



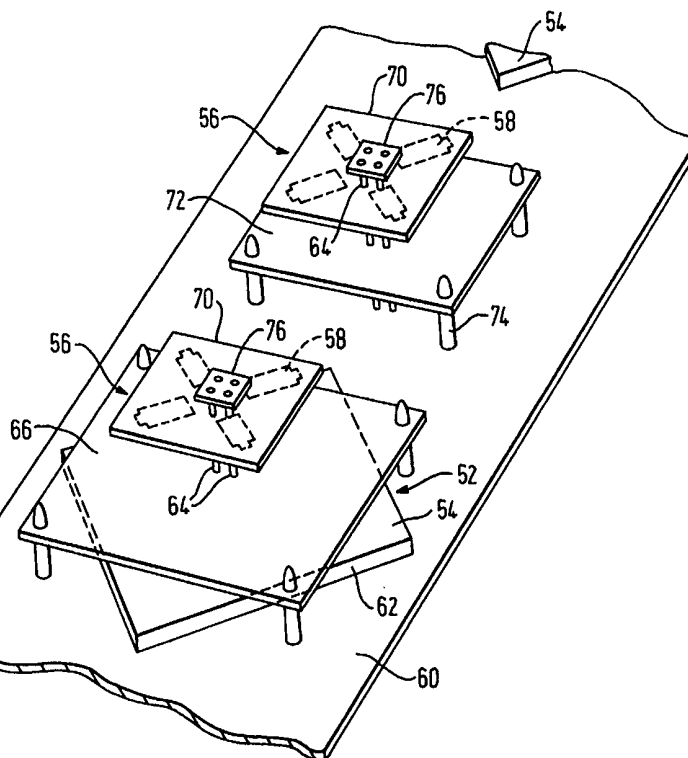
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification <sup>6</sup> : <b>H01Q 21/30, 21/06, 9/04</b></p>	<p><b>A2</b></p>	<p>(11) International Publication Number: <b>WO 99/59223</b> (43) International Publication Date: 18 November 1999 (18.11.99)</p>
<p>(21) International Application Number: PCT/GB99/01480 (22) International Filing Date: 11 May 1999 (11.05.99) (30) Priority Data: 9810047.2 11 May 1998 (11.05.98) GB 9810050.6 11 May 1998 (11.05.98) GB (71) Applicant (for all designated States except US): CSA LIMITED [GB/GB]; Knight Road, Rochester, Kent ME2 2AX (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): ARCHER, Martin, Joseph [GB/GB]; 19 Heathfield Road, Penenden Heath, Maidstone, Kent ME14 2AD (GB). COLLINS, Brian, Stuart [GB/GB]; 64 Park Avenue, Sittingbourne, Kent ME10 1QY (GB). HUANG, Tao [CN/GB]; 16 Windmill Close, Frindsbury, Rochester, Kent ME2 3XN (GB). LIU, Zidong [CN/GB]; 39B Cuxton Road, Strood, Kent ME2 2BU (GB). (74) Agent: ABNETT, Richard, Charles; Reddie &amp; Grose, 16 Theobalds Road, London WC1X 8PL (GB).</p>		<p>(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> Without international search report and to be republished upon receipt of that report.</p>

(54) Title: DUAL-BAND MICROSTRIP ANTENNA ARRAY

(57) Abstract

A dual-band antenna array (50) for use in a base station for mobile telephone communications consists of a first linear array of microstrip or patch antennas (52) for use over the GSM band and a second linear array of crossed dipoles (56) for use over the PCN band. The PCN antennas are at half the spacings of the GSM antennas. Alternate ones of the PCN crossed dipole antennas are located above respective GSM patch antennas, and a conductive plate or sheet (66) between them functions both as a parasitic element for the microstrip antenna and as a reflector for the crossed dipole antenna.



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## DUAL-BAND MICROSTRIP ANTENNA ARRAY

### Background of the Invention

This invention relates to microstrip antennas,  
5 sometimes known as patch antennas. More particularly the  
invention relates to the construction of microstrip  
antenna arrays, and to dual-band antenna structures using  
microstrip elements. Patch antennas are used for example  
in mobile telephone communications.

10 A patch antenna comprises a thin metallic strip or  
patch placed a small fraction of a wavelength above a  
ground plane. The patch may be of any of a variety of  
shapes but most typically is circular, or is rectangular  
(which term as used herein includes square) with length L  
15 and width W, as shown in Figure 1 of the accompanying  
drawings. The known patch antenna 10 shown in Figure 1  
has a conductive patch 12 mounted on a material dielectric  
substrate 14, which is mounted on a conductive ground  
plane 16. The dielectric can however be air. The  
20 direction of maximum radiation of the antenna is generally  
normal to the plane of the patch 12. The material  
dielectric substrate 14 has dielectric constant  $\epsilon_r$ ,  
typically in the range  $2.2 \leq \epsilon_r \leq 12$ . The substrate  
typically provides the spacing between the patch and the  
25 ground plane. For microwave frequencies, small substrate  
thicknesses  $h$  are preferred to minimise undesired  
radiation and coupling, and also lead to smaller element  
sizes. However they then have smaller bandwidths, the  
bandwidth of a patch antenna generally being quite narrow  
30 in any event.

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The feed to a rectangular patch will normally be by means of a short microstrip line 18 to the mid-point of one of its sides, as shown in Figure 1. Assuming that the dimensions of the patch are properly chosen, this provides essentially plane polarized radiation with the direction of polarization being perpendicular to that side of the patch to which the feed is connected at the middle, i.e. in the direction of the arrow P in Figure 1.

It is known to provide such antennas with a parasitic element in the form of a thin planar conductor substantially parallel to the patch and spaced above it, that is to the other side of the patch from the ground plane.

As noted above, patch antennas are used for example for mobile telephone communications. Mobile telephones use two main frequency ranges, namely 860 to 970 GHz for GSM telephones and either 1710 to 1880 GHz for the PCN band or 1850 to 1990 GHz for the PCS band. There is a need for an antenna for a mobile telephone system base station capable of dual-band operation on both the GSM band and either the PCN or the PCS band (which may for convenience be referred to as the "PCN/PCS band"). The frequencies of the PCN/PCS band are approximately double those of the GSM band, and the same antenna clearly can not be used for both. This is thus an illustration of one instance where a dual-band antenna is required to operate over two bands which are approximately an octave (a factor of two) apart. Other instances will arise where operation over two different bands is wanted.

It has been proposed, see for example J.R. James and P.S. Hall (Editors) "Handbook of Microstrip Antennas", pub. Peter Peregrinus, 1989, ISBN 0 86341 1509, to form a dual-band patch antenna by stacking two antenna elements. This is diagrammatically illustrated with the dual-band antenna 30 shown in Figure 2. The dual-band antenna 30 comprises a first antenna section 32 for use at a lower frequency band. This has a square radiating patch 34

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above a dielectric substrate 36 carrying or mounted on a ground plane 38. The second antenna section for use at a higher frequency band comprises a second square patch 44 forming part of the second antenna section 43 and mounted on the upper surface of a piece of dielectric 42 adhered over the patch 34.

In this way an antenna structure is formed which can operate for transmission and/or reception over two frequency ranges to provide plane polarised radiation. The lengths of the sides of the patches 34 and 44 are approximately half the wavelength (actually half the electrical wavelength, account being taken of the dielectric constant, etc.). The thickness of the substrate 36 is typically about 2mm. Note that the drawings are not to scale.

United Kingdom Patent Application GB-A-2,251,340 (equivalent United States Patent US-A-5,216,430) shows in Figure 5 an antenna array structure where two different frequencies of 2.265 and 2.087 GHz are transmitted by respective side-by-side arrays. The arrays comprise square patches of the same size and spacing and are driven to provide circular polarisation. The elements of the two arrays are offset from the common longitudinal axis and the resultant pattern will be asymmetric. United States Patent US-A-4,012,741 also has two antenna arrays, as shown in Figure 3 of that patent, with elements and spacings in common.

There is a need for dual band antenna structures for use as a mobile telephone communication station to be as small as possible. Such antennas may be mounted on buildings and in order to provide a dual band facility the current antennas have to be quite large.

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### Summary of the Invention

The invention in its various aspects is defined in the independent claims below, to which reference should now be made. Advantageous features are set forth in the  
5 appendant claims.

A preferred embodiment of the invention is described in more detail below. The preferred embodiment takes the form of a dual-band antenna array for use in a base station for mobile telephone communications which consist  
10 of a first linear array of microstrip or patch antennas for use over the GSM band and a second linear array of crossed dipoles for use over the PCN band. The PCN antennas are at half the spacings of the GSM antennas. Alternate ones of the PCN crossed dipole antennas are  
15 located above respective GSM patch antennas, and a conductive plate or sheet between them functions both as a parasitic element for the microstrip antenna and as a reflector for the crossed dipole antenna.

### Brief Description of the Drawings

20 The invention will be described in more detail, by way of example, with reference to the accompanying drawings, in which:

**Figure 1** is a general view of a known patch or microstrip antenna;

25 **Figure 2** is an illustrative side view of a known dual-band stacked patch antenna arrangement;

**Figure 3** is a plan view of a first dual-band antenna array embodying the invention for use on the GSM and PCN bands;

30 **Figure 4** is a side view relative to Figure 3 of the antenna elements;

**Figure 5** is an isometric view of two of the antenna element stations in the array of Figures 3 and 4, showing the two types of structure used;

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**Figure 6** is a side view showing a combined GSM and PCN antenna structure in the array of Figure 3;

**Figure 7** is a side view of a PCN only antenna structure in the array of Figure 3;

5 **Figure 8** is a detail showing the top of the PCN antennas;

**Figure 9** is a diagrammatic detail showing the arrangement of the patch element in the GSM antennas;

10 **Figure 10** is a view similar to Figure 5 of a slightly modified antenna structure;

**Figure 11** shows the feeds to the GSM antenna patches;

**Figure 12** shows the feeds to the PCN antenna dipoles; and

15 **Figure 13** is a diagrammatic view similar to Figure 3 of a second dual band antenna array embodying the invention.

#### **Detailed Description of the Preferred Embodiments**

The first embodiment of the invention will be described with reference to Figures 3 to 12, and takes the form of a dual band antenna array for use both on the GSM and the PCN/PCS frequency bands for mobile telephone communication. The antenna array is illustrated in plan view in Figure 3, with the weather protection removed and, in side view in Figure 4, and a portion thereof is shown in isometric view in Figure 5.

25 Referring first to these figures, the array 50 consists of a linear array of antenna structures. These comprise GSM microstrip antennas 52 each comprising a patch antenna element 54, and PCN/PCS antennas 56 each taking the form of a crossed dipole 58. The GSM antennas 52 are spaced at twice the spacings of the PCN/PCS antennas 56, as there is approximately a factor of two difference in the frequencies of the two bands concerned. Alternatively the PCN/PCS antennas can be regarded as being at substantially half the spacings of the GSM

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antennas. This relationship holds best if the PCN/PCS antennas are in fact PCN antennas. As shown in Figure 3 therefore, each GSM antenna 52 has a PCN/PCS antenna 56 at the same location. Additionally, between each pair of GSM antennas 52 there is a further PCN/PCS antenna 56. Thus as shown, there are three GSM antennas 52, and seven PCN/PCS antennas 56. The antenna array is mounted on a base board 60 which is constituted by double-sided printed circuit board and the upper conductive surface of which forms the ground plane for the patches 54. The antenna array is accommodated in a suitable housing (not shown) which may be of elongate channel shape, with a weatherproof radome covering the exposed face.

A side view of the array is shown in Figure 4. As noted above, the upper surface of the base board 60 constitutes the ground plane for the antenna structure. The patch antenna elements 54 are mounted on a dielectric substrate 62 so as to be spaced by about 6mm from the base board 60. This is a relatively large spacing in microstrip terms, and is designed to ensure that the GSM antenna has a sufficiently broad bandwidth. Projecting upwardly as seen in Figure 4 from the centre of the patch antenna element 54, are four small cylindrical rods 64, best seen in Figures 5 to 7, to support the elements of the PCN/PCS antennas 56 which are above the GSM antennas. Similar rods are fixed to the base board between the patch antennas to support the elements of the alternate PCN/PCS antennas 56.

Referring to Figures 4 and 6, and to the nearer antenna as seen in Figure 5, the structure of one of the GSM antennas 52 with the PCN/PCS antenna mounted thereon will be described. Mounted above each patch antenna element 54 is an aluminium plate 66 forming a parasitic element for the patch antenna element 54. The plate 66 is mounted on the base board 60 by means of four plastic spacers 68 illustrated in Figure 5. As an alternative, the plate can be formed of printed circuit board.



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The crossed dipoles 58 are mounted on the upper side of a square piece of printed circuit board 70 which itself is held near the top end of the rods 64. The crossed dipoles are arranged at  $45^\circ$  to the length of the array.

5 The crossed dipoles 58 which are arranged above the GSM antennas 52 make use of the plate 66 as a reflector. The plate or layer 66 thus operates as a parasitic element for the GSM antenna with the patch antenna element 54, and as a reflector for the PCN/PCS antenna 56 with the crossed

10 dipoles 58.

Those crossed dipoles which are not located above a GSM antenna 52, for example the one seen in Figure 7 or the further one as seen in Figure 5, have a conductive aluminium plate 72 beneath them to operate as a reflector.

15 The size of the plate 72 differs from the size of the plate 66, so that the plate 72 does not resonate at GSM frequencies. The plate 72 is held in position by plastics supports or spacers 74 similar to the spacers 68, but arranged to give a different spacing from the base

20 board 60.

The sizes, spacings and orientations of the various elements are designed in well known manner so as to provide the required frequency bandwidths for the GSM antennas and the PCN/PCS antennas.

25 The top ends of the rods 64 terminate in a small square piece of board 76 which secures them together. This is also shown in the detailed view of Figure 8. As is seen, there are four rods 64, two of which carry conductors forming feeds to the dipole elements.

30 Referring to Figure 6, the lefthand rod shown constitutes a coaxial feed to the dipole. The outer conductor is connected at 78 to one side of one of the dipoles. The centre conductor is carried over the small terminating piece of board 76, as shown at 80 in Figure 8, and is

35 connected to the diametrically opposed one of the four rods 64. This rod is connected at 82 to the opposed half

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of the dipole element 58. The other one of the pair of crossed dipoles is similarly connected.

Figure 6 shows a shorting slider 84 which may be incorporated if desired to provide a short between the rods 64. This is included at an appropriate location to provide the required radiation characteristics for the dipole.

The PCN/PCS antenna-only location is shown in Figure 7. Here there is no patch antenna 54, as there is in Figure 6, and the plate 72 replaces the plate 66. In other respects the construction is similar to that shown in Figure 6.

Figure 9 is a detail showing the orientation of the patch antenna element 54. The patch 54 is square, but is not aligned with the length of the array but rather is rotated by  $45^\circ$  relative thereto. Nevertheless, the parasitic element constituted by the plate 66, shown in dashed lines on Figure 9 for clarity, is indeed aligned with the length of the array. We have found that such a rotational offset of the parasitic element from the patch does not deleteriously affect the operation of the GSM antenna, and may indeed improve it.

Figure 9 also shows the two feed points to the patch antenna element 54. The feed points 86 are located at the mid point of two adjacent sides of the square patch 54. As seen in Figure 6, the feed is upwardly from the underside of the base board 60. The two feeds are electrically independent and isolated and may be used to transmit or receive two independent signals.

We have found that an improvement can be achieved by adding two strips 88 one to either side of the parasitic element 66. The strips extend transverse to the length of the array and lie between the parasitic element 66 and the adjacent antenna structure. These strips are shown in Figure 9. For a patch size of about 135mm, the strips are about 6mm wide and spaced about 6mm from the associated parasitic element. If the parasitic element is formed by

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the conductive sheet on a piece of single-sided circuit board, the strips 88 can readily be formed by etching on the same piece of board. The addition of the strips 88 is found to improve the isolation between the two feed points 86.

5 A modification of the antenna structure is shown in Figure 10, which is an isometric view similar to Figure 5. In this modification, the printed circuit board 70 carrying the etched crossed dipoles 58 is extended to be substantially the same size as the dielectric substrate 10 66, and carries, surrounding the dipoles 58 and in substantially the same plane as them, four parasitic reflector strips 102 etched on the same printed circuit board 70. These strips 102 can be in either of the two 15 orientations shown in Figure 10, that is either parallel and perpendicular to the length of the array, as shown for the nearer of the two structures, or at 45 degrees to it, as shown for the further of the two structures seen in this figure. The strips 102 can be straight, as shown, or 20 slightly curved.

As mentioned above, the top side of the base plate carries a conductive layer constituting the ground plane, and the underside may carry conductive tracks comprising the feed to some or all of the antenna elements. One 25 possible arrangement for the tracks on the underside of the base board 60 is indicated in Figure 11 which shows a corporate feed to an antenna array including six GSM antennas 52. The details of such arrangements are determined using known techniques to meet the particular 30 array requirement. Empirical testing may be necessary to determine the optimum precise arrangement for the tracks feeding the several patch elements.

Figure 12 shows a similar corporate feed arrangement for the crossed dipoles 58 in an antenna array which has a 35 total of twelve PCN/PCS antennas. These tracks may be disposed upon a lower printed circuit board (not shown) beneath the base board 60, and connect to the coaxial

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feeds constituted by the rods 64 and wires within them. Alternatively the feed arrangement of Figure 12 may be mounted on the underside of the base board 60 together with the GSM feed arrangement of Figure 11.

5           The arrangement described has the substantial advantage of considerable compactness compared with existing dual band antenna arrays for telephone use. The array can be used as a base station with which individual mobile telephones communicate for transmission and  
10           reception. The array will normally be mounted with its length vertical rather than in the apparently horizontal orientation shown.

          The arrangement is economical of components, and is particularly effective in that regard in using the  
15           aluminium plate 66 both as a parasite element for the GSM antenna and a reflector for the PCN/PCS antenna. It should be mentioned that the arrangement works best at PCN frequencies, which are more closely double the GSM  
          frequency range than the PCS frequencies. While the GSM  
20           and PCN/PCS arrays have been shown as being of broadly similar length, this is not necessary and the PCN/PCS array could, for example, be of shorter length than the GSM array not, therefore, occupying the full length of the  
          structure, but instead one of the arrays may occupy at  
25           least a substantial part of the length of the dual-band antenna array.

          Various other modifications may be made to the arrangement illustrated in Figures 3 to 12. In particular, the dipoles may take a different form from  
30           that shown. The printed circuit-type dipoles as shown in Figures 5 and 8, could, for example, be replaced by pieces of wire of appropriate length. Alternatively or  
          additionally, the dipoles could be arranged in the vertical plane, in the orientation shown in Figure 6,  
35           rather than in the horizontal plane as shown. It will be appreciated that when the array as a whole is vertical, both orientations are, in fact, vertical in use. In the

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illustrated arrangement, the dipole is vertical and parallel to the base board, whereas in the non-illustrated alternative the dipole is vertical and perpendicular to the base board 60.

5           In another modification, while square patches have been described and illustrated, it should be noted that circular patches may be used instead. Some deviation from a precisely square or circular shape is possible, for example by the addition of tabs.

10           An alternative embodiment is indicated in outline in Figure 13. In the antenna array 90 shown here, a base board 92 supports three GSM antennas 94 and six PCN/PCS antennas 96. In this case, the PCN/PCS antennas, while lying at half the spacing of the GSM antennas, are not  
15           located on top of them but rather are located at one quarter and three quarters of the distance between two GSM antennas. In order to accommodate the PCN/PCS antennas, the GSM patches 98 are not square but rather are of  
20           cruciform shape. The PCN/PCS antennas 96 may take the form of square or circular ring dipoles 100. These can be arranged to fit in the interstices of the crossed patches in the manner illustrated in Figure 13.

25           While preferred embodiments of the invention have been described by way of example, it will be appreciated that the invention may be implemented in other ways than those illustrated.

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**CLAIMS**

1. A dual-band antenna array comprising:  
a first linear array of microstrip antennas at a  
first spacing; and  
5 a second linear array of antennas at a second  
spacing, the second spacing being substantially equal to  
half the first spacing, and the antennas of the second  
linear array being interleaved along the length of the  
dual-band antenna array with the antennas of the first  
10 linear array over at least a substantial part of the  
length of the dual-band antenna array.
2. A dual-band antenna array according to claim 1, in  
which the second linear array is an array of dipoles.
3. A dual-band antenna array according to claim 1, in  
15 which the operational frequency range of the second linear  
array of antennas differs from the operational range of  
the first linear array of microstrip antennas.
4. A dual-band antenna array according to claim 1, in  
which alternate ones of the antennas of the second linear  
20 array of antennas are located above antennas of the first  
linear array of microstrip antennas.
5. A dual-band antenna array according to claim 4,  
including a conductive layer between each microstrip  
antenna and the associated antenna of the second array  
25 which functions as a parasitic element for the microstrip  
antenna.
6. A dual-band antenna array according to claim 5, in  
which the second linear array is an array of dipoles, and  
the conductive layer also functions as a reflector for the  
30 associated dipole.

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7. A dual-band antenna array according to claim 5, in which the other antennas of the second array are provided with a conductive layer which functions as a reflector, the conductive layer of those antennas of the second array which are above a microstrip antenna differing in size from those that are not.

8. A dual-band antenna array according to claim 1, in which two antennas of the second linear array are located between each pair of microstrip antennas at substantially one-quarter and three-quarters of the spacing between them.

9. A dual-band antenna array according to claim 8, in which the microstrip antennas are of cruciform shape.

10. A dual-band antenna element comprising:  
a microstrip antenna including a patch element; and  
a dipole antenna mounted above the patch element;  
in which the size of the microstrip antenna and the size of the dipole antenna are such that the operational frequency range of the dipole antenna differs from the operational range of the microstrip antenna.

11. A dual-band antenna element according to claim 10, including a conductive plate or sheet between the microstrip antenna and the dipole antenna which functions both as a parasitic element for the microstrip antenna and as a reflector for the dipole antenna.

12. A dual-band antenna element according to claim 11, in which the patch element and the conductive plate or sheet are both substantially square, and the conductive plate or sheet is rotationally offset by 45 degrees relative to the patch element.

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13. A dual-band antenna element according to claim 10, in which the dipole antenna is formed by crossed dipoles.

14. A dual-band antenna element according to claim 10, including a plurality of parasitic elements surrounding  
5 and in substantially the same plane as the dipole antenna.

15. A dual-band antenna array comprising:

a first linear array of microstrip antennas at a first spacing, each microstrip antenna including a patch element; and

10 a second linear array of second antennas at a second spacing, the second spacing being smaller than the first spacing such that the second antennas are interleaved with the microstrip antennas over at least a substantial part of the length of the dual-band antenna array;

15 in which the microstrip antennas and the second antennas are constructed such that the operational frequency range of the second antennas differs from the operational frequency range of the microstrip antennas.

16. A dual-band antenna array according to claim 15, in  
20 which the second antennas are dipole antennas.

17. A dual-band antenna array according to claim 16, in which the dipole antennas are formed by crossed dipoles.

18. A dual-band antenna array according to claim 15, in which alternate ones of the second antennas are mounted  
25 above corresponding ones of the patch elements.

19. A dual-band antenna array according to claim 18, including a conductive plate or sheet between each microstrip antenna and the corresponding second antenna which functions both as a parasitic element for the  
30 microstrip antenna and as a reflector for the second antenna.



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20. A dual-band antenna array according to claim 19, in  
which the patch element and the conductive plate or sheet  
are both substantially square, and the conductive plate or  
sheet is rotationally offset by 45 degrees relative to the  
5 patch element.

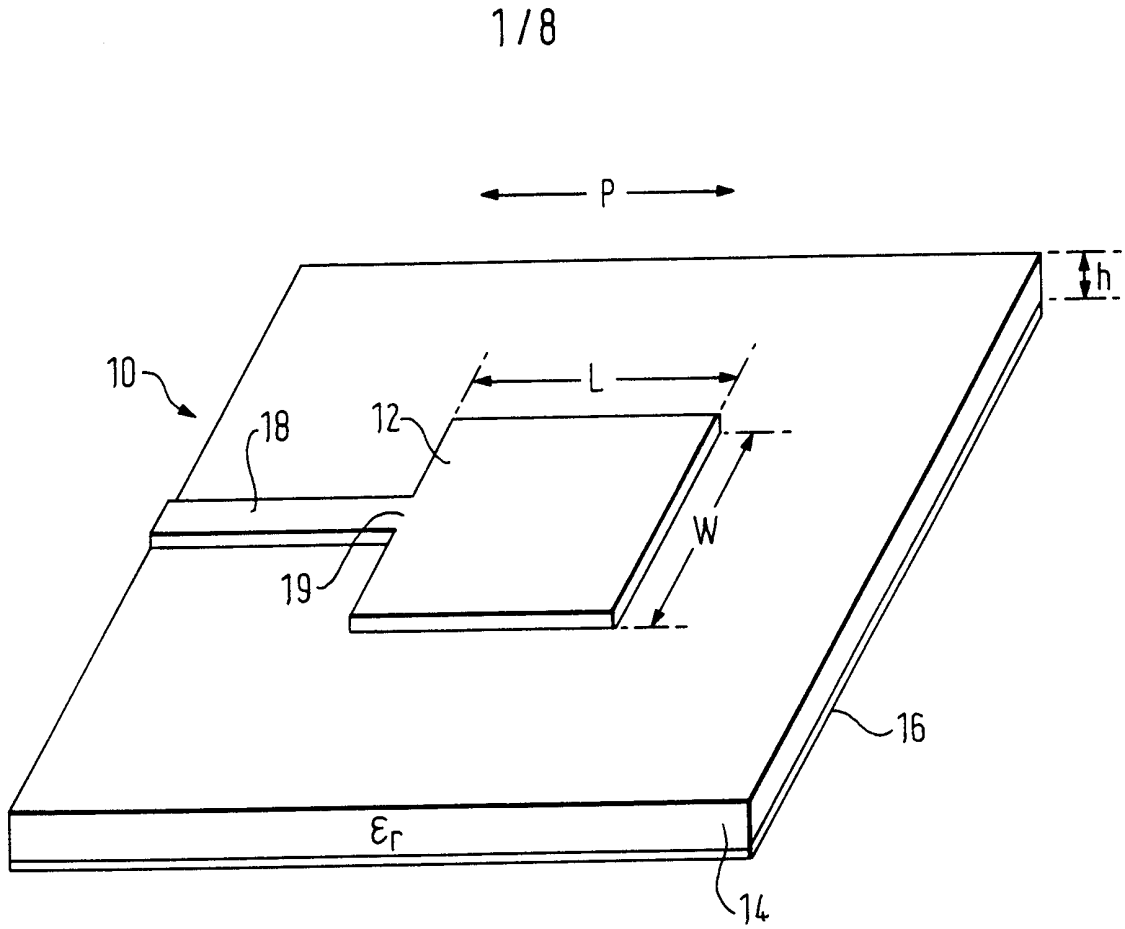


FIG. 1  
PRIOR ART

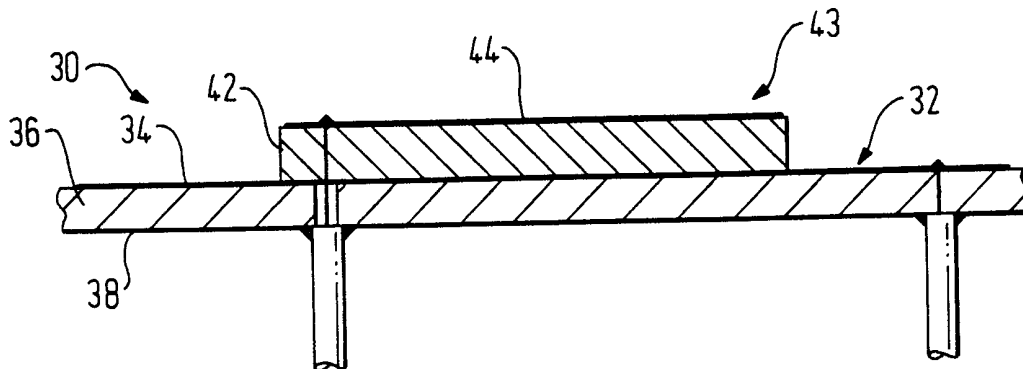


FIG. 2  
PRIOR ART

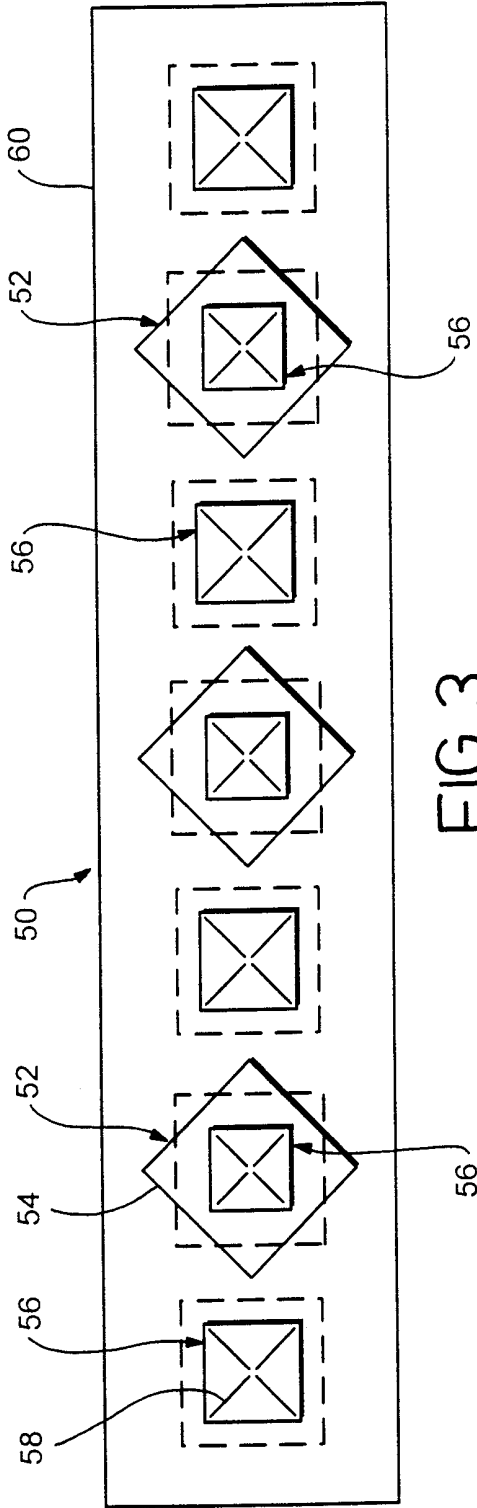


FIG. 3

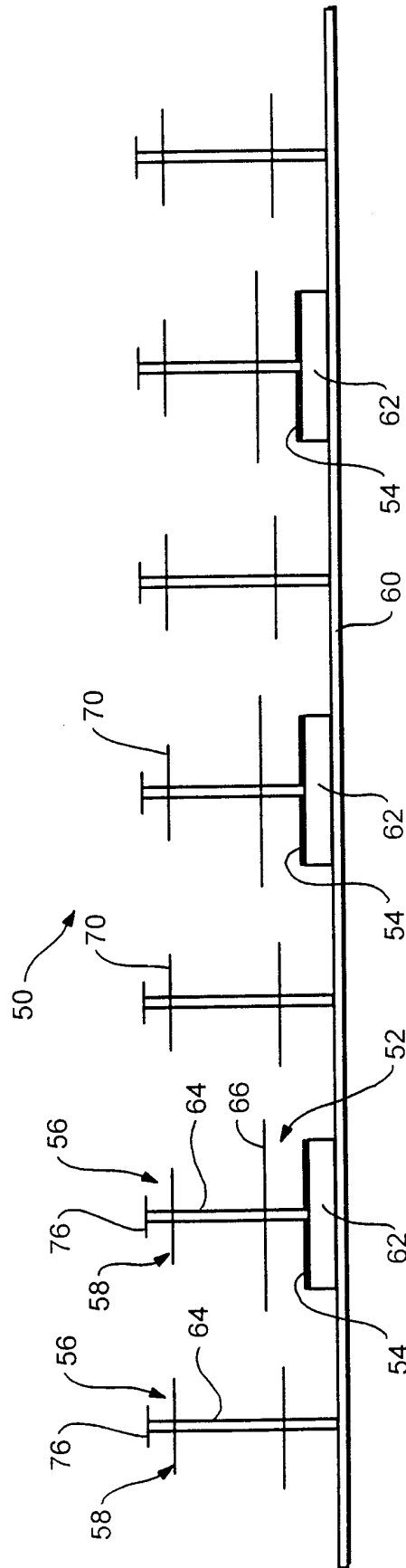


FIG. 4

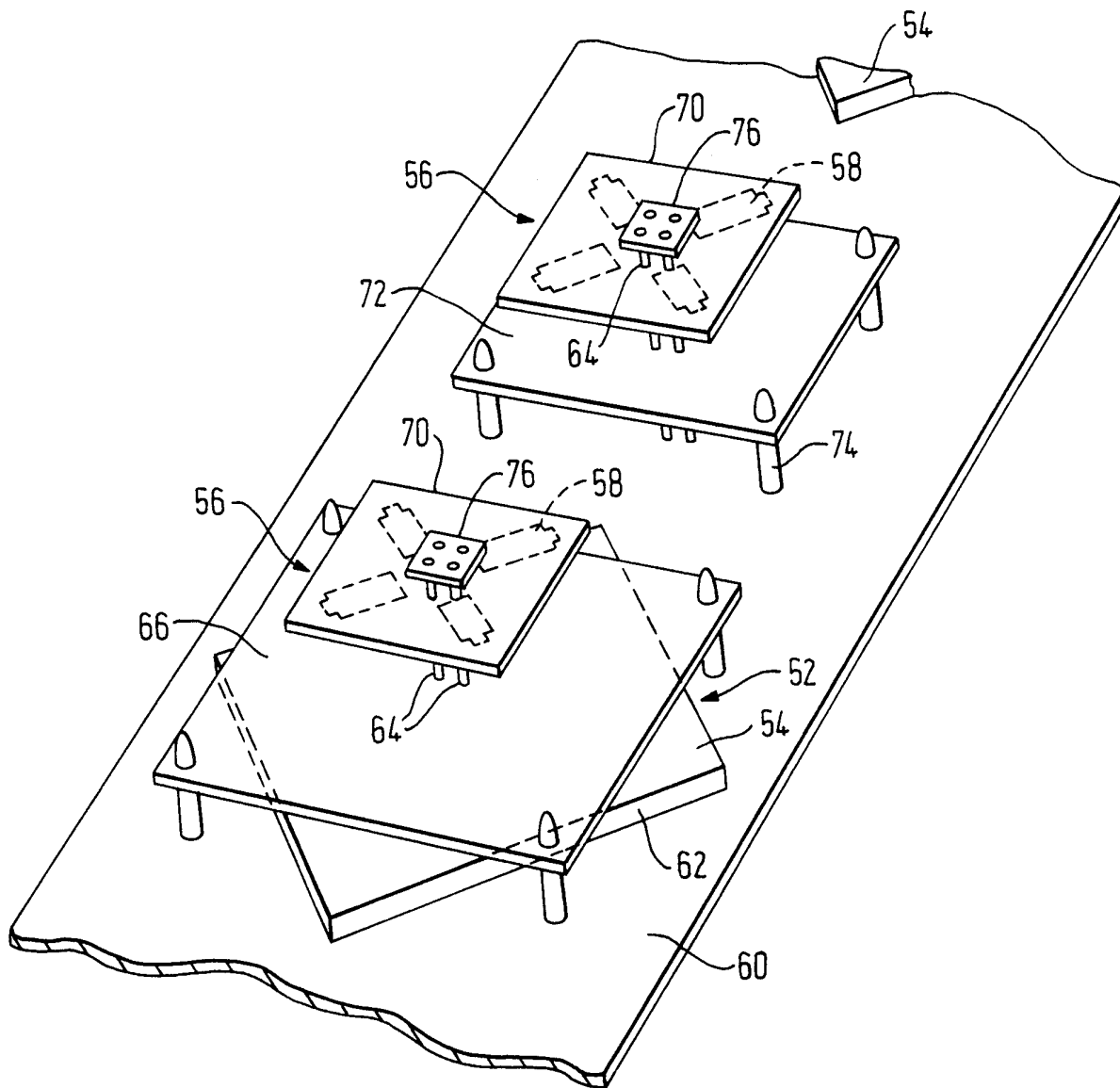


FIG. 5

FIG. 6

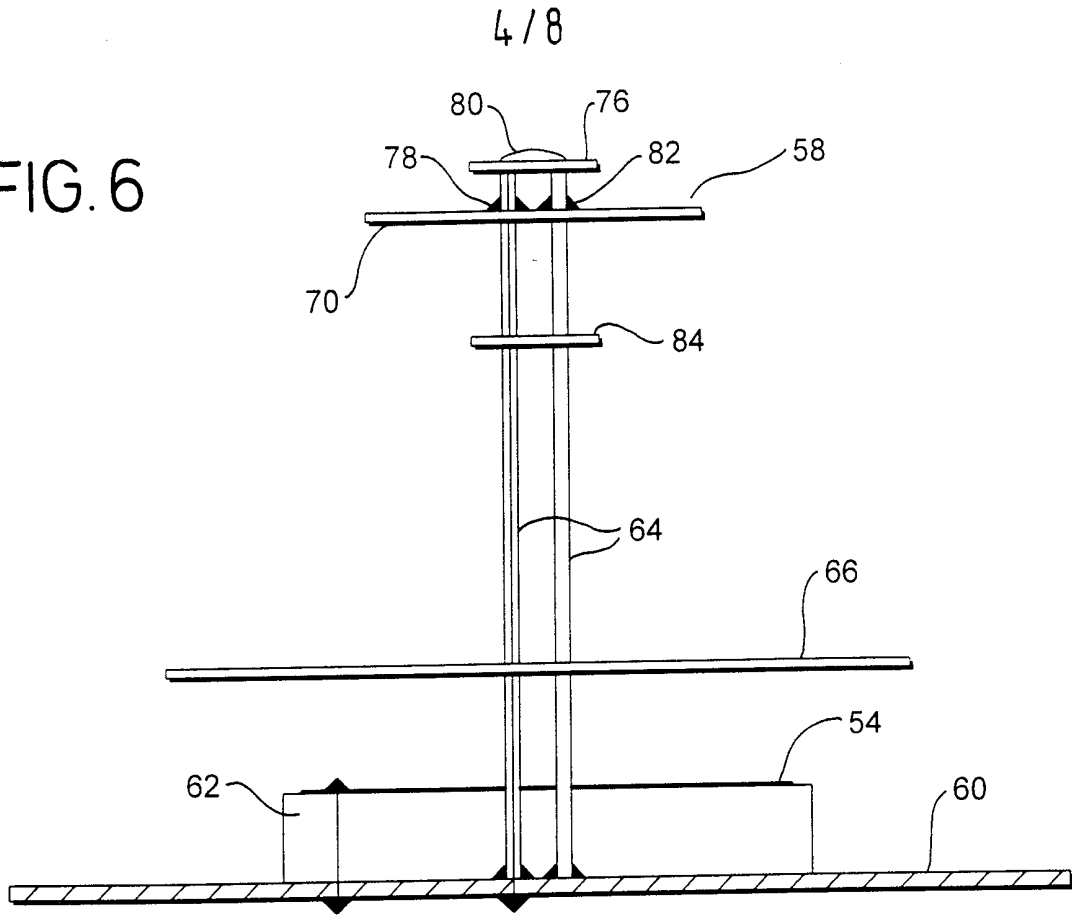
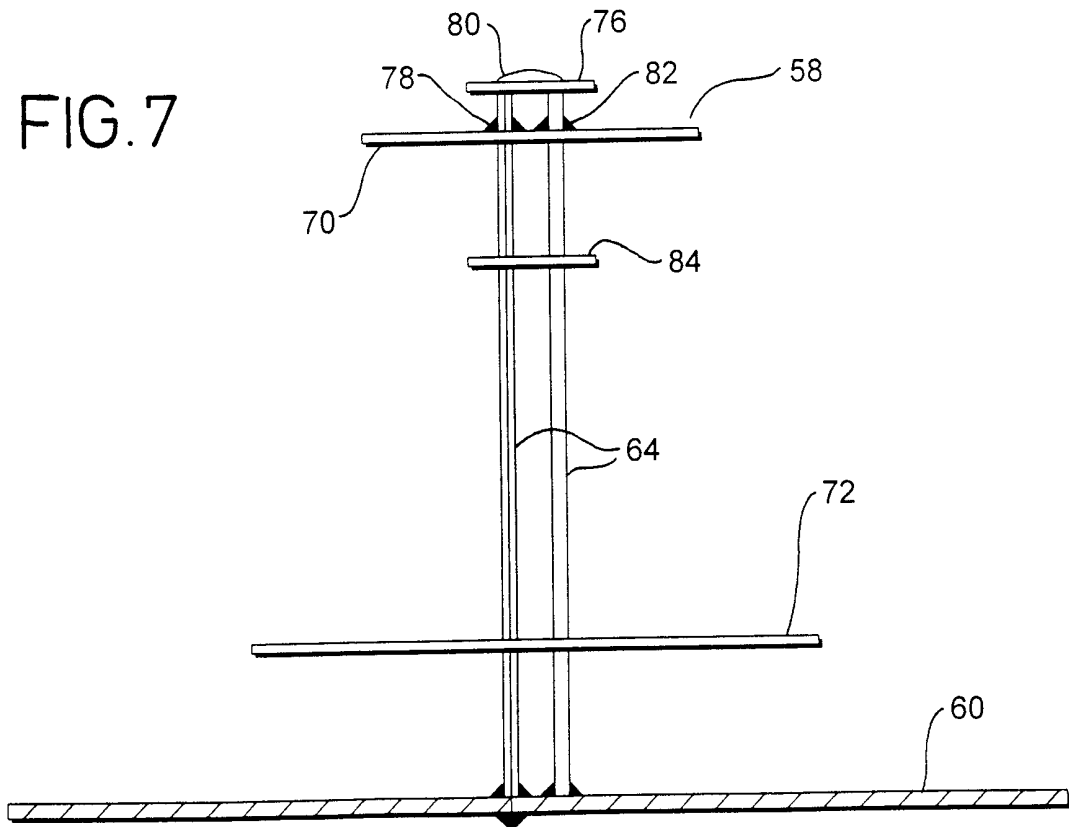


FIG. 7



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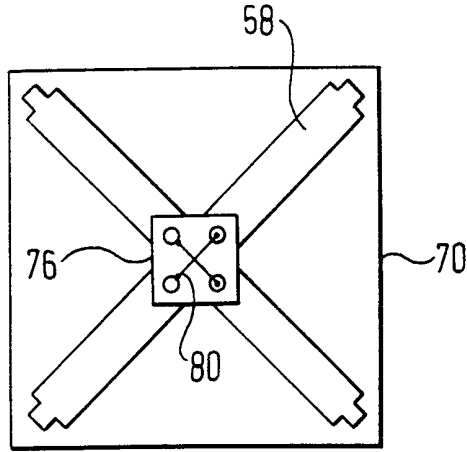


FIG. 8

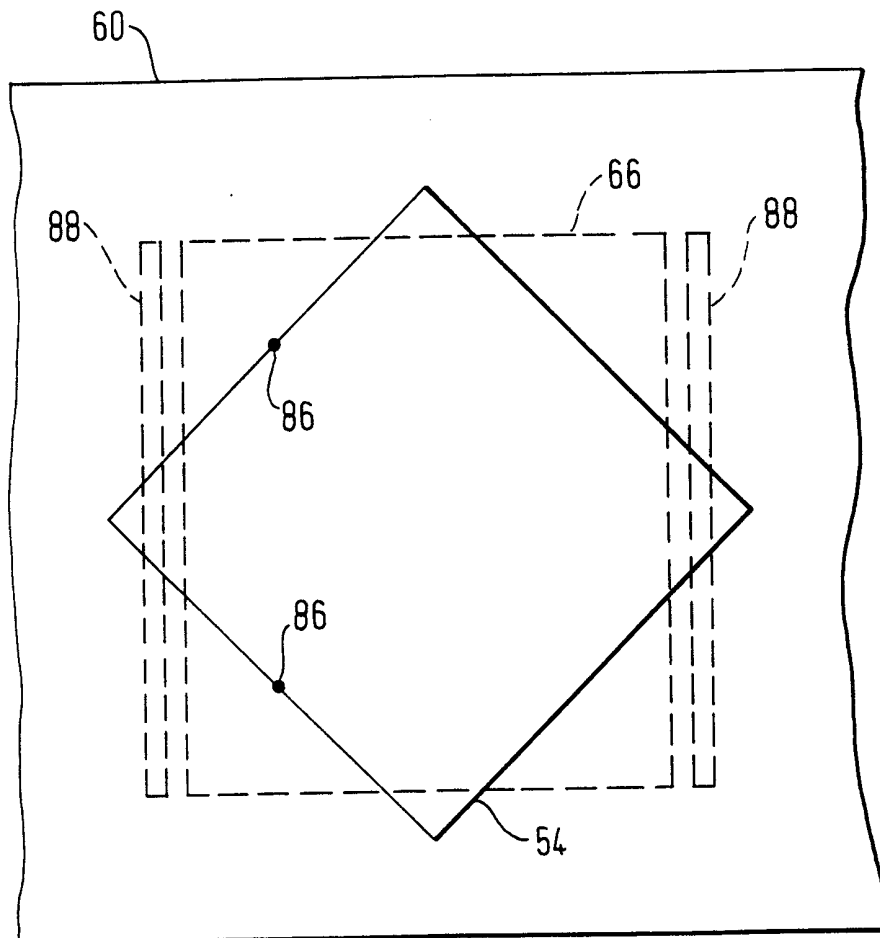


FIG. 9

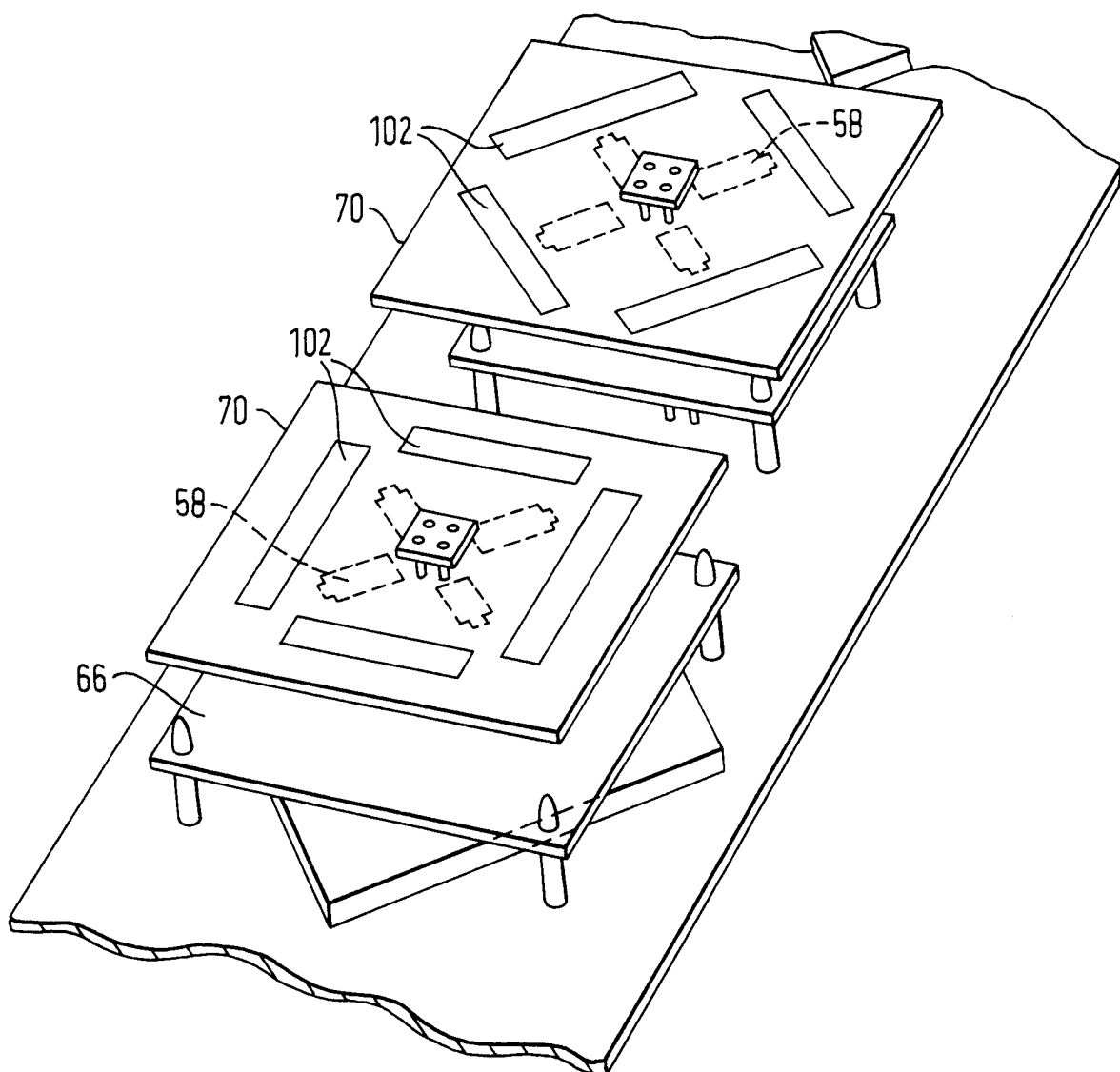


FIG. 10

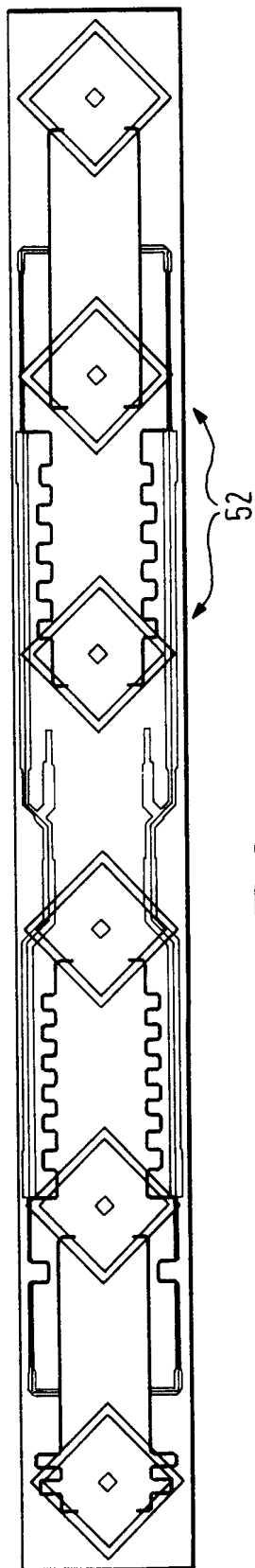


FIG. 11

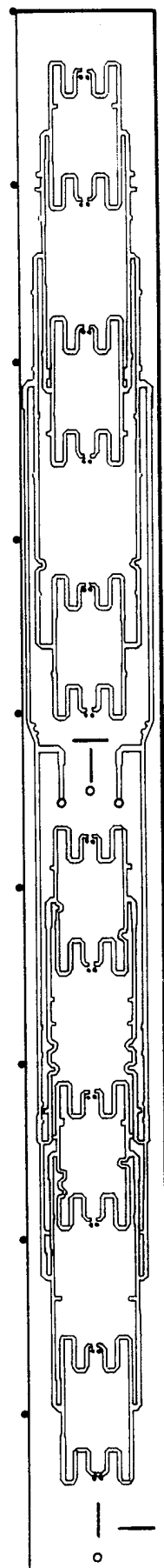


FIG. 12



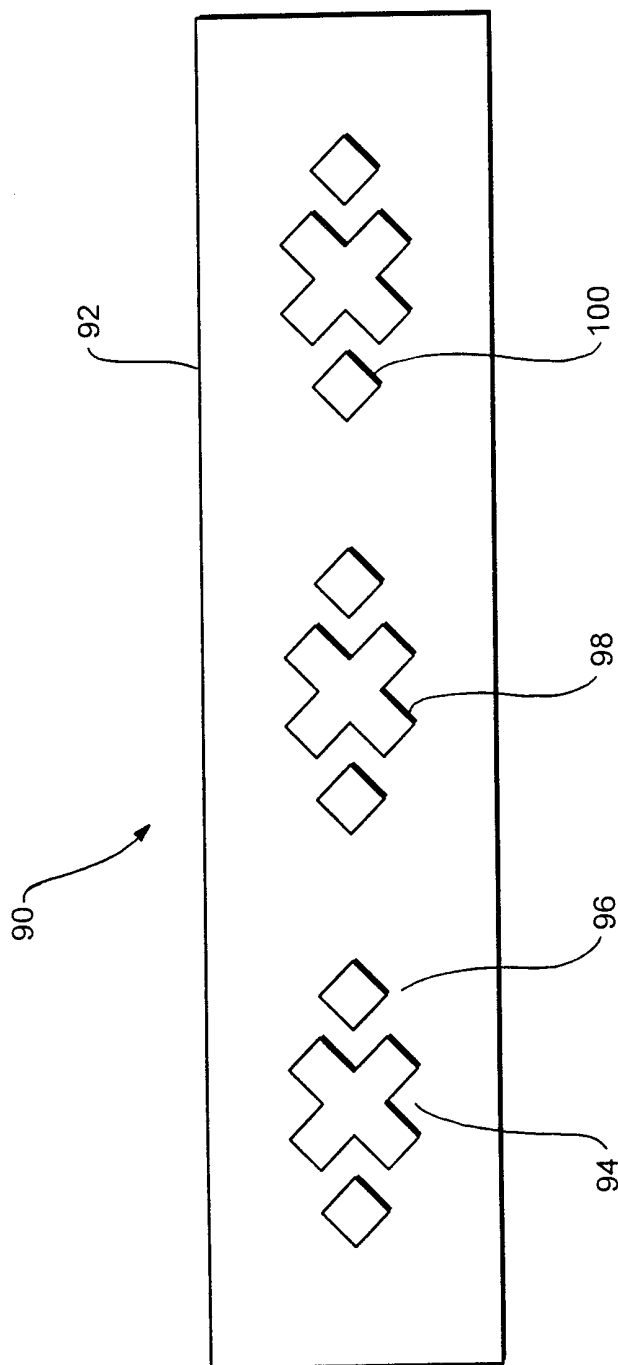


FIG. 13