the common feed line 21 at the T-junction 20 is less than a quarter-wavelength. This arrangement produces a 'squinted' radiation pattern in which the angle between the beam axis and the boresight is a function of the degree of the offset X and thus of the signal phase difference at the feed points of the two patch sections. The size of the patch 7 and the permittivity of the substrate 11 will also affect the angle off boresight which can be achieved. It will be appreciated, therefore, that, by varying the relative phase of the signals at the two feed points of the patch, the beam can be steered in a plane normal to the short-circuit and to the plane of the antenna.

Of course, the use of a T-junction and different length feed striplines to produce the phase difference at the patch feed points is given by way of example only. Many other possibilities exist, the alternatives including, for example, the use of a hybrid network, a Wilkinson splitter or a Lange coupler.

Likewise, the short-circuit 17 is not essentially realised by means of plated-through holes, although this is a convenient and preferred method when the antenna is fabricated in microstripline. Alternatives include the use of a row of conducting pins inserted through the substrate or a plated physical slot in the board.

The patch sections may be fed in a number of ways other than that described; for instance, by means of a coaxial cable having its centre conductor fed through the board and connected to the patch. Alternatively, there may be provided a capacitive coupling between a feed stripline and the patch. However, the use of a stripline conductor formed as an extension of the conductive patch layer is preferred from a fabrication viewpoint since the patch, feed line and ground plane can then all be formed on a single piece of microstripline circuit board.

It should be noted also that a patch antenna in accordance with the invention does not essentially comprise a single patch element divided into two patch sections by a common short-circuit. The two patch sections may be separate elements provided each section has a short-circuited edge to the common ground plane, and that the two short-circuited edges are disposed adjacent one another. It should be noted that such an arrangement is distinguished from that which occurs in a known array of quarter-wavelength patch elements in that in the known array the short-circuited edges of adjacent patches are not disposed adjacent one another, but rather with open-circuit edges facing short-circuit edges, i.e. in a repeated pattern of identically disposed patches. Even if the quarter-wavelength patches were arranged alternately, with (relatively) adjacent short-circuited edges, the radiating edges are not then known to be spaced apart by a resonant spacing.

A patch antenna in accordance with the invention may be incorporated in a planar array, in which the elements in the array are fed in such manner that the overall beam shape and beam axis angle relative to boresight can be accurately controlled. Two adjacent elements in one possible array configuration are shown, by way of example only, in Figure 4, to which reference is now made. Although only two patches 7′, 7″ are shown, the array would, of course, normally comprise a greater number of elements.

In this particular configuration, each patch is fed with signals which are in anti-phase, hence the unequal lengths of the pairs of striplines 8′, 9′ and 8″, 9″ on either side of their respective T-junctions 20′ and 20″. In addition, the signals at the two feed points of each patch have unequal magnitudes by virtue of the two striplines in each pair having different widths and therefore different impedances.

As can be seen, the striplines 8′ and 9″ which feed the 'outer' patch sections 15′ and 16″ have a lesser width (i.e. higher impedance) than the striplines 9′ and 8″ which feed the 'inner' patch sections 16′ and 15″. This arrangement gives rise to an overall radiation characteristic having a narrower central beam and reduced sidelobe levels than can be achieved using arrays of conventional patch elements. Further adjustment of the phase and amplitude conditions at the feed points of the patches may be used to 'fine tune' the beam shape according to requirements.

The feed lines 21′,21″ for the two patches are coupled to a main feed line 23 for the antenna by means of a T-junction 22. The additional patches in a larger array would be similarly coupled to the main feed line in a conventional 'tree' structure.

Claims

1. A patch antenna comprising two co-planar adjacent conductive patch sections (15,16), an underlying ground plane (12), adjacent edges (17) of said patch sections being short-circuited (10) to said ground plane, and feed means (8,9) for feeding each patch section at a respective point remote from said adjacent edges, the beam axis of the antenna having a direction, in a plane normal to the short-circuited edges, which is dependent upon the relative phases of the signals at the feed points.

2. A patch antenna according to Claim 1, comprising a single conductive patch (7) divided into said patch sections (15,16) by a common short-circuit (10) at said adjacent edges (17).

3. A patch antenna according to Claim 2, wherein said single conductive patch (7) has a resonant dimension (L_o) normal to said common short-circuit (10) and corresponding substantially to a half-wavelength at the operative frequency of the antenna.

4. A patch antenna according to Claim 2 or Claim 3, wherein there are two said feed points, said feed means comprising respective feed striplines (8,9) electrically coupled to said patch sections at the two feed points.

5. A patch antenna according to Claim 4, wherein said feed striplines (8,9) form continuous conductive layers with the patch sections (15,16) at said feed points, there being a notch (18,19) in each patch section in the vicinity of its feed stripline to provide impedance matching between the feed stripline and the patch section.

6. A patch antenna according to Claim 4 or Claim 5, wherein said feed means further comprises a common feed line (21) to which said feed striplines (8,9) are connected at a junction (20), the lengths of the two feed striplines determining the relative phases of the signals at said feed points.

7. A patch antenna according to Claim 6, wherein said feed striplines (8′,9′; 8″,9″) present unequal impedance to said common feed line (21′; 21″) at said junction (20′; 20″) so that said signals have different magnitude at said feed points.

8. A patch antenna according to any one of Claims 2 to 7, wherein said single conductive patch (7) and said ground plane (12) are separated by an intervening dielectric substrate (11), said common short-circuit comprising a row of plated-through holes (10) formed in the substrate.

9. An antenna comprising a planar array of patch antennas (7′, 7″), each in accordance with any one of Claims 6 to 8, said patch antennas being arranged so that said short-circuited edges lie

substantially parallel to one another and said common feed lines (21′, 21″) being coupled (22) to a single feed line (23) for the antenna, the relative signal phases and amplitudes at adjacent patch sections (16′,15″) in the array determining the overall radiation pattern of the antenna.

Fig. 1.

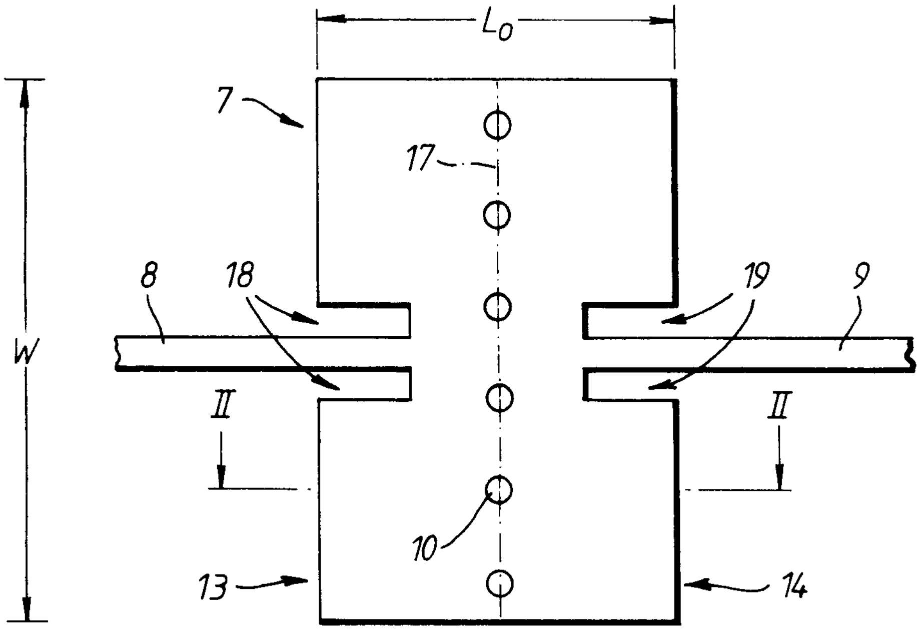


Fig. 2.

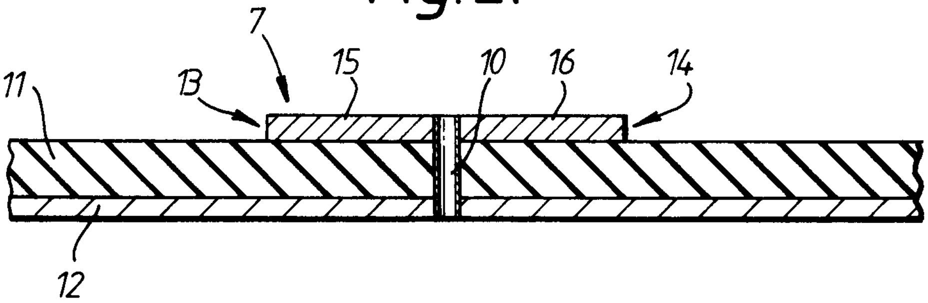


Fig.3(a)

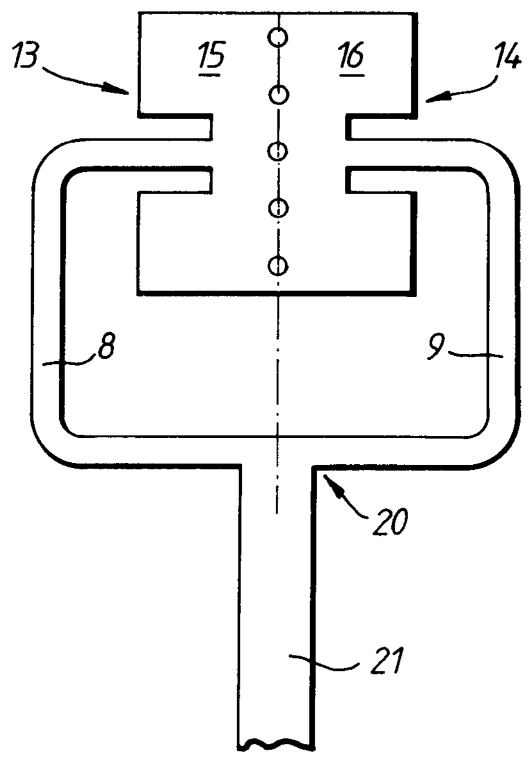


Fig.3(b)

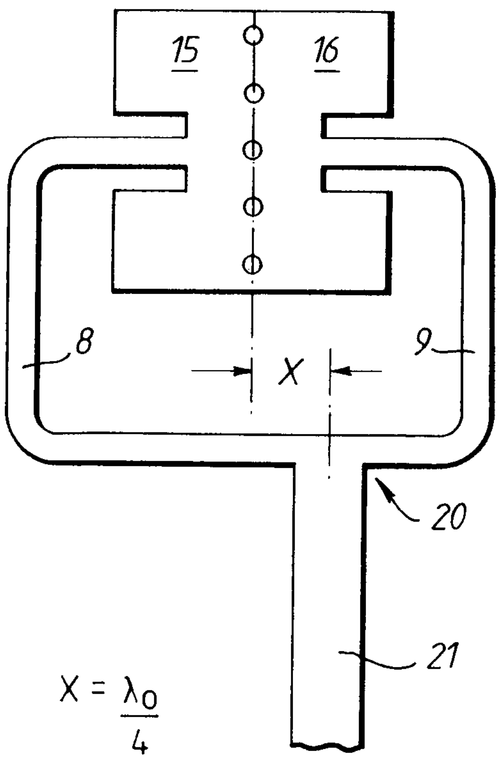


Fig.3(c)

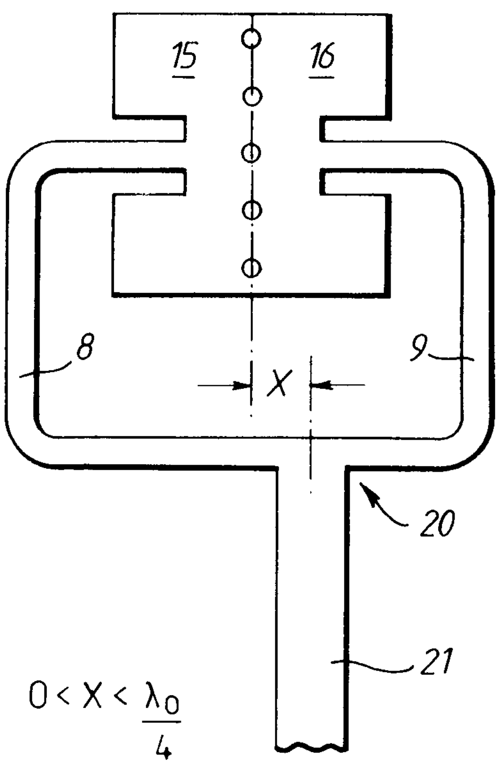
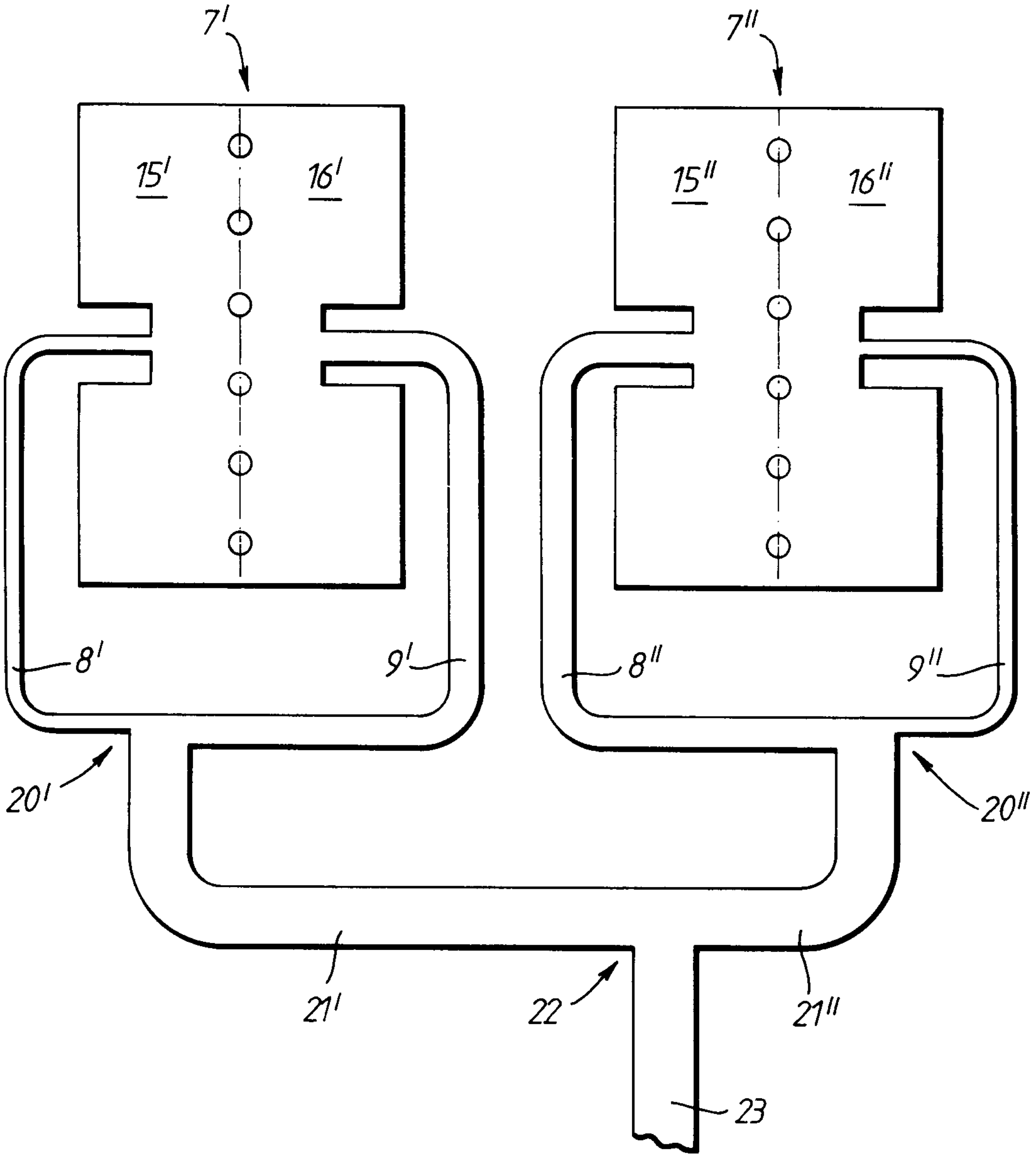


Fig. 4.



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EUROPEAN SEARCH REPORT

Application Number

EP 91 31 1860

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	PATENT ABSTRACTS OF JAPAN vol. 13, no. 16 (E-703)(3364) 13 January 1989 & JP-A-63 222 503 (SUMITOMO ELECTRIC IND) 16 September 1988	1-3,8	H01Q9/04 H01Q21/06
Y	* abstract *	4-6	
Y	US-A-4 040 060 (KALOI) * column 2, line 57 - column 3, line 33 * * column 4, line 36 - line 46 * * column 5, line 15 - line 19 * * figures 3,9 *	4-6	
A		9	
A	EP-A-0 345 454 (YAGI ANTENNA CO.) * abstract * * column 5, line 17 - column 7, line 17 * * figures 7,8 *	6,7,9	
A	IEEE AP-S INTERNATIONAL SYMPOSIUM DIGEST; ANTENNAS AND PROPAGATION vol. II, June 1989, NEW YORK, US pages 882 - 885; WANG, J. ET AL.: 'Design Study of a Low Sidelobe Microstrip Antenna Array and Feed Network.' * page 882, paragraph 2 - page 883, paragraph 1 *	6,7,9	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H01Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	07 MAY 1992	JEPSEN J.

CATEGORY OF CITED DOCUMENTS

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