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**(54) STACKED BOWTIE RADIATOR WITH INTEGRATED BALUN**

GESTAPELTER BOWTIE-HEIZKÖRPER MIT INTEGRIERTEM BALUN

ÉLÉMENT RAYONNANT EN BOUCLE EMPILÉ À SYMÉTRISEUR INTÉGRÉ

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**Description**

## FIELD

- 5 **[0001]** The concepts, systems, circuits and techniques described herein relate generally to radio frequency (RF) circuits and more particularly to an RF antenna and integrated balun.

## BACKGROUND

- 10 **[0002]** As is known in the art, phased array antennas are comprised of a plurality of antenna elements or radiators. As is also known, in the design of such antenna elements, a trade-off must typically be made between an operating frequency bandwidth characteristics and cross-polarization isolation characteristics. For example, with proper design, an array of dipole elements can be provided a relatively high cross-polarization isolation characteristics in all scan planes; however, bandwidth is limited. On the other hand, array antennas provided from notch radiators or Vivaldi radiators (for  
15 example) are capable of operating over a relatively wide frequency bandwidth, but have a relatively low cross-polarization isolation characteristic off the principal axes.

- [0003]** Droopy bowtie elements disposed above a ground plane are a well known means for producing nominally circular polarized (CP) reception or transmission radiation patterns at frequencies from VHF to microwave wavelengths. Droopy bowtie elements are often coupled to a balun which is realized in a co-axial configuration involving separate  
20 subassemblies for achieving balun matching and arm phasing functions. Such a design typically results in an integrated antenna-balun assembly having good bandwidth but a poor cross-polarization isolation characteristic. Furthermore, such a design is relatively difficult to assemble (high recurring engineering cost) and cannot easily be adapted to different operating frequencies or polarizations (high non-recurring engineering cost).

- [0004]** It would, therefore, be desirable to provide an integrated antenna element for use in a phased array antenna which has good wideband RF performance, good cross-polarization isolation characteristics, and which reduces both  
25 recurring and non-recurring engineering costs.

**[0005]** US 2011/0291907 A1 describes an antenna element and balun. The antenna includes a plurality of droopy bowtie antenna elements.

- [0006]** US 4,668,956 describes a broadband cup antenna comprising dipole means having at least one pair of short  
30 spiral type monopoles diametrically disposed in a common plane in proximity to the open end of the cup. Parasitic elements are in juxtaposition with the monopoles and are electrically connected by a conductive ring mounted about coaxial lines.

**[0007]** US 5,418,544 describes an antenna element formed from two stacked crossed grid dipole elements.

## 35 SUMMARY

- [0008]** In accordance with one aspect of the concepts, systems, circuits and techniques described herein, an antenna element comprises a dielectric substrate having a general pyramidal shape with a feed point provided at the center. The substrate has an inner surface and an outer surface. Four driven conductors are disposed over the inner surface of the  
40 substrate, each of the driven conductors has a generally triangular shape with one vertex terminating proximate the feed point. In addition, four passive conductors are disposed over the outer surface of said substrate, each of the passive conductors being opposite to at least one inner conductor. In some aspects, each passive conductor may have a smaller surface area compared to corresponding ones of the driven conductors.

- [0009]** In accordance with another aspect of the invention, the feed point of the antenna element is electrically coupled to a quad-line vertical balun column. The quad-line balun column has a square cross-sectional shape and a central  
45 conductive member with first and second opposing ends. The central conductive member includes four (4) dielectric balun slabs, each having a first surface disposed over a conductive surface of the central member and a second opposing conductive surface.

- [0010]** In accordance with another aspect of the invention, the antenna element driven conductors are fed by the balun and the passive conductors are parasitically coupled to the corresponding ones of the driven conductors.

- [0011]** In accordance with another aspect of the invention, an antenna assembly comprises a printed circuit board (PCB), a feed circuit disposed on one surface of the circuit board, an antenna element, and a quad-line balun column electrically coupled to the feed circuit at one end and electrically coupled to the antenna element at an opposite end. The antenna element comprises a dielectric radiator block having a height and a cavity region formed therein with the  
55 cavity region having a pair of opposing surfaces and a feed point provide at the center point of the cavity. The antenna element further comprises a conductive layer disposed on each of the surfaces, each conductive layer coupled to the feed point. The quad-line balun column comprises a central member having four conductive surfaces and first and second opposing conductive ends. The balun column further comprises four (4) dielectric balun slabs, each having a

first surface disposed over a conductive surface of the central member and a second opposing conductive surface.

**[0012]** In accordance with another aspect of the invention, the antenna assembly feed circuit comprises a ground conductor coupled to each balun central member conductive surface, a first feed conductor coupled to first balun slab feed conductor, a second feed conductor coupled to second balun slab feed conductor, a third feed conductor coupled to third balun slab feed conductor, and a fourth feed conductor coupled to fourth balun slab feed conductor.

**[0013]** In accordance with another aspect of the invention, the antenna assembly further comprises a support structure over which the antenna element is disposed, wherein a first end of the balun is exposed through a first opening in the support structure and a second end of said balun is exposed through a second opening in the support structure.

**[0014]** In accordance with another aspect of the invention, a plurality of antenna assemblies are provided, arranged in a two-dimensional array pattern.

**[0015]** In accordance with another aspect of the invention, a method for assembling an antenna assembly includes coupling a first end of a quad-line vertical balun column to a circuit board and coupling a second end of the balun to an antenna element.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0016]** The foregoing features of the invention, as well as the invention itself may be more fully understood from the following detailed description of the drawings, in which:

FIG. 1 is an isometric view of an integrated antenna element having a stacked bowtie antenna element and a quad-line balun column;

FIG. 1A is an inverted isometric view of the stacked bowtie antenna element of FIG. 1;

FIG. 1B is a cross-sectional view of the integrated antenna element of FIG. 1;

FIG. 2 is a side view of a partial stacked bowtie antenna element;

FIGS. 3-3B are perspective views of stacked bowtie antenna elements;

FIG. 4 is an isometric view of a partial unit-cell assembly having a quad-line balun, a feed circuit, and a support structure;

FIG. 4A is a cross-sectional view of the partial unit-cell assembly of FIG. 4.

FIG. 5 is an isometric view of a quad-line balun;

FIG. 5A is a top view of the quad-line balun of FIG. 5;

FIG. 6 is a top view of a feed circuit disposed over a printed circuit board (PCB);

FIG. 6A is a side view of the PCB of FIG. 6;

FIG. 7 is a block diagram of an antenna system utilizing a quad-line balun column and a stacked bowtie antenna element;

FIG. 8 is a block diagram of an antenna system utilizing a quad-line balun column and a stacked bowtie antenna element;

FIG. 9 is an isometric view of an "egg crate" support structure for use in an antenna array assembly;

FIGS. 9A and 9B are isometric views of an antenna array assembly; and

FIG. 9C is a side view of the antenna array assembly in FIGS. 9A and 9B.

**[0017]** It should be understood that in an effort to promote clarity in the drawings and the text, the drawings are not necessarily to scale, emphasis instead is generally placed upon illustrating the principles of the invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0018]** Before describing the various embodiments of the circuits, systems and techniques described herein, some introductory concepts and terminology are explained.

**[0019]** Reference is sometimes made herein to a quad-line balun column coupled to an antenna element of a particular type, size and/or shape. For example, one type of antenna element is a so-called stacked bowtie antenna element, a type of turnstile antenna, having a size and shape compatible with operation at a particular frequency (e.g. 10 GHz) or over a particular range of frequencies (e.g. the L, S, C, and/or X-band frequency ranges). Those of ordinary skill in the art will recognize, of course, that other shapes and types of antenna elements (e.g. an antenna element other than a droopy bowtie antenna element) may also be used with a quad line balun column and that the size of one or more antenna elements may be selected for operation at any frequency in the RF frequency range (e.g. any frequency in the range of about 1 GHz to about 100 GHz). The types of radiating elements which may be used with a quad-line balun column (e.g. to form an array) include but are not limited to bowties, notch elements, dipoles, slots or any other antenna element (regardless of whether the element is a printed circuit element) known to those of ordinary skill in the art.

**[0020]** It should also be appreciated that within the embodiments involving an array, the antenna elements in the array

can be provided having any one of a plurality of different antenna element lattice arrangements including periodic lattice arrangements (or configurations) such as rectangular, square, triangular (e.g. equilateral or isosceles triangular), and spiral configurations as well as non-periodic or arbitrary lattice arrangements.

**[0021]** Applications in which at least some embodiments of the balun and/or stacked bowtie antenna element described herein may be used include, but are not limited to: radar, electronic warfare (EW) and communication systems for a wide variety of applications including ship based, airborne, missile and satellite applications.

**[0022]** As will also be explained further herein, at least some embodiments of an integrated balun and stacked bowtie antenna element are applicable, but not limited to, military, airborne, shipborne, communications, unmanned aerial vehicles (UAV) and/or commercial wireless applications.

**[0023]** Referring now to FIGS. 1-1B in which like structures are provided having like reference designations throughout the several views, an integrated antenna element 10 includes a quad-line balun column 12 (or more simply balun 12) having a first end electrically coupled to a feed point of a stacked bowtie antenna element 14 (herein also referred to as antenna element 14). Since balun column 12 is electrically coupled to the center of antenna element 14, the element is also sometimes referred to as a center-fed stacked bowtie antenna element 14.

**[0024]** In some embodiments, the balun column 12 can be mechanically coupled to the antenna element 14 using any technique known in the art including but not limited to soldering, welding, adhering using epoxy, or friction fitting. In preferred embodiments, the antenna element 14 has an opening 14a through which balun column 14 can be inserted. As described further below in conjunction with FIGS. 9-9C, this configuration allows the integrated antenna element 14 to be assembled using commercial pick-and-place robots and, therefore, may reduce recurring costs.

**[0025]** The antenna element 14 is a three-dimensional structure which may have a truncated pyramidal shape, as shown in FIGS. 1-1B. In FIG. 1A, the antenna element 14 is shown upside down to reveal a cavity 19 formed by the pyramidal shape. The antenna element 14 includes a plurality, here four (4), stacked bowtie radiators 20, each having a driven conductor 20b and a passive conductor 20a separated by a dielectric material 20c. In preferred embodiments, the antenna element 14 can be a single structure formed by injecting liquid crystal polymer (LCP) into a mold of any suitable shape and size. It will be appreciated that LCP can further serve as the dielectric 20c. In another embodiment, each stacked bowtie radiator 20 is manufactured separately and later secured together (e.g. by epoxy) to form the antenna element 14. Thus, the dielectric 20c may be either a single piece of dielectric or four separate pieces of dielectric. In some embodiments, slots may be provided between adjacent stacked bowtie radiators 20 to improve isolation and reduce LCP usage/cost. In a preferred embodiment, such slots have a length of about 180 mils.

**[0026]** The driven conductors 20b may be provided as four surface-plated metal wings within pyramidal shaped cavity 19 of antenna element 14. The metal wings can be formed through any subtractive or additive process known to those of ordinary skill in the art. The passive conductors 20a may also be provided as four surface-plated metal wings disposed opposite each driven conductor 20b. For reasons that will be discussed below, each driven conductor 20b may have a larger surface area than each corresponding passive conductor 20a. In a preferred embodiment, the antenna element 14 is copper plated and copper is selectively removed/etched using a laser to form conductive surfaces 20a and 20b.

**[0027]** In preferred embodiments, the antenna element 14 has a width/length  $w_4$  (shown in FIG. 1A) of about 380 mils and a height  $h_1$  (shown in FIG. 1B) of about 140 mils, and the passive conductors 21 have a long edge width  $w_5$  of about 284 mils, a short edge width  $w_6$  of about 84 mils, and a tapered edge length of about 147 mils (shown in FIG. 1).

**[0028]** Referring now to Fig. 1B, one end of balun column 12 is electrically coupled to the driven conductors 20b (only two driven conductors 20b are visible in FIG. 1B). In one embodiment, balun column 12 is coupled to the driven conductors 20b via a solder connection. Those of ordinary skill in the art will appreciate, of course, that techniques other than soldering may also be used to couple balun column 12 to conductors 20b. Such techniques, include but are not limited to welding techniques, and conductive epoxy techniques.

**[0029]** Still referring to FIG. 1B, the operation and advantages of the stacked bowtie radiators 20 will now be described. As previously mentioned, driven conductors 20b are electrically coupled to balun column 12, which in turn is electrically coupled to a feed circuit (not shown). In contrast, passive conductors 20a are not electrically coupled to the feed circuit. Further, each driven conductor 20b is arranged opposite and has a smaller surface area than corresponding ones of the passive conductors 20a. Therefore, it should be appreciated that the driven conductors 20b are driven/fed by the feed circuit that operate over a first frequency band (centered around a first resonant frequency), whereas the passive conductors 20a are "parasitic elements" not driven/fed by the feed circuit that operate over a second frequency band (centered around a second resonant frequency). Thus, the stacked bowtie radiators disclosed herein provide increased bandwidth and operating range compared with existing turnstile radiators.

**[0030]** As shown in FIG. 1B, each stacked bowtie radiator 20 may have a generally straight shape. In other embodiments, each radiator 20 may have a convex shape or a concave (negative convex) shape. As illustrated in FIGS. 2 and 3, a convexity factor,  $\Delta$ , controls the shape of the driven conductors 20b. It should be appreciated that the shape of dielectrics 20c and passive conductors 20a can be adapted to generally match the shape of the driven conductors 20b. Thus, changing the convexity factor changes the radiator shape from a convex shape, to a straight shape, to a concave shape. The convexity factor may typically vary from about 0.2 mm to about -0.2 mm for operation in the X-band frequency

range. Such a variation usually has a minor effect on the antenna impedance characteristics but, at the same time, it provides acceptable mechanical tolerances to be established for antenna manufacturing. Convexity also provides another design parameter that can be used to optimize element pattern performance with respect to bandwidth. It should, however, be appreciated that regardless of the convexity factor setting, stacked bowtie performance can be tolerated to variations in this factor which make it amenable to established manufacturing processes.

**[0031]** Referring now to FIG. 2 in which like structures are provided having like reference designations as in FIGS. 1-1B, a convexity factor ( $\Delta$ ) controls the shape of the driven conductors 20b. As shown in FIGS. 1-1B, the stacked bowtie radiators 20 may have a generally straight shape. In other embodiments, the radiators 20 may have a convex shape or a concave (negative convex) shape. It will be appreciated that the shape of dielectrics 20c and passive conductors 20a can be adapted to generally match the shape of the driven conductors 20b. Thus, changing the convexity factor changes the radiator shape from a convex shape, to a straight shape, to a concave shape.

**[0032]** The convexity factor may typically vary from about 0.2 mm to about -0.2 mm for operation in the X-band frequency range. Such a variation usually has a minor effect on the antenna impedance characteristics but, at the same time, it provides acceptable mechanical tolerances to be established for antenna manufacturing. Convexity also provides another design parameter that can be used to optimize element pattern performance with respect to bandwidth. It should, however, be appreciated that regardless of the convexity factor setting, stacked bowtie performance can be tolerated to variations in this factor which make it amenable to established manufacturing processes.

**[0033]** Referring now to FIGS. 3-3B in which like structures of FIGS. 1-1B and 2 are provided having like reference designations, an antenna element 14 (FIG. 3) has a convexity factor ( $\Delta$ ) set equal to zero. Thus, the element 14 and corresponding driven conductors 20b, dielectric 20c, and passive conductors (not shown) are said to be straight or non-convex. An antenna element 14' in FIG. 3A is provided having a convexity factor ( $\Delta$ ) set equal to 0.06. Thus, element 14' and corresponding driven conductors 20b', dielectric 20c', and passive conductors (not shown) have a positive convexity and are said to be convex. In FIG. 3B, an antenna element 14" is provided having a convexity factor ( $\Delta$ ) set equal to -0.06. Thus, element 14" and corresponding driven conductors 20b", dielectric 20c", and passive conductors (not shown) have a negative convexity and are thus said to be concave.

**[0034]** Referring now to FIGS. 4 and 4A in which like structures of FIGS. 1-1B are provided having like reference designations, a support structure 30 is disposed over a printed circuit board (PCB) 40. A feed circuit 42 is disposed (e.g. printed) onto a surface of the PCB 40, as shown. A quad-line balun column 12 has a first end electrically coupled to feed circuit 42 and mechanically coupled to PCB 40. Feed circuit 42, in turn, may be coupled to other RF circuits (not shown on FIG. 4A), here through via holes 44 for example. In some embodiments, balun column 12 may be electrically coupled to feed circuit 42 via solder connections 46. The solder connections 46 could, of course, also provide mechanical coupling. In a preferred embodiment, the first end of the balun column includes a post, such as post 72 in FIG. 5, which may fit inside a post receptor, such as receptor 48 in FIG. 6 to secure the balun column to the PCB. The feed circuit 42 is discussed more fully below in conjunction with FIGS. 6 and 6A.

**[0035]** The balun column 12 further has a second end which may be exposed through, and extend past, an opening in the support structure 30, as shown. It should be appreciated that the second end of balun column 12 can be electrically and mechanically coupled to an antenna element, such as antenna element 14, as shown in FIGS. 1-1B.

**[0036]** For ease of reference, the combination of a support structure, a feed circuit, a balun column, and a stacked bowtie antenna (not shown in FIG. 4) may hereinafter be referred to as a "unit cell."

**[0037]** In some embodiments, the support structure 30 or portions thereof is/are fabricated using injection molding techniques. However, it should be appreciated that other techniques known in the art may be used to fabricate the support structure 30. In one embodiment, the support structure 30 has conductive surfaces (e.g. metallized walls), thereby providing electrical isolation and suppress surface wave mode coupling between adjacent unit cells within an array antenna (such as the array shown in FIG. 9B). In preferred embodiments, the support structure 30 has a height  $h_2$  of 160 mils., a thickness  $d_2$  of 30 mils., and a width/length  $w_3$  of 440 mils.

**[0038]** Column 12 includes a plurality of, here four (4), dielectric substrates 15a-15d (only dielectric substrates 15b and 15c being visible in Fig. 4A) with each substrate 15a-15d having conductors 13a-13d (only conductors 13a-13c visible in Fig. 4A) disposed thereon with each of the conductors 13a-13d having a first end coupled to a corresponding one of four radiators 20 and a second end coupled to a conductor 42 on PCB 40. In one particular embodiment, conductors 13a-13d are provided having a width equal to the width of the respective substrates 15a-15d on which they are disposed. In other embodiments, the width of conductors 13a-13d is less than the width of the respective substrates. In general, the width of conductors 13a-13d are selected to provide desired impedance and isolation characteristics.

**[0039]** Referring now to FIGS. 5 and 5A a vertical rectangular transmission line, known as a quad-line balun column 70, is shown. The balun column 70 includes a central conductive member 78 having a square cross-sectional shape. Dielectric substrates 82a-82d are disposed over external surfaces of the central member 78. In some embodiments, dielectric substrates 82a-82d are composed of Rogers RT/duroid 6010 PTFE dielectric material. Dielectric substrates 82a-82d may be secured to central member 78 using solder, glue, epoxy, welding or any other fastening technique well-known to those of ordinary skill in the art.

**[0040]** In the embodiment shown in FIG. 5A, dielectric substrates 82a-82d are each provided having conductive material 80a-80d (conductors 80a and 80d not visible in FIG. 5) disposed on one surface, but not on the opposing surface. This is because the central member 78 is provided as an opposing conductor. Thus, the dielectric substrates 82a-82d and respective conductive surfaces 80a-80b form four adjacent coplanar microstrip transmission lines sharing the same ground provided by the central conductive member 78 (i.e. each disposed on side surfaces of the central conductive member). In other embodiments, it may be desirable or necessary to provide a central member that is not conductive and instead provide separate conductors on the opposing surface of dielectric substrates 82a-82d. It should be appreciated that balun column 70 is the same or similar to balun column 12 in FIGS. 1-1B, 4, and 4A, in which case conductors 80a-80d may correspond to conductors 13a-13d respectively.

**[0041]** In one embodiment, the central conductive member 78 is provided having a square or rectangular cross-sectional shape and is provided as a solid metal conductor (e.g. a copper or brass bar). In other embodiments, the central conductive member need not be solid (e.g. it could be hollow or partially hollow). Also, the central conductive member 78 may be provided from a nonconductive material and have a conductive coating or a conductive surface disposed thereover to provide a central conductive member 78. In one embodiment, the central conductive member 78 is provided from a machining technique. In other embodiments, the conductive member 78 may be formed via a molding technique (e.g. injection molding). Other techniques known to those of ordinary skill in the art may also be used to provide a central conductive member.

**[0042]** In the embodiment of FIG. 5A, conductors 80a-80d have a width substantially equal to the width of the respective dielectric substrates 82a-82d on which the conductors 80a-80d are disposed. In other embodiments, each conductor 80a-80d may have a width which is less than the width of the respective dielectric substrates 82a-82d on which it is disposed.

**[0043]** A mounting post 72 may be provided upon the column 70 for mechanically coupling to a PCB. In some embodiments, the mounting post 72 is made of a conductive material and therefore also provides electrical coupling to central conductive member 78 and a feed circuit, such as feed circuit 42 shown in FIG. 6. Of course the mounting post 72 could be made of non-conductive material and a separate means for electrically coupling the central conductive member 78 to a feed circuit may be provided.

**[0044]** Those of ordinary skill in the art will appreciate that certain dimensions of the balun column 70 may affect its operating performance. In general, each dielectric substrate 82a-82d has height  $h_1$ , width  $w_2$ , and thickness  $d_1$ , as shown. The central conductive member 78 has a width  $w_1$  and generally the same height  $h_1$  (not including mounting post 72) as each dielectric substrate 82a-82d. In some preferred embodiments,  $w_1$  is chosen to be 50 mils.,  $w_2$  is chosen to be 25 mils.,  $d_1$  is chosen to be 10 mil., and  $h_1$  is chosen to be 300 mils. It should be appreciated that, in general, the height  $h_1$  should be chosen based on the desired operating frequency range.

**[0045]** In one exemplary embodiment, the quad line balun includes coplanar microstrip transmission lines provided from Rogers RT/duroid 6010 PTFE ceramic laminate having a relative dielectric constant ( $\epsilon_r$ ) in the range of about 10.2 to about 10.9 and a loss tangent of about 0.0023. The laminate is provided having a conductive material disposed on opposing surfaces thereof. The conductive material may be provided as  $\frac{1}{2}$  oz. of rolled copper or electrodeposited (ED) copper, for example. The transmission lines are cut, etched or otherwise provided from a dielectric sheet, as double-sided strips, and then coupled to a central conductive member using a soldering technique or other suitable attachment technique. The transmission lines may be soldered to the central conductive member 78.

**[0046]** Such a balun construction results in two coplanar transmission line pairs which are highly isolated (in the electrical sense) and which are appropriate for feeding two antennas. This is due to the bulky central conductor and a high-dielectric constant dielectric material used for line filling; furthermore, the lines are isolated by air gaps. It will further be appreciated that balun column 70 provides a higher isolation between two turnstile antenna elements than prior art baluns or feeds since two pairs of feeding transmission lines are shielded.

**[0047]** As illustrated in FIGS. 5 and 5A, the balun transmission lines may each have a characteristic impedance of about 30 Ohms per port, assuming that opposite are fed out of phase by 180 deg. This means a 60 Ohm impedance per one dipole antenna that is fed with two ports in series, which should provide a good impedance match to a stacked bowtie radiator such as that discussed in conjunction with Figs 1-3B above. Moreover, a balun constructed as described is suitable for operation over the L-Band, S-band, C-band, and X-band frequency ranges, without changing balun dimensions (excepting length).

**[0048]** Referring now to FIGS. 6 and 6A in which like structures of FIGS. 4 and 4A are provided having like reference designations, a feed circuit 42 is disposed (e.g. printed) onto a surface of a PCB 40, as shown. The feed circuit 42 includes four feed lines 42a-42d which can each be electrically coupled one of four coplanar transmission line conductors provided upon a quad-line balun column, such as conductors 80a-80d in FIG. 5. The feed circuit 42 also includes a center conductor 48 which can be electrically coupled to a quad-line balun column central conductive member, such as member 78 in FIG. 5. Such electrical couplings can be made, for example, using a solder reflow technique to form a conductive solder joints. The feed lines 42a-42d and center conductor 48 can be provided upon the PCB using either a subtractive or an additive PCB manufacturing process.

**[0049]** The PCB 40 may provide or be electrically coupled to additional RF circuitry (not shown), such as an RF distribution circuit. The feed lines 42a-42d may be electrically coupled to the additional RF circuitry via holes 44a-44d (hole 42a not shown in FIG. 6A). It should be appreciated that the holes 44a-44d may be provided in the PCB 40 via a machining operating (e.g. via a punching technique, a milling technique, or via any other technique known to those of ordinary skill in the art).

**[0050]** In a preferred embodiment, PCB 40 also includes a balun post receptor which accepts a balun column post, such as post 72 in FIG. 5, to secure the balun column to the PCB. For ease of reference, the center connector 48 may herein also be referred to as the balun post receptor 48. The balun post receptor 48 may be a recess which extends entirely through the PCB 40 (e.g. as a through hole) or may extend only partway into the PCB. The balun post receptor 48 may be provided in the PCB 40 by any process known to those of ordinary skill in the art. In a preferred embodiment, the balun column post 72 and post receptor 48 have complimentary cross-sectional shapes such that the balun column post mates with the receptor, thereby securing the balun 70 (in FIG. 5) to the PCB 40. In some embodiments, the post 72 may be knurled and may be press fit into receptor 48. It should be appreciated that other means, including but not limited to fasteners and brackets, may also be used to secure a balun column to the PCB 40.

**[0051]** Referring now to FIG. 7, three reference planes and three separate microwave network elements of the complete quad-line balun-based antenna radiator are shown. The feeding balun for only one antenna element is shown. For a symmetric antenna load with input impedance,  $Z_D$ , the antenna model in FIG. 7 simplifies as shown in FIG. 8.

**[0052]** Referring now to FIG. 8, a block diagram of a complete quad-line balun-based antenna radiator with a symmetric antenna load is shown. It should be noted that to promote clarity in the drawing, the balun for only one antenna element is shown.

**[0053]** It should be noted that using the delay line on one port (e.g. port 1c in FIG. 8) already introduces asymmetry into the setup. Such asymmetry may be taken into account via a power divider model.

**[0054]** The power divider may be provided as either a T-divider or a Wilkinson power divider.

**[0055]** The model of the quad line balun column is that of a transmission line with termination impedance  $Z_T = Z_D/2$ .

$$Z_{in} = Z_0 \frac{Z_T + jZ_0 \tan \beta L}{Z_0 + jZ_T \tan \beta L} \quad \text{Equation 1}$$

in which:

L is a length of the quad line balun length;

$Z_0$  is the characteristic impedance of the quad line balun;

$Z_T$  is the termination impedance of the quad line balun;

Similarly, the ratio of input voltage  $V_{in}$  to output voltage  $V_T$  of the quad line balun, is found from the ABCD matrix of a two-port network, in the form,

$$\frac{V_{in}}{V_T} = \cos \beta L + j \frac{Z_0}{Z_T} \sin \beta L \quad \text{Equation 2}$$

**[0056]** For the phase shifter, a simple  $\lambda/2$  delay line may be used, whose transmission line model is also given by Equations 1 and 2.

**[0057]** Referring now to FIGS. 9-9C in which like structures are provided having like reference designations throughout the several views, an antenna array assembly 96 (also sometimes referred to herein as antenna array 96, array antenna 96, or more simply array 96) is shown in various stages of an assembly process, described hereinbelow.

**[0058]** Referring now to FIGS. 9B and 9C, antenna array 96 comprises a plurality of unit cells, here twelve (12) unit cells arranged in a 2x6 rectangular lattice shape. Each of unit cells may be the same as or similar to the unit cell described above in conjunction with FIG. 4 and includes a balun column 92, a stacked bowtie antenna element 94, and a support structure 90a. Each support structure 90a includes two openings at opposing ends.

**[0059]** In the preferred embodiment show in FIGS. 9-9C, the plurality of unit cell support structures 90a are provided by a single "egg crate" support structure 90. In one embodiment, the egg crate 90 is formed via an injection molding technique, however it should be appreciated that other fabrication techniques can also be used. The egg crate 90 may be bonded to a PCB (not shown in FIGS. 9-9C) having a plurality of feed circuits. The feed circuits may be arranged on the PCB such that, when the egg crate 90 is disposed over the PCB, each feed circuit is exposed through one opening of a corresponding support structure 90a.

**[0060]** The array 96 is provided having a length L, a width W and a thickness T. In one particular embodiment, for

operation in the X-band frequency range, the array 96 is provided having 8 rows and 16 columns. It should be appreciated that array 96 may be used as a subarray in a larger array structure provided form a plurality of such subarrays 96.

**[0061]** It should further be appreciated that although FIGS. 9-9C illustrate an exemplary array shape and array lattice geometry, array shapes other than rectangular or substantially rectangular shapes could also be used. For example, circular, elliptical or other regular or even non-regular shapes may be used. It should also be appreciated that array geometries other than rectangular or triangular may also be used. It should be noted that although the array is here shown having a square shape and a particular number of antenna elements, an antenna array having any array shape and/or physical size or any number of antenna elements may also be used. The array shape and/or physical size may be determined by a number of factors, including bandwidth requirements, polarization requirements, power requirements, and/or desired scan volume. One of ordinary skill in the art will thus appreciate that the concepts, structures and techniques described herein are applicable to various sizes and shapes of antennas arrays and that any number of antenna elements may be used.

**[0062]** In some embodiments, a radome may be disposed over the array 96 to protect it from weather and/or conceal it from view.

**[0063]** Having described the structure of antenna array 96, an exemplary process of assembling such an array will now be discussed. First, as shown in FIG. 9, the empty egg crate 90 has a plurality of support structures 90a and may be bounded to a PCB having a plurality of feed circuits (not shown). Next, as shown in FIG. 9A, a balun column 92 having a post at one end (such as balun column 70 in FIG. 5) is inserted through each support structure 90a and into a balun column post receptor provided as part of a corresponding one of the feed circuits. Next, an antenna element 94 having an opening through which the balun column can be inserted (such as antenna element 14 in FIG. 1) is placed over the balun column 92 and brought down to rest upon the support structure 90a. Next, solder paste can be applied at each electrical connection, including between the balun column 92 and the feed circuit, and between the balun column 92 and the antenna element 94. Finally, the entire array assembly 96 can be run through a solder re-flow oven to cure the electrical connections. It should be appreciated that array 96 assembly process may proceed in a different order from than described hereinabove. For example, the antenna assembly 94 may be placed upon the support structure 90a before the balun column is inserted.

**[0064]** Those having ordinary skill in the art should appreciate that the integrated antenna element design, the scalable phased array antenna architecture, and the assembly techniques describe above allow commercial fabrication and assembly processes to be leveraged, thereby reducing recurring engineering costs. For example, the stacked bowtie antenna element can be fabricated using injection molding and copper plating/etching techniques. The balun column and coplanar transmission lines can be mass produced using a cast and automated soldering techniques. Further, automated assembly techniques, such as commercial pick-and-place robots and solder re-flow lines, may be used to easily and inexpensively assemble unit cells, sub-array assemblies, and entire phased array antennas. Moreover, the design and architectures herein described can easily be adapted to a wide range of frequency bands, including dual-band radars, and are polarization diverse. Thus, the phased array antenna architecture and fabrication technique described herein offers a cost effective solution for design, fabrication, and assembly of phased arrays antennas that can be used in a wide variety of radar missions or communication missions for ground, sea and airborne platforms.

**[0065]** Variations, modifications, and other implementations of what is described herein can occur to those of ordinary skill in the art without departing from the scope of the concepts as described and claimed. It is felt, therefore, that the scope of protection should not be limited to or by the disclosed embodiments, but rather, should be limited only by the scope of the appended claims.

## Claims

1. An integrated antenna element (10) comprising:  
an antenna element (14) comprising:

a dielectric substrate (20c) having a generally pyramidal shape with a feed point provided at the center, the substrate (20c) having an inner surface and an outer surface;

at least two inner conductors (20b) disposed over the inner surface of the substrate (20c), each of the inner conductors (20b) having a generally triangular shape with one vertex terminating proximate the feed point;  
**characterised in that** the antenna element further comprises:

at least two outer conductors (20a) disposed over the outer surface of said substrate (20c), each of the outer conductors (20a) opposite to at least one inner conductor (20b).

2. The integrated antenna element (10) of Claim 1 having at least four inner conductors (20b) disposed over the inner surface of said dielectric substrate (20c) and at least four outer conductors (20a) disposed over the outer surface

of the dielectric substrate (20c) wherein said four outer conductors (20a) are disposed to be parasitically coupled to at least one of said four inner conductors (20b).

3. The integrated antenna element (10) of Claim 1 wherein the surface area of the outer conductors (20a) is less than the surface area of any corresponding ones of the inner conductors (20b).

4. The integrated antenna element (10) of Claim 1 further comprising:  
a quad-line vertical balun column (70) having an end electrically coupled to the feed point of the antenna element (10), the quad-line vertical balun column (70) comprising:

a central member (13a) having four continuously connected conductive surfaces and first and second opposing conductive ends, the central member having a square cross-sectional shape;

a first dielectric balun slab (82a) having a first surface disposed over a first conductive surface of the central member (78) and wherein a second opposing surface of the first balun slab (82a) has a respective conductor (80a) disposed thereon;

a second dielectric balun slab (82b) having a first surface disposed over a second conductive surface of the central member (78) and wherein a second opposing surface of the second dielectric slab (82b) has a respective conductor (80b) disposed thereon;

a third dielectric balun slab (82c) having a first surface disposed over a third conductive surface of the central member (78) and wherein a second opposing surface of the balun slab (82c) has a respective conductor (80c) disposed thereon; and

a fourth dielectric balun slab (82d) having a first surface disposed over a fourth conductive surface of the central member (78) and wherein a second opposing surface of the fourth balun slab (82d) has a respective conductor (80d) disposed thereon.

5. The integrated antenna element (10) of Claim 4 wherein the antenna element (14) has an opening to receive the balun column (70).

6. The integrated antenna element (10) of Claim 4 wherein the inner conductors (20b) are fed by the balun column (70) and the outer conductors (20a) are parasitically coupled to the corresponding ones of the inner conductors (20b).

7. An antenna assembly comprising:

a. a circuit board (40);

b. a feed circuit (42) disposed on one surface of the circuit board (40);

c. the antenna element of claim 1;

d. a quad-line vertical balun column (70) having a first end electrically coupled to the feed circuit (42) and a second end electrically coupled to the antenna (14) feed point, the quad-line vertical balun column (70) comprising:

i. a central member (78) having four conductive surfaces and first and second opposing conductive ends;

ii. a first dielectric balun slab (82a) having a first surface disposed over a first conductive surface of the central member (78) and wherein a second opposing surface of the first balun slab (82a) has a respective feed conductor (80a) disposed thereon;

iii. a second dielectric balun slab (82b) having a first surface disposed over a second conductive surface of the central member (78) and wherein a second opposing surface of the second balun slab (82b) has a respective feed conductor (80b) disposed thereon;

iv. a third dielectric balun slab (82c) having a first surface disposed over a third conductive surface of the central member (78) and wherein a second opposing surface of the third balun slab (82c) has a respective feed conductor (80c) disposed thereon, and

v. a fourth dielectric balun slab (82d) having a first surface disposed over a fourth conductive surface of the central member (78) and wherein a second opposing surface of the fourth balun slab (82d) has a respective feed conductor (80d) disposed thereon.

8. The antenna assembly of Claim 7 wherein each feed circuit comprises:

a. a ground conductor coupled to each balun central member conductive surface;

b. a first feed conductor (42a) coupled to first balun slab feed conductor (80a);

- c. a second feed conductor (42b) coupled to second balun slab feed conductor (80b);
- d. a third feed conductor (42c) coupled to third balun slab feed conductor (80c); and
- e. a fourth feed conductor (42d) coupled to fourth balun slab feed conductor (80d).

9. The antenna assembly of Claim 7 wherein the feed circuit is a first of a plurality of feed circuits, the antenna element (94) is the first of a plurality of antenna elements, and the quad-line vertical balun column (92) is the first of a plurality of quad-line vertical balun columns, each of the quad-line vertical balun columns are electrically coupled to a corresponding feed circuit at one end and electrically coupled to a corresponding antenna element at the opposite end.

10. The antenna assembly of Claim 9 wherein the feed circuits are arranged in a two-dimensional array pattern on the circuit board (40).

11. The antenna assembly of Claim 7 further comprising a support structure (30) over which the antenna element (14) is disposed, wherein a first end of the balun column (70) is exposed through a first opening in the support structure (30) and a second end of said balun column (70) is exposed through a second opening in the support structure (30).

12. A method comprising:

coupling a first end of a quad-line vertical balun column (70) to a circuit board (40); and  
coupling a second end of the quad-line vertical balun column (70) to an antenna element (14), the antenna element (14) comprising:

a dielectric substrate (20c) having a generally pyramidal shape with a feed point provided at the center, the substrate (20c) having an inner surface and an outer surface;

at least two inner conductors (20b) disposed over the inner surface of the substrate (20c), each of the inner conductors (20b) having a generally triangular shape with one vertex terminating proximate the feed point; and

at least two outer conductors (20a) disposed over the outer surface of said substrate (20c), each of the outer conductors (20a) opposite to at least one inner conductor (20b).

13. The method of Claim 12 wherein first end of the balun column (70) is coupled to the circuit board (40) before second end of balun column (70) is coupled to the antenna element (14).

14. The method of Claim 12 wherein second end of the balun column (70) is coupled to the antenna element (14) before first end of balun column (70) is coupled to the circuit board (40).

15. The method of Claim 12 wherein the first end of the balun column (70) includes a post (72), the circuit board (40) provides a recess (48) capable of receiving the post (72), and the first end of the balun column (70) is coupled to the circuit board (40) by inserting the post (72) into the recess (48).

## Patentansprüche

1. Integriertes Antennenelement (10), das Folgendes umfasst:

ein Antennenelement (14), das Folgendes umfasst:

ein dielektrisches Substrat (20c), das eine im Wesentlichen Pyramidenform mit einem in der Mitte bereitgestellten Speisepunkt aufweist, wobei das Substrat (20c) eine Innenfläche und eine Außenfläche aufweist;

mindestens zwei innere Leiter (20b), die über der Innenfläche des Substrats (20c) angeordnet sind, wobei jeder der inneren Leiter (20b) eine im Wesentlichen Dreiecksform aufweist, wobei eine Spitze in der Nähe des Speisepunkts endet; **dadurch gekennzeichnet, dass** das Antennenelement ferner Folgendes umfasst:

mindestens zwei äußere Leiter (20a), die über der Außenfläche des Substrats (20c) bereitgestellt sind, wobei jeder der äußeren Leiter (20a) mindestens einem inneren Leiter (20b) gegenüberliegt.

2. Integriertes Antennenelement (10) nach Anspruch 1, das mindestens vier innere Leiter (20b), die über der Innenfläche des dielektrischen Substrats (20c) angeordnet sind, und mindestens vier äußere Leiter (20a), die über der Außenfläche des dielektrischen Substrats (20c) angeordnet sind, aufweist, wobei die vier äußeren Leiter (20a) derart angeordnet sind, dass sie an mindestens einen der vier inneren Leiter (20b) parasitisch gekoppelt sind.

3. Integriertes Antennenelement (10) nach Anspruch 1, wobei die Oberfläche der äußeren Leiter (20a) kleiner ist als die Oberfläche beliebiger entsprechender der inneren Leiter (20b).

4. Integriertes Antennenelement (10) nach Anspruch 1, das ferner Folgendes umfasst:  
eine vertikale Vierleitungsbalunsäule (70) mit einem Ende, das elektrisch an den Speisepunkt des Antennenelements (10) gekoppelt ist, wobei die vertikale Vierleitungsbalunsäule (12) Folgendes umfasst:

eine zentrale Komponente (13a) mit vier durchgehend verbundenen leitfähigen Flächen und einem ersten und einem zweiten gegenüberliegenden leitfähigen Ende, wobei die zentrale Komponente eine quadratische Querschnittsform aufweist;

eine erste dielektrische Balunplatte (82a) mit einer ersten Fläche, die über einer ersten leitfähigen Fläche der zentralen Komponente (78) angeordnet ist, und wobei eine zweite gegenüberliegende Fläche der ersten Balunplatte (82a) einen jeweiligen Leiter (80a) aufweist, der darauf angeordnet ist;

eine zweite dielektrische Balunplatte (82b) mit einer ersten Fläche, die über einer zweiten leitfähigen Fläche der zentralen Komponente (78) angeordnet ist, und wobei eine zweite gegenüberliegende Fläche der zweiten dielektrischen Platte (82b) einen jeweiligen Leiter (80b) aufweist, der darauf angeordnet ist;

eine dritte dielektrische Balunplatte (82c) mit einer ersten Fläche, die über einer dritten leitfähigen Fläche der zentralen Komponente (78) angeordnet ist, und wobei eine zweite gegenüberliegende Fläche der Balunplatte (82c) einen jeweiligen Leiter (80c) aufweist, der darauf angeordnet ist; und

eine vierte dielektrische Balunplatte (82d) mit einer ersten Fläche, die über einer vierten leitfähigen Fläche der zentralen Komponente (78) angeordnet ist, und wobei eine zweite gegenüberliegende Fläche der vierten Balunplatte (82d) einen jeweiligen Leiter (80d) aufweist, der darauf angeordnet ist.

5. Integriertes Antennenelement (10) nach Anspruch 4, wobei das Antennenelement (14) eine Öffnung zum Aufnehmen der Balunsäule (70) aufweist.

6. Integriertes Antennenelement (10) nach Anspruch 4, wobei die inneren Leiter (20b) vom Balunsäule (70) zugeführt werden und die äußeren Leiter (20a) parasitisch an die entsprechenden der inneren Leiter (20b) gekoppelt sind.

7. Antennenanordnung, die Folgendes umfasst:

a. eine Leiterplatte (40);

b. eine Speiseschaltung (42), die auf einer Fläche der Leiterplatte (40) angeordnet ist;

c. das Antennenelement nach Anspruch 1;

d. eine vertikale Vierleitungsbalunsäule (70) mit einem ersten Ende, das elektrisch an die Speiseschaltung (42) gekoppelt ist, und einem zweiten Ende, das elektrisch an den Speisepunkt der Antenne (14) gekoppelt ist, wobei die vertikale Vierleitungsbalunsäule (70) Folgendes umfasst:

i. eine zentrale Komponente (78) mit vier leitfähigen Flächen und einem ersten und einem zweiten gegenüberliegenden leitfähigen Ende;

ii. eine erste dielektrische Balunplatte (82a) mit einer ersten Fläche, die über einer ersten leitfähigen Fläche der zentralen Komponente (78) angeordnet ist, und wobei eine zweite gegenüberliegende Fläche der ersten Balunplatte (82a) einen jeweiligen Speiseleiter (80a) aufweist, der darauf angeordnet ist;

iii. eine zweite dielektrische Balunplatte (82b) mit einer ersten Fläche, die über einer zweiten leitfähigen Fläche der zentralen Komponente (78) angeordnet ist, und wobei eine zweite gegenüberliegende Fläche der zweiten Balunplatte (82b) einen jeweiligen Speiseleiter (80b) aufweist, der darauf angeordnet ist;

iv. eine dritte dielektrische Balunplatte (82c) mit einer ersten Fläche, die über einer dritten leitfähigen Fläche der zentralen Komponente (78) angeordnet ist, und wobei eine zweite gegenüberliegende Fläche der dritten Balunplatte (82c) einen jeweiligen Speiseleiter (80c) aufweist, der darauf angeordnet ist, und

v. eine vierte dielektrische Balunplatte (82d) mit einer ersten Fläche, die über einer vierten leitfähigen Fläche der zentralen Komponente (78) angeordnet ist, und wobei eine zweite gegenüberliegende Fläche der vierten Balunplatte (82d) einen jeweiligen Speiseleiter (80d) aufweist, der darauf angeordnet ist.

8. Antennenanordnung nach Anspruch 7, wobei jede Speiseschaltung Folgendes umfasst:

a. einen Erdungsleiter, der an jede leitfähige Fläche der zentralen Komponente des Baluns gekoppelt ist;

b. einen ersten Speiseleiter (42a), der an den Speiseleiter (80a) der ersten Balunplatte gekoppelt ist;

c. einen zweiten Speiseleiter (42b), der an den Speiseleiter (80b) der zweiten Balunplatte gekoppelt ist;

- d. einen dritten Speiseleiter (42c), der an den Speiseleiter (80c) der dritten Balunplatte gekoppelt ist; und
- e. einen vierten Speiseleiter (42d), der an den Speiseleiter (80d) der vierten Balunplatte gekoppelt ist.

9. Antennenanordnung nach Anspruch 7, wobei die Speiseschaltung eine erste einer Vielzahl von Speiseleitungen ist, das Antennenelement (94) das erste einer Vielzahl von Antennenelementen ist und die vertikale Vierleitungsbalunsäule (92) die erste einer Vielzahl von vertikalen Vierleitungsbalunsäulen ist, wobei jeder der vertikalen Vierleitungsbalunsäulen an einem Ende elektrisch an eine entsprechende Speiseschaltung gekoppelt ist und am gegenüberliegenden Ende elektrisch an ein entsprechendes Antennenelement gekoppelt ist.

10. Antennenanordnung nach Anspruch 9, wobei die Speiseschaltungen in einem zweidimensionalen Arraymuster auf der Leiterplatte (40) positioniert sind.

11. Antennenanordnung nach Anspruch 7, die ferner eine Stützstruktur (30) umfasst, über der das Antennenelement (14) angeordnet ist, wobei ein erstes Ende des Balunsäule (70) durch eine erste Öffnung in der Stützstruktur (30) exponiert ist und ein zweites Ende des Balunsäule (70) durch eine zweite Öffnung in der Stützstruktur (30) exponiert ist.

12. Verfahren, das Folgendes umfasst:

Koppeln eines ersten Endes einer vertikalen Vierleitungsbalunsäule (70) an eine Leiterplatte (40) und Koppeln eines zweiten Endes des vertikalen Vierleitungsbalunsäule (70) an ein Antennenelement (14), wobei das Antennenelement (14) Folgendes umfasst:

ein dielektrisches Substrat (20c), das eine im Wesentlichen Pyramidenform mit einem in der Mitte bereitgestellten Speisepunkt aufweist, wobei das Substrat (20c) eine Innenfläche und eine Außenfläche aufweist; mindestens zwei innere Leiter (20b), die über der Innenfläche des Substrats (20c) angeordnet sind, wobei jeder der inneren Leiter (20b) eine im Wesentlichen Dreiecksform aufweist, wobei eine Spitze in der Nähe des Speisepunkts endet; und mindestens zwei äußere Leiter (20a), die über der Außenfläche des Substrats (20c) bereitgestellt sind, wobei jeder der äußeren Leiter (20a) mindestens einem inneren Leiter (20b) gegenüberliegt.

13. Verfahren nach Anspruch 12, wobei das erste Ende des Balunsäule (70) an die Leiterplatte (40) gekoppelt wird, bevor das zweite Ende des Balunsäulen (70) an das Antennenelement (14) gekoppelt wird.

14. Verfahren nach Anspruch 12, wobei das zweite Ende des Balunsäule (70) an das Antennenelement (14) gekoppelt wird, bevor das erste Ende des Balunsäule (70) an die Leiterplatte (40) gekoppelt wird.

15. Verfahren nach Anspruch 12, wobei das erste Ende des Balunsäule (70) einen Pfosten (72) beinhaltet, die Leiterplatte (40) eine Ausnehmung (48) bereitstellt, die zum Aufnehmen des Pfostens (72) in der Lage ist, und das erste Ende des Balunsäule (70) durch Einsetzen des Pfostens (72) in die Ausnehmung (48) an die Leiterplatte (40) gekoppelt wird.

## Revendications

1. Élément d'antenne intégré (10) comprenant :  
un élément d'antenne (14) comprenant :

un substrat diélectrique (20c) ayant une forme généralement pyramidale avec un point d'alimentation disposé au centre, le substrat (20c) ayant une surface interne et une surface externe ;  
au moins deux conducteurs internes (20b) disposés sur la surface interne du substrat (20c), chacun des conducteurs internes (20b) ayant une forme généralement triangulaire avec un sommet se terminant à proximité du point d'alimentation ; **caractérisé en ce que** l'élément d'antenne comprend en outre :  
au moins deux conducteurs externes (20a) disposés sur la surface externe dudit substrat (20c), chacun des conducteurs externes (20a) étant opposé à au moins un conducteur interne (20b).

2. Élément d'antenne intégré (10) selon la revendication 1, ayant au moins quatre conducteurs internes (20b) disposés sur la surface interne dudit substrat diélectrique (20c) et au moins quatre conducteurs externes (20a) disposés sur

la surface externe du substrat diélectrique (20c), dans lequel lesdits quatre conducteurs externes (20a) sont disposés de sorte à être couplés de manière parasite à au moins l'un desdits quatre conducteurs internes (20b).

3. Élément d'antenne intégré (10) selon la revendication 1, dans lequel l'aire superficielle des conducteurs externes (20a) est inférieure à l'aire superficielle de n'importe quels conducteurs internes correspondants des conducteurs internes (20b).

4. Élément d'antenne intégré (10) selon la revendication 1, comprenant en outre :  
une colonne de symétriseur vertical à lignes quad (70) ayant une extrémité couplée électriquement au point d'alimentation de l'élément d'antenne (10), la colonne de symétriseur vertical à lignes quad (70) comprenant :

un élément central (13a) ayant quatre surfaces conductrices raccordées de manière continue et des première et seconde extrémités conductrices opposées, l'élément central ayant une forme carrée en coupe transversale ;  
une première plaque diélectrique de symétriseur (82a) ayant une première surface disposée sur une première surface conductrice de l'élément central (78) et dans lequel une seconde surface opposée de la première plaque de symétriseur (82a) comporte un conducteur respectif (80a) disposé sur cette dernière ;  
une deuxième plaque diélectrique de symétriseur (82b) ayant une première surface disposée sur une deuxième surface conductrice de l'élément central (78) et dans lequel une seconde surface opposée de la deuxième plaque de symétriseur (82b) comporte un conducteur respectif (80b) disposé sur cette dernière ;  
une troisième plaque diélectrique de symétriseur (82c) ayant une première surface disposée sur une troisième surface conductrice de l'élément central (78) et dans lequel une seconde surface opposée de la plaque de symétriseur (82c) comporte un conducteur respectif (80c) disposé sur cette dernière ; et  
une quatrième plaque diélectrique de symétriseur (82d) ayant une première surface disposée sur une quatrième surface conductrice de l'élément central (78) et dans lequel une seconde surface opposée de la quatrième plaque de symétriseur (82d) comporte un conducteur respectif (80d) disposé sur cette dernière.

5. Élément d'antenne intégré (10) selon la revendication 4, dans lequel l'élément d'antenne (14) comportant une ouverture pour recevoir la colonne de symétriseur (70).

6. Élément d'antenne intégré (10) selon la revendication 4, dans lequel les conducteurs internes (20b) sont alimentés par la colonne de symétriseur (70) et les conducteurs externes (20a) sont couplés de manière parasite aux conducteurs internes correspondants des conducteurs internes (20b).

7. Ensemble antenne comprenant :

a. une carte de circuit imprimé (40) ;  
b. un circuit d'alimentation (42) disposé sur une seule surface de la carte de circuit imprimé (40) ;  
c. l'élément d'antenne selon la revendication 1 ;  
d. une colonne de symétriseur vertical à lignes quad (70) ayant une première extrémité couplée électriquement au circuit d'alimentation (42) et une seconde extrémité couplée électriquement au point d'alimentation d'antenne (14), la colonne de symétriseur vertical à lignes quad (70) comprenant :

i. un élément central (78) ayant quatre surfaces conductrices et des première et seconde extrémités conductrices opposées ;  
ii. une première plaque diélectrique de symétriseur (82a) ayant une première surface disposée sur une première surface conductrice de l'élément central (78) et dans lequel une seconde surface opposée de la première plaque de symétriseur (82a) comporte un conducteur d'alimentation respectif (80a) disposé sur cette dernière ;  
iii. une deuxième plaque diélectrique de symétriseur (82b) ayant une première surface disposée sur une deuxième surface conductrice de l'élément central (78) et dans lequel une seconde surface opposée de la deuxième plaque de symétriseur (82b) comporte un conducteur d'alimentation respectif (80b) disposé sur cette dernière ;  
iv. une troisième plaque diélectrique de symétriseur (82c) ayant une première surface disposée sur une troisième surface conductrice de l'élément central (78) et dans lequel une seconde surface opposée de la troisième plaque de symétriseur (82c) comporte un conducteur d'alimentation respectif (80c) disposé sur cette dernière ; et  
v. une quatrième plaque diélectrique de symétriseur (82d) ayant une première surface disposée sur une quatrième surface conductrice de l'élément central (78) et dans lequel une seconde surface opposée de

la quatrième plaque de symétriseur (82d) comporte un conducteur d'alimentation respectif (80d) disposé sur cette dernière.

8. Ensemble antenne selon la revendication 7, dans lequel chaque circuit d'alimentation comprend :

- a. un conducteur de mise à la terre couplé à chaque surface conductrice d'élément central de symétriseur ;
- b. un premier conducteur d'alimentation (42a) couplé à un premier conducteur d'alimentation de plaque de symétriseur (80a) ;
- c. un deuxième conducteur d'alimentation (42b) couplé à un deuxième conducteur d'alimentation de plaque de symétriseur (80b) ;
- d. un troisième conducteur d'alimentation (42c) couplé à un troisième conducteur d'alimentation de plaque de symétriseur (80c) ; et
- e. un quatrième conducteur d'alimentation (42d) couplé à un quatrième conducteur d'alimentation de plaque de symétriseur (80d).

9. Ensemble antenne selon la revendication 7, dans lequel le circuit d'alimentation est un premier circuit d'alimentation d'une pluralité de circuits d'alimentation, l'élément d'antenne (94) est le premier élément d'antenne d'une pluralité d'éléments d'antenne et la colonne de symétriseur vertical à lignes quad (92) est la première colonne de symétriseur vertical à lignes quad d'une pluralité de symétriseurs verticaux à lignes quad, chacun des colonnes symétriseurs verticaux à lignes quad est couplé électriquement à un circuit d'alimentation correspondant au niveau d'une extrémité et couplé électriquement à un élément d'antenne correspondant au niveau de l'extrémité opposée.

10. Ensemble antenne selon la revendication 9, dans lequel les circuits d'alimentation sont agencés selon un motif de réseau bidimensionnel sur la carte de circuit imprimé (40).

11. Ensemble antenne selon la revendication 7, comprenant en outre une structure de support (30) sur laquelle l'élément d'antenne (14) est disposé, dans lequel une première extrémité de la colonne symétriseur (70) est exposée à travers une première ouverture dans la structure de support (30) et une seconde extrémité de ladite colonne symétriseur (70) est exposée à travers une seconde ouverture dans la structure de support (30).

12. Procédé consistant :

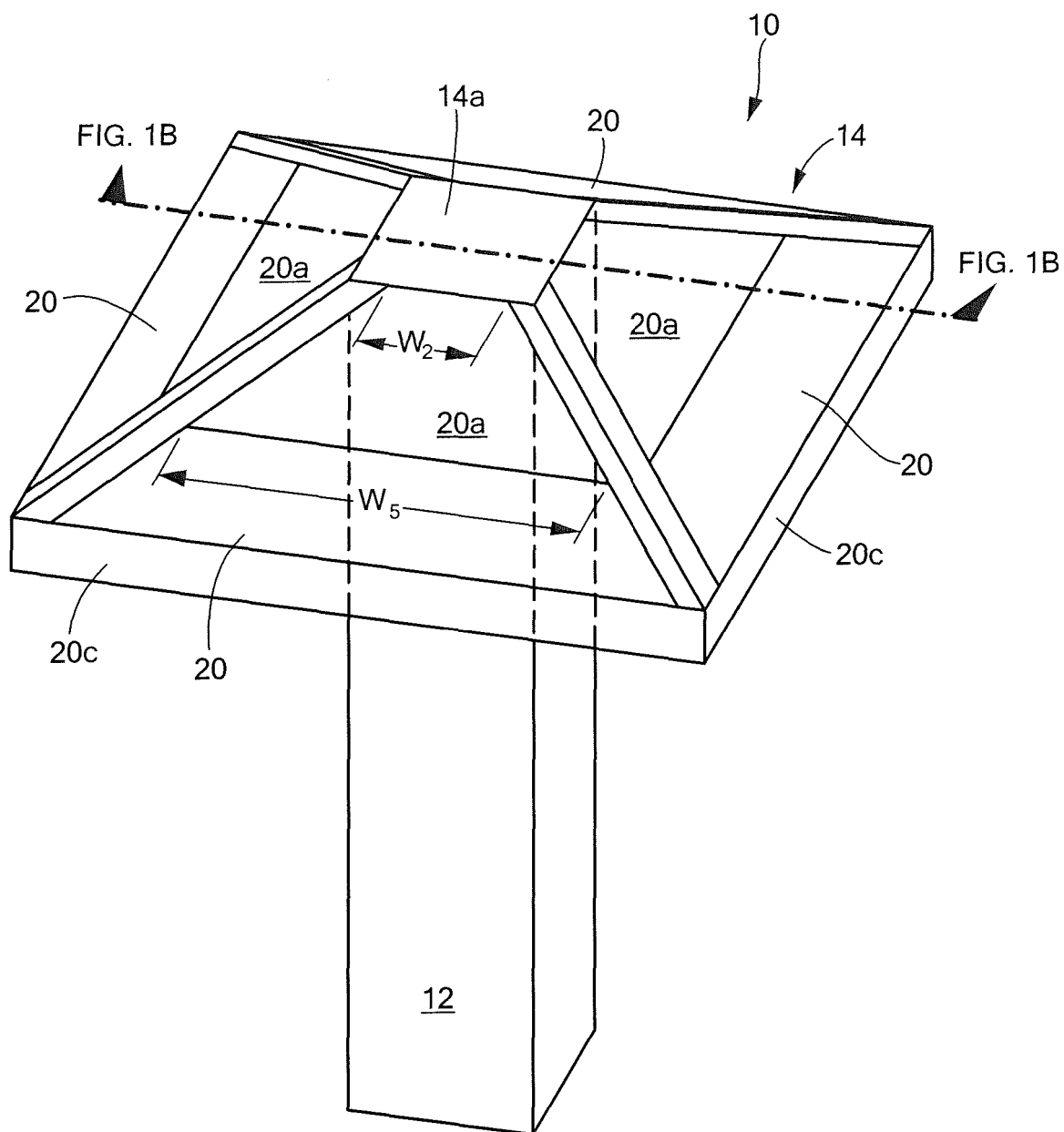
- à coupler une première extrémité d'une colonne de symétriseur vertical à lignes quad (70) à une carte de circuit imprimé (40) ; et
- à coupler une seconde extrémité de la colonne symétriseur vertical à lignes quad (70) à un élément d'antenne (14), l'élément d'antenne (14) comprenant :

- un substrat diélectrique (20c) ayant une forme généralement pyramidale avec un point d'alimentation disposé au centre, le substrat (20c) ayant une surface interne et une surface externe ;
- au moins deux conducteurs internes (20b) disposés sur la surface interne du substrat (20c), chacun des conducteurs internes (20b) ayant une forme généralement triangulaire avec un sommet se terminant à proximité du point d'alimentation ; et
- au moins deux conducteurs externes (20a) disposés sur la surface externe dudit substrat (20c), chacun des conducteurs externes (20a) étant opposé à au moins un conducteur interne (20b).

13. Procédé selon la revendication 12, dans lequel une première extrémité de la colonne symétriseur (70) est couplée à la carte de circuit imprimé (40) avant qu'une seconde extrémité de la colonne symétriseur (70) ne soit couplée à l'élément d'antenne (14).

14. Procédé selon la revendication 12, dans lequel une seconde extrémité de la colonne symétriseur (70) est couplée à l'élément d'antenne (14) avant que la première extrémité de la colonne symétriseur (70) ne soit couplée à la carte de circuit imprimé (40).

15. Procédé selon la revendication 12, dans lequel la première extrémité de la colonne symétriseur (70) comprend un montant (72), la carte de circuit imprimé (40) fournit un évidement (48) qui peut recevoir le montant (72) et la première extrémité de la colonne symétriseur (70) est couplée à la carte de circuit imprimé (40) en insérant le montant (72) dans l'évidement (48) .



**FIG. 1**

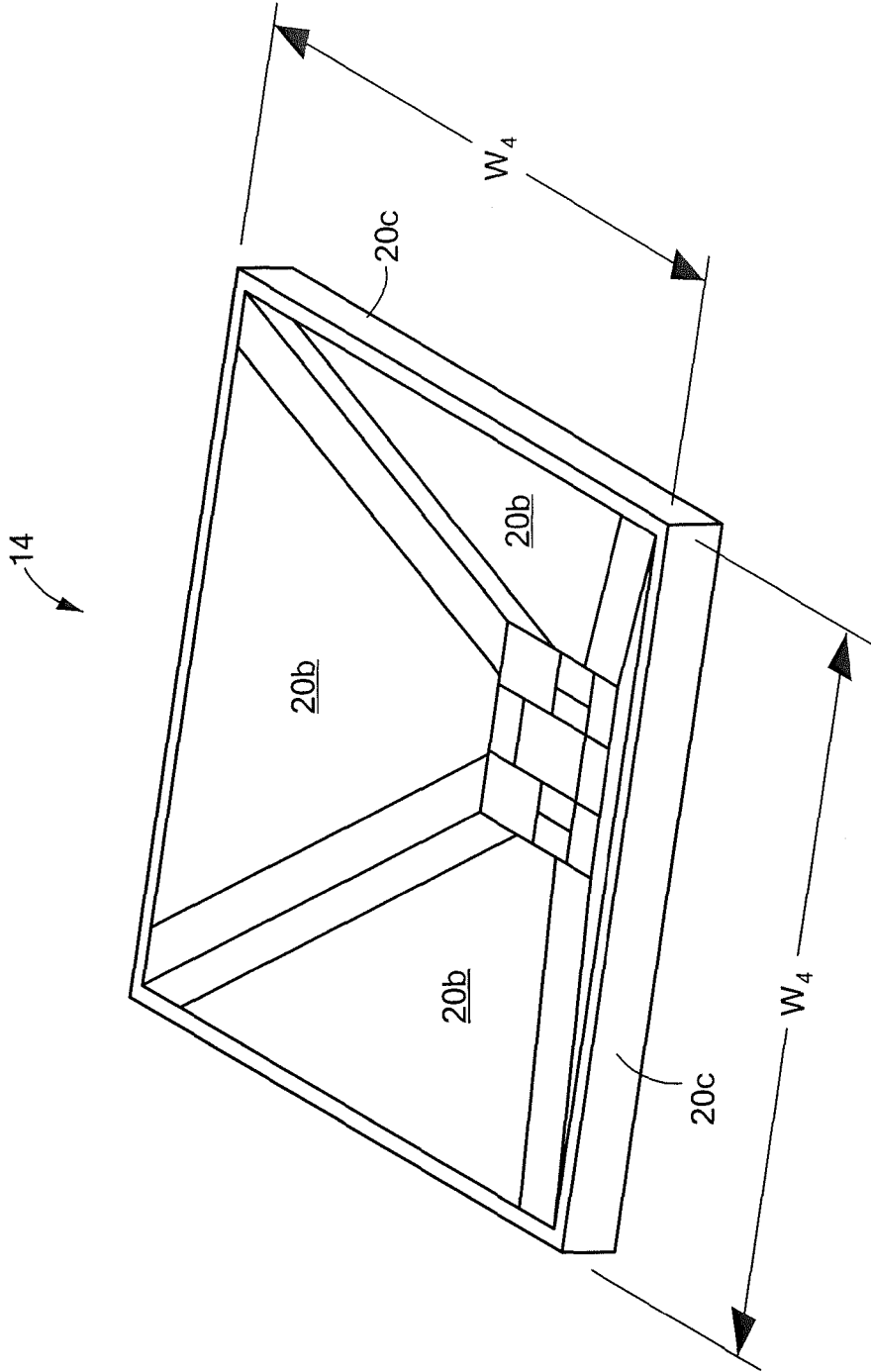
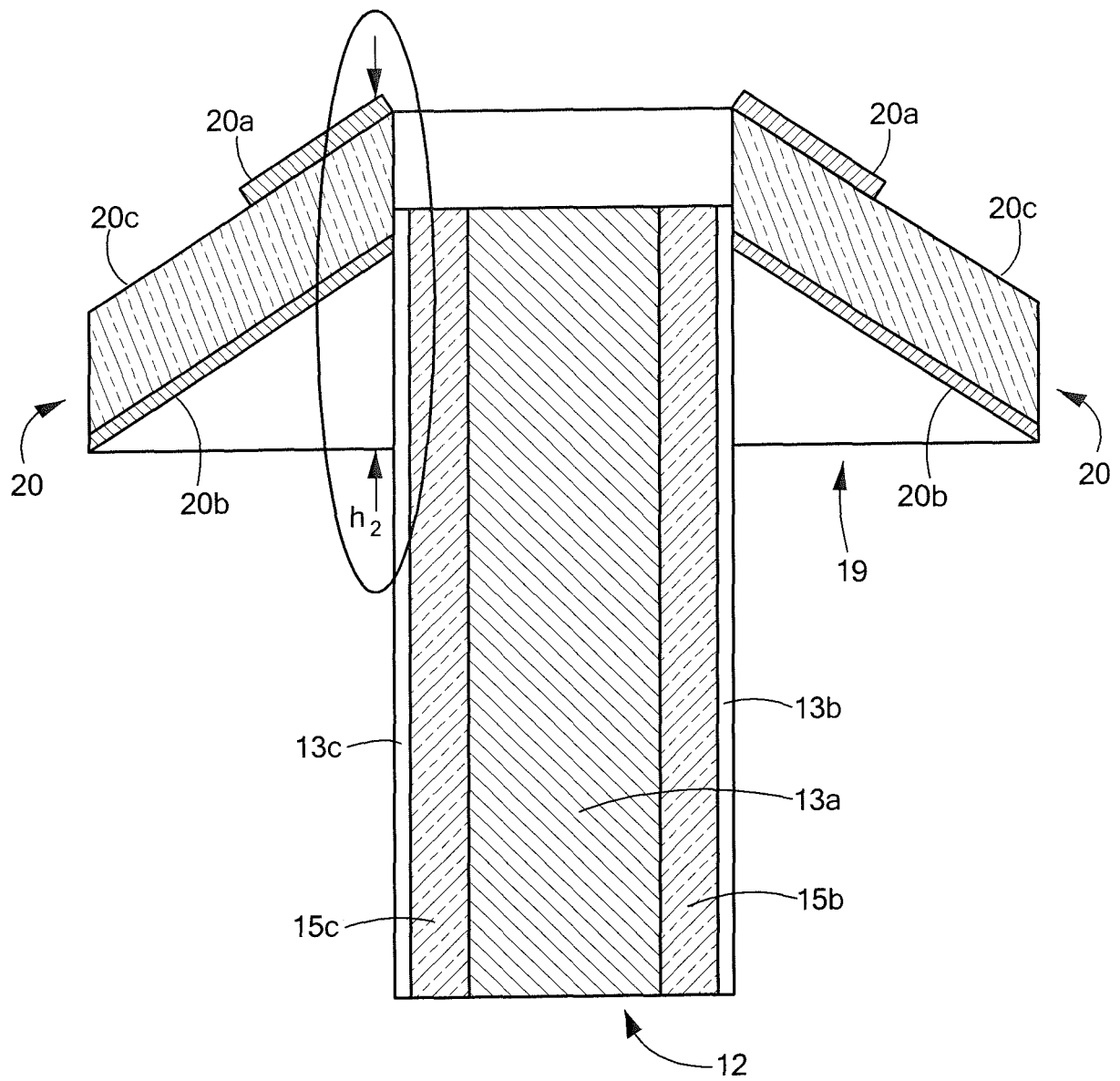


FIG. 1A



**FIG. 1B**

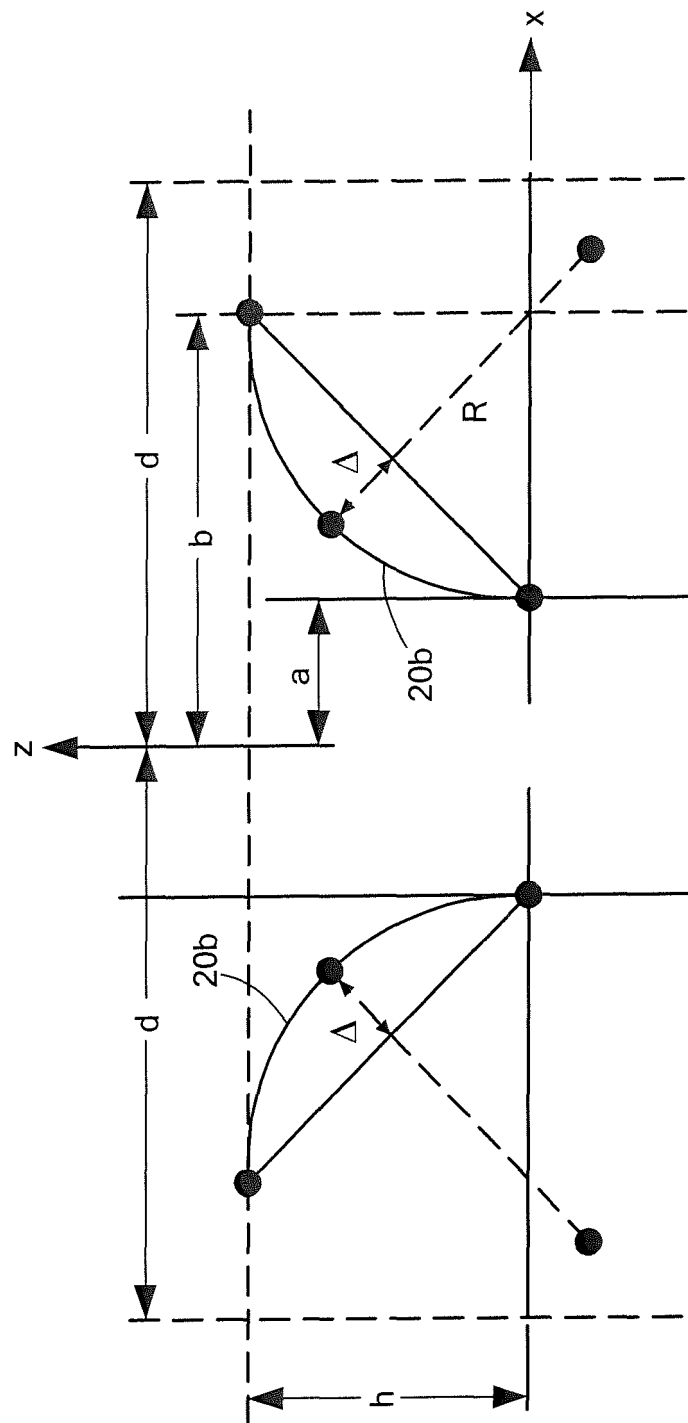
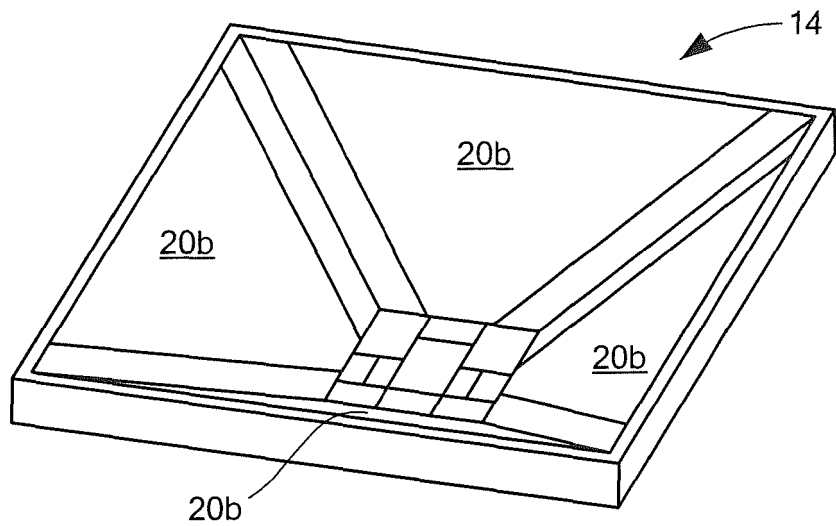
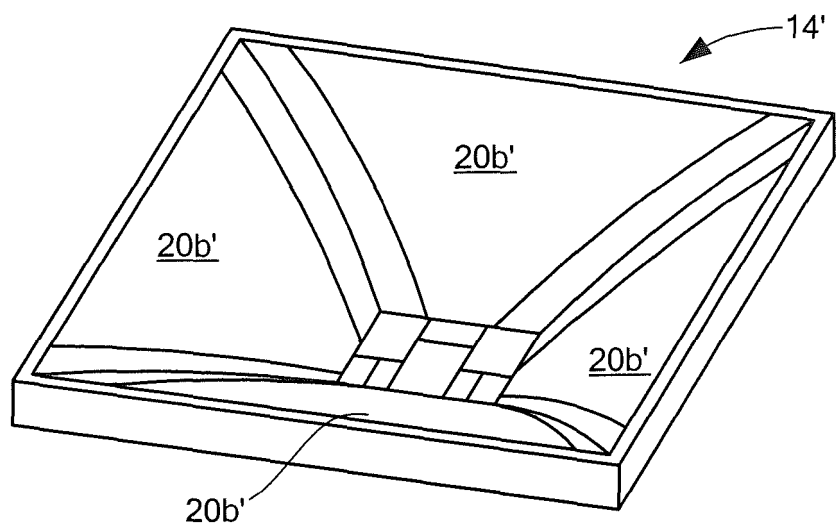


FIG. 2

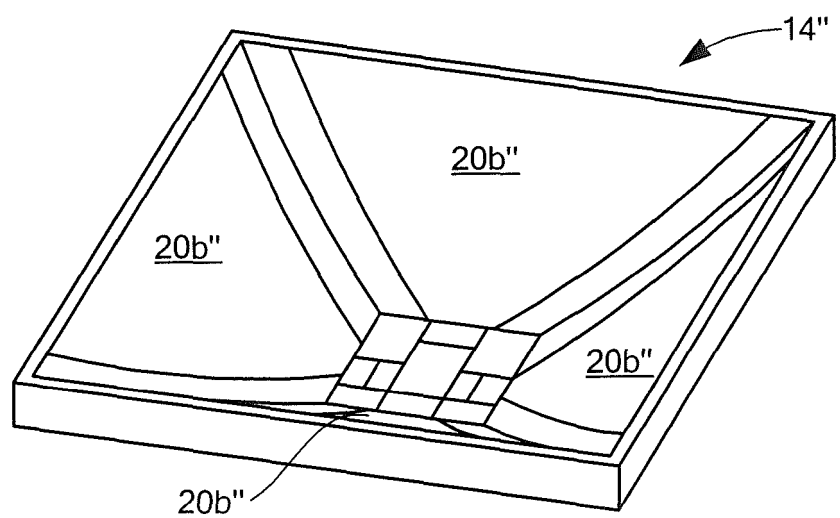
**FIG. 3**

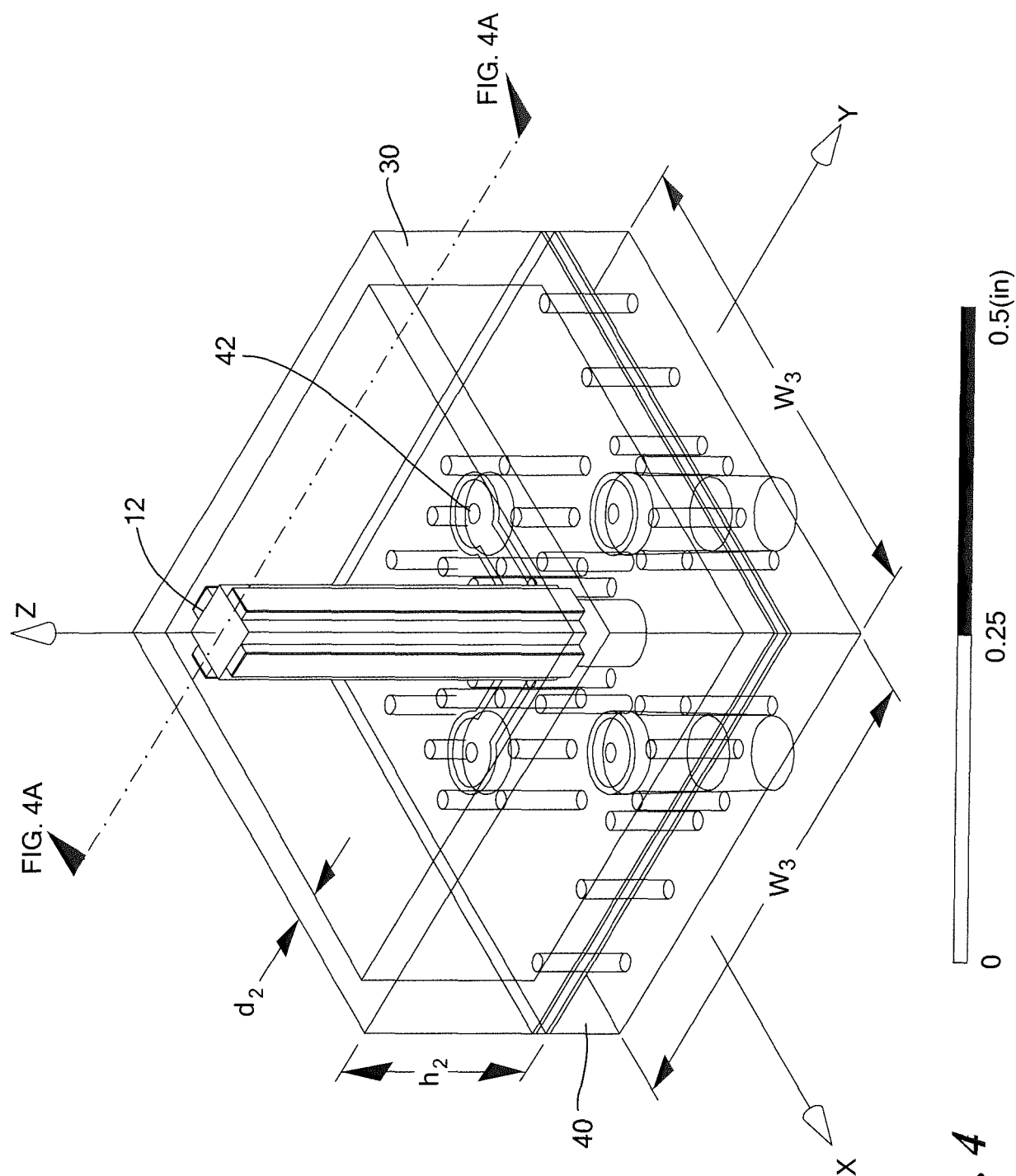


**FIG. 3A**



**FIG. 3B**





**FIG. 4**

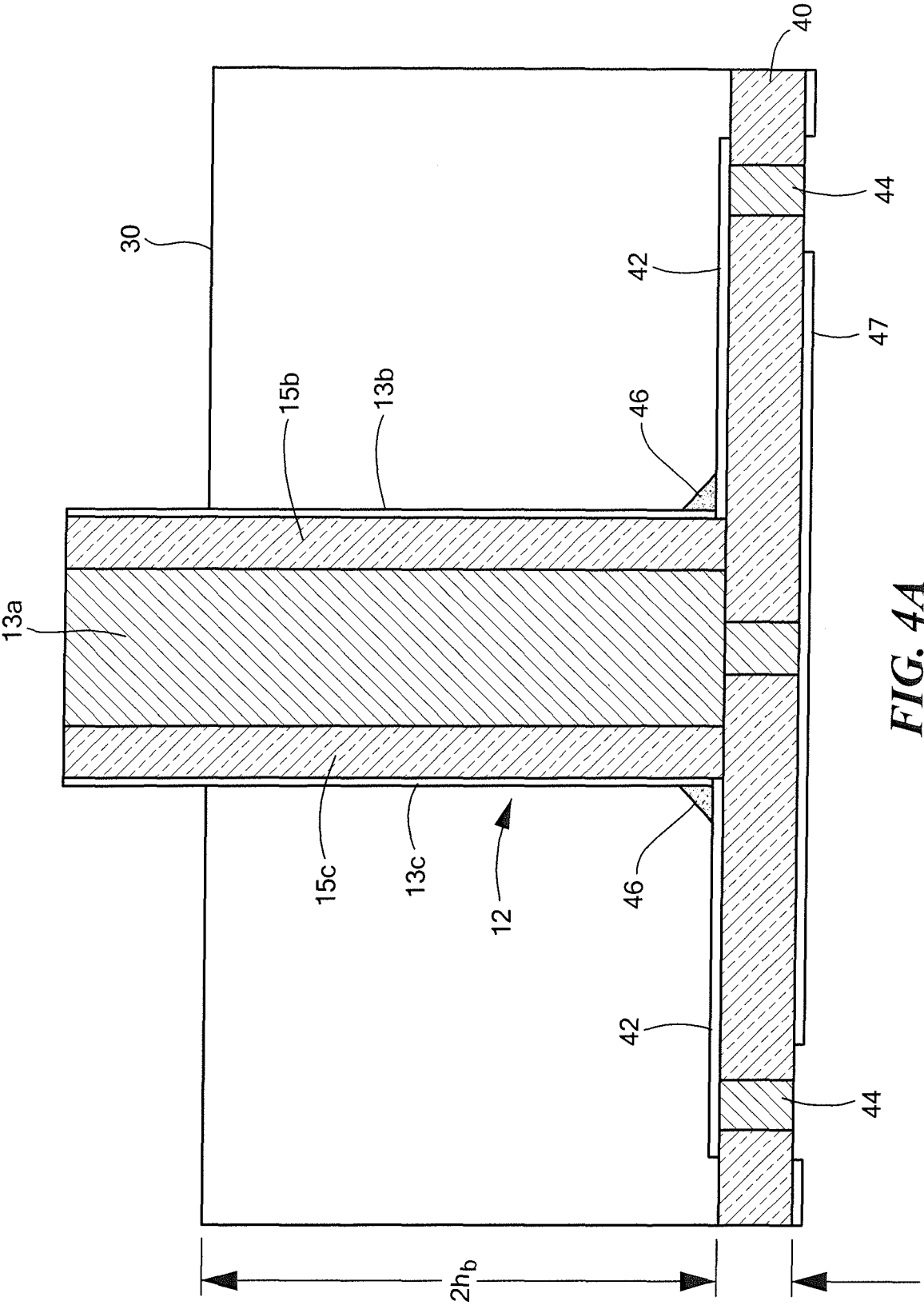


FIG. 4A

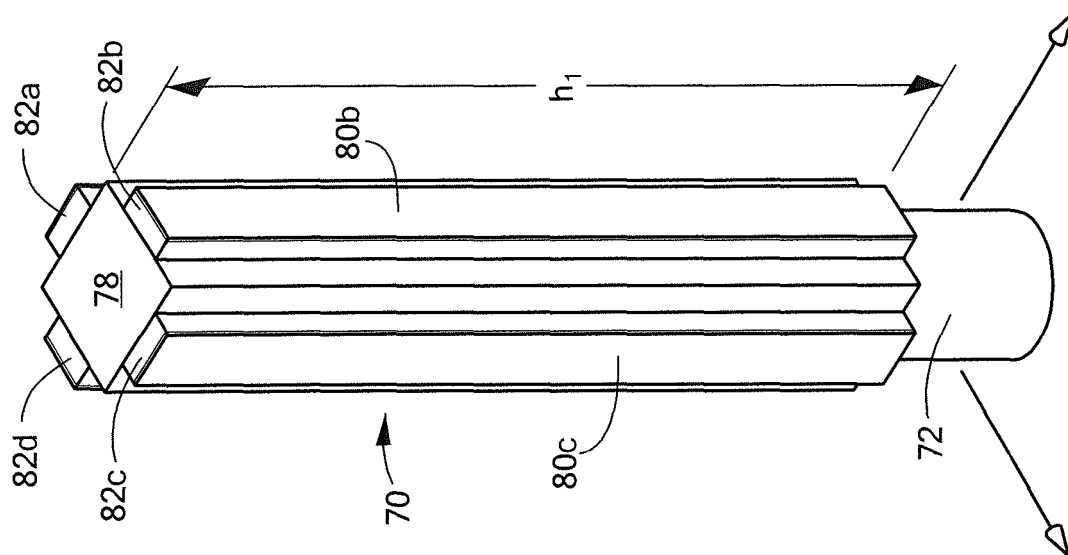


FIG. 5

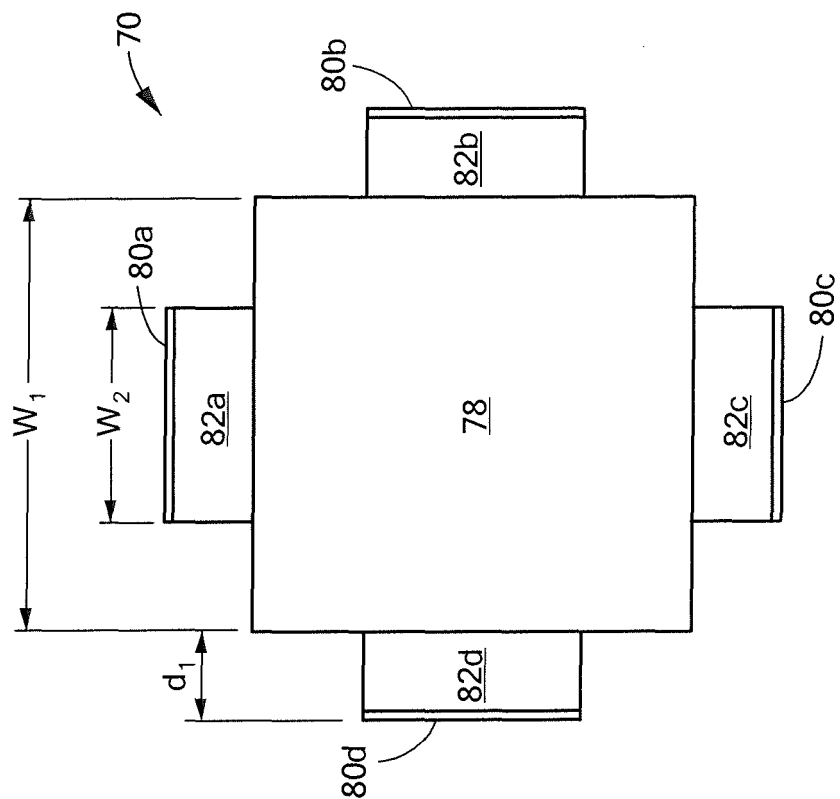
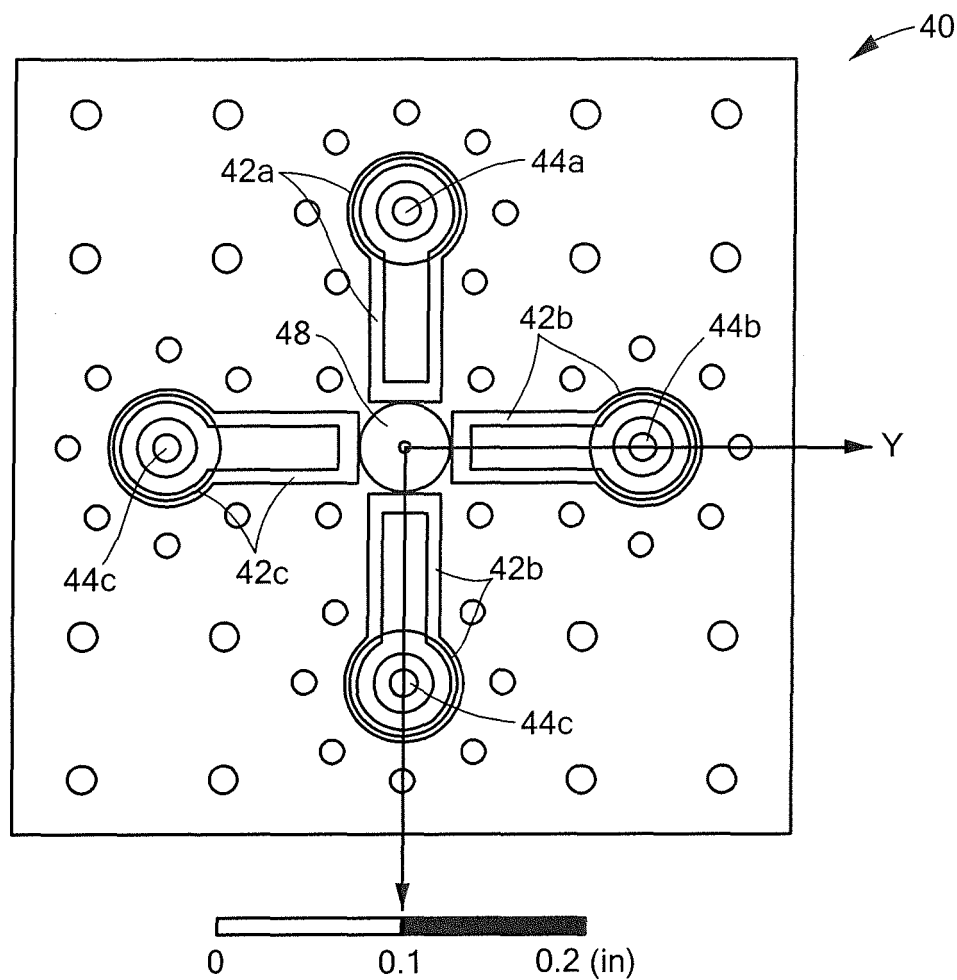
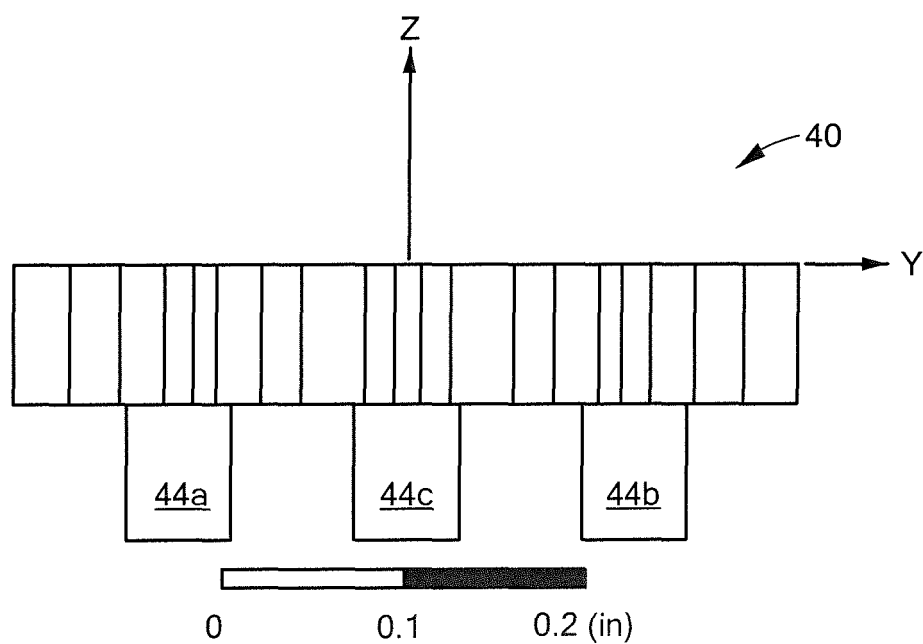


FIG. 5A

**FIG. 6**



**FIG. 6A**



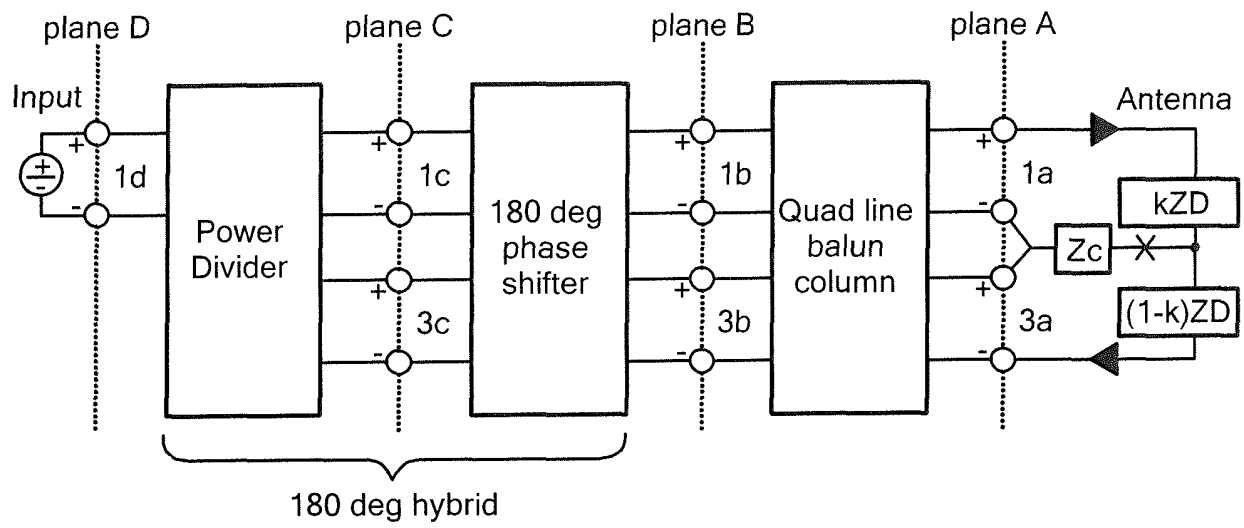


FIG. 7

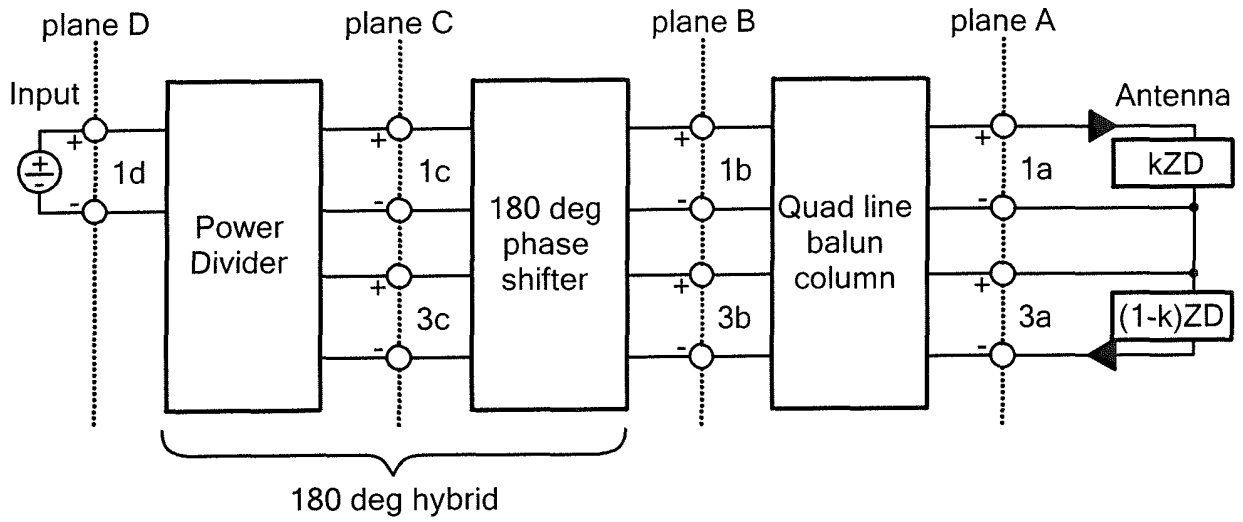
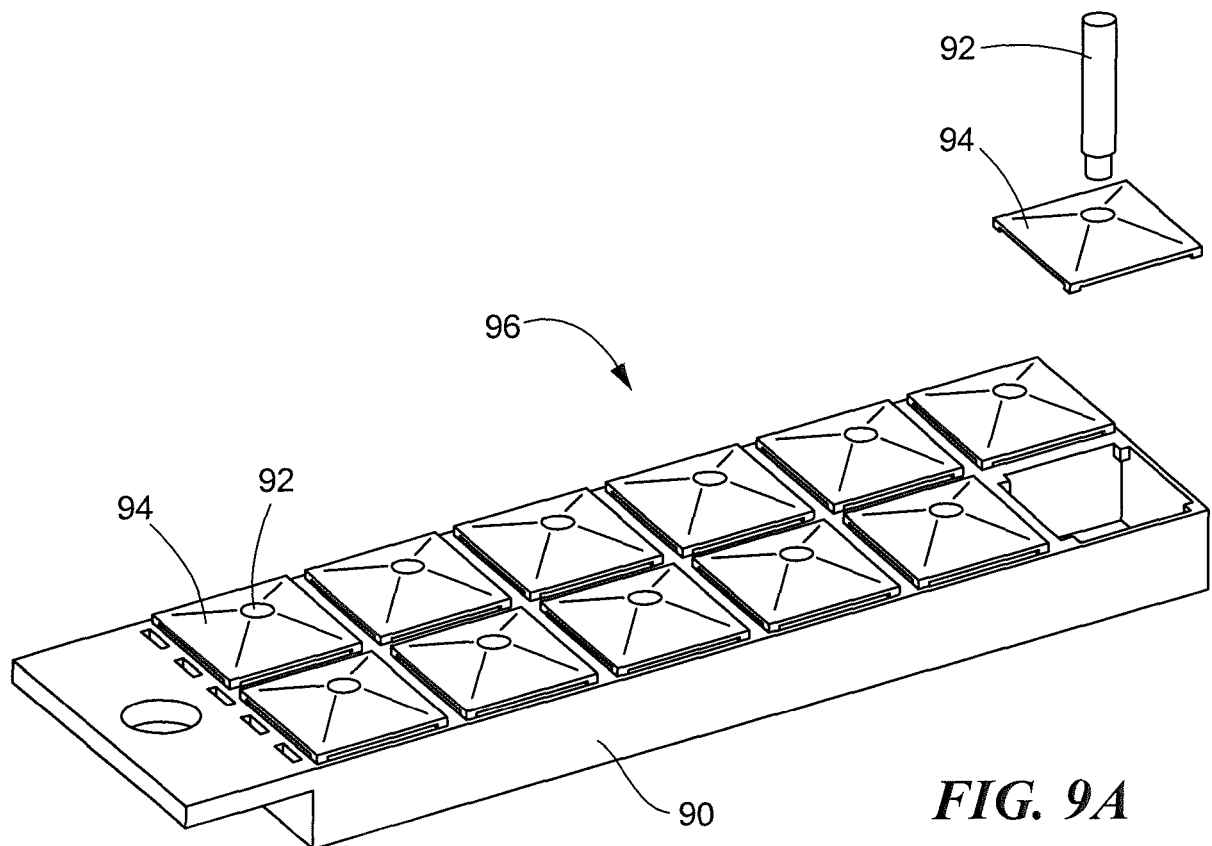
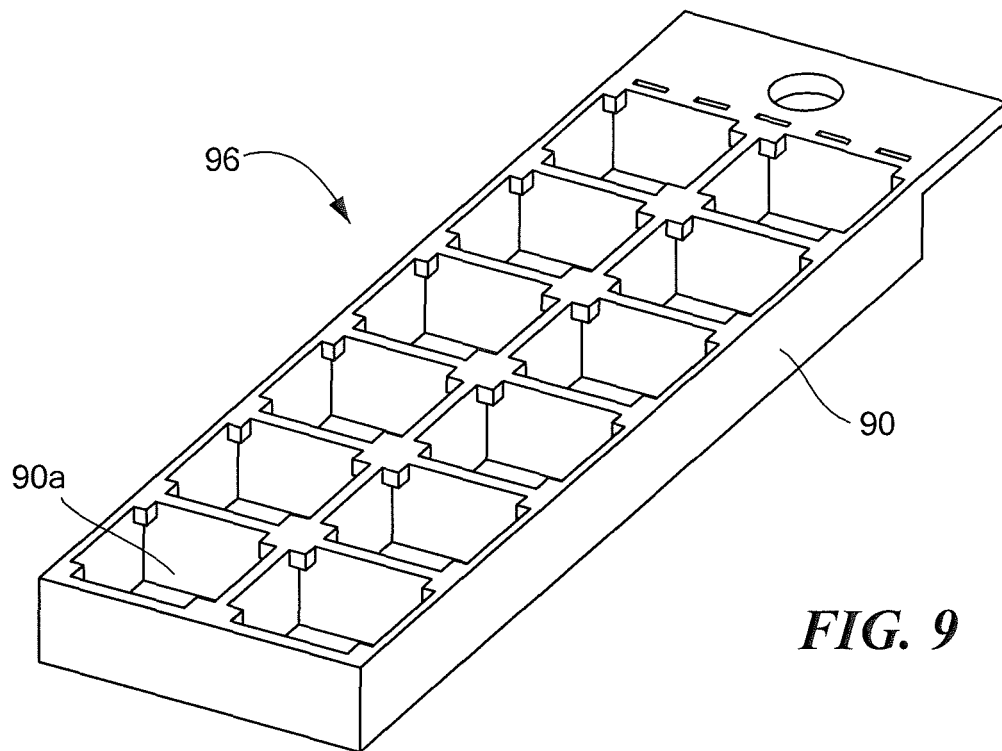


FIG. 8



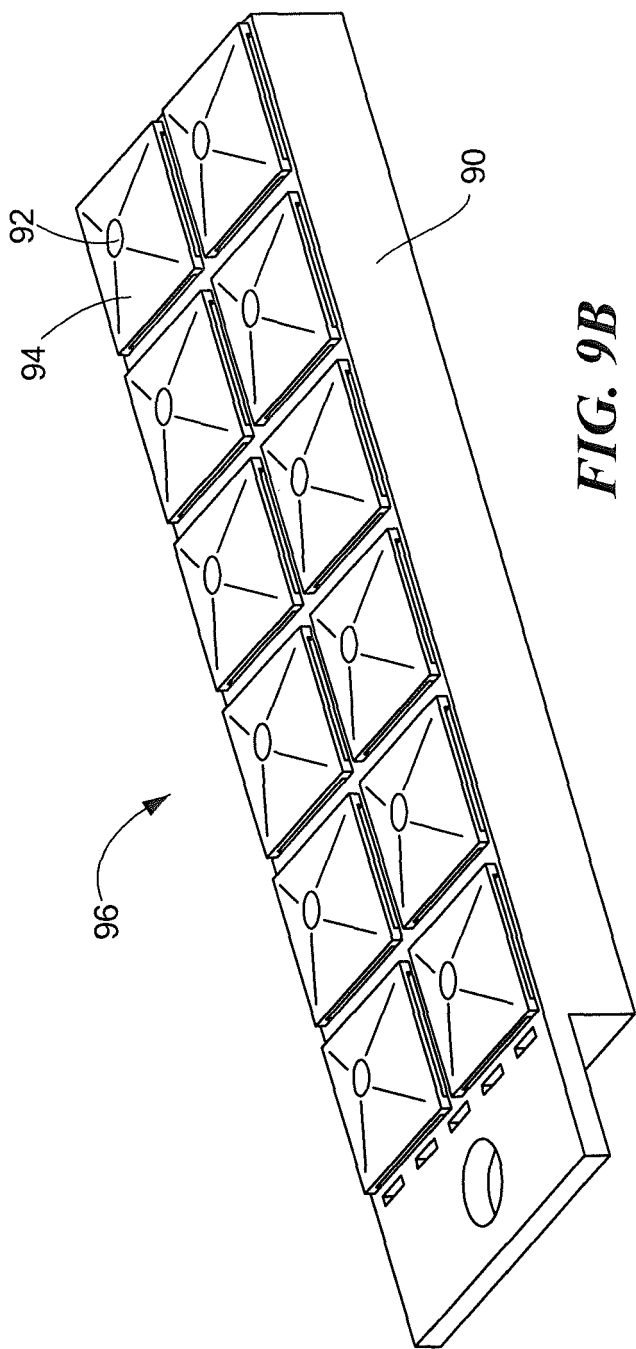


FIG. 9B

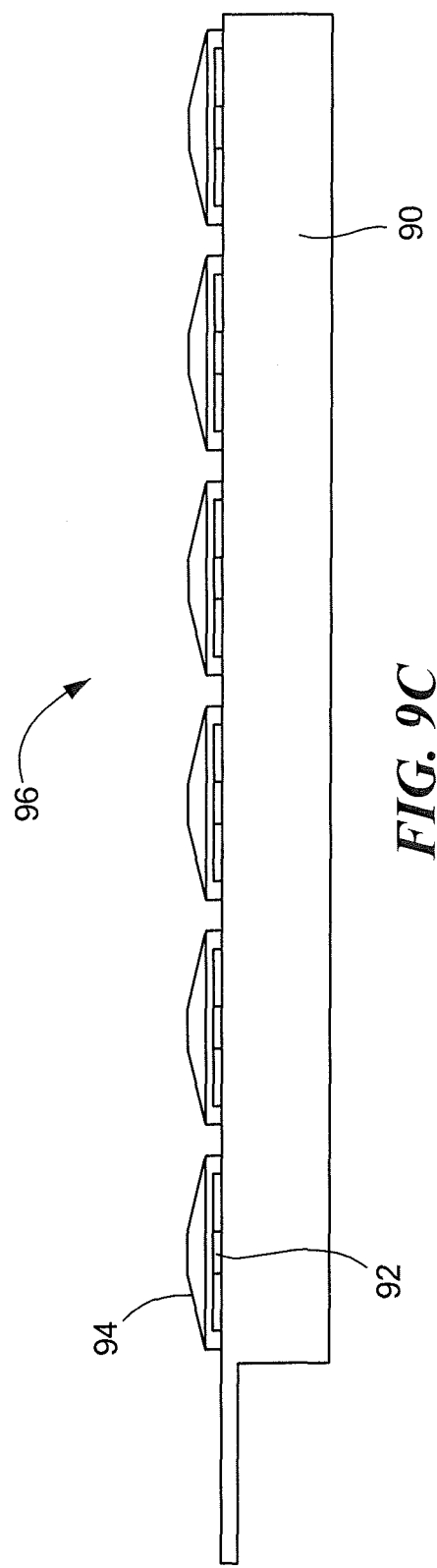


FIG. 9C

**REFERENCES CITED IN THE DESCRIPTION**

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