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(54) **System and method for a radio frequency (RF) transition design for a phased array antenna system utilizing a beam forming network**

System und Verfahren zum Entwurf einer Funkfrequenz-Übertragung für ein Phasenarray-Antennensystem mit einem strahlungsabgebenden Netzwerk

Système et procédé pour une conception de transmission radiofréquence (RF) pour un système d'antenne réseau à commande de phase utilisant un réseau à réalisation de faisceau

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Description

BACKGROUND

[0001] The present disclosure relates generally to beam forming networks and more particularly to phased array antennas utilizing such networks.

[0002] Active phased array antenna systems are capable of forming one or more antenna beams of electromagnetic energy and electronically steering the beams to targets, with no mechanical moving parts involved. A phased array antenna system has many advantages over other types of mechanical antennas, such as dishes, in terms of beam steering agility and speed, low profiles, low observability, and low maintenance.

[0003] A beam forming network is a major and critical part of a phased array antenna system. The beam forming network is responsible for collecting all the electromagnetic signals from the array antenna modules and combining them in a phase coherent way for the optimum antenna performance. The element spacing in a phased array is typically at one-half of the wavelength for electromagnetic waves in space.

[0004] There are design challenges when utilizing a phased array antenna system. Firstly, it is important that the phased array include a rhombic shape of aperture for low observabilty requirements of the system. In addition, the system should be as small as possible to conserve space while still having the same performance characteristics of conventional shaped phased array antenna systems. Furthermore, as array antenna frequency increases, the element spacing decreases in an inversely proportional manner. Due to this tight spacing in phased arrays at microwave frequencies, transitions of radio frequency (RF) energy from inside of the beam forming network printed wiring board to the backside of the antenna have always been one of the critical RF design factors in phased array development. Conventional designs had tighter tolerances in the feature alignments of the RF transition, which limits the choice of suppliers for the systems and impacts the cost and schedule for producing the antennas as well.

[0005] What is needed is a method and system to overcome the above-identified issues. One or more of the present embodiments address one or more of the above-identified needs and others.

[0006] The features, functions, and advantages can be achieved independently in various embodiments of the present invention or may be combined in yet other embodiments.

[0007] WO 03/049231 describes a phased array antenna system having an antenna integrated printed wiring board formed from a photolithographic process to create a single part.

SUMMARY OF THE INVENTION

[0008] In accordance with an aspect of the present invention there is provided a system and method according to the accompanying claims.

[0009] One or more systems and methods for forming phased array beams are disclosed. According to one embodiment, a phased array antenna system is described in claim 1. According to another embodiment, a method is described in claim 6. According to another embodiment, a radio frequency "RF" transition system includes a stripline trace section with openings in ground planes and forms a quarter wavelength resonator, and an electromagnetic mechanism to couple the RF energy from the stripline trace section to a connector, wherein the RF signal energy is transferred from inside a beam forming network printed wiring board to an antenna back plane with minimal RF losses.

[0010] According to another embodiment, a radio-frequency "RF" transition module includes a first port, a can coupled above the first port, the can including dielectric material therein; wherein the can tunes the transition module by varying the properties of the dielectric material, a connector coupled to the first port, and a second port coupled to the connector, wherein the transition modules provide RF signals to a phased array antenna system.

[0011] According to another embodiment, a phased array antenna system includes a printed wiring board formed in rhombic shape that accommodates requirements for low observability, a beam forming network located within the printed wiring board, wherein the beam forming network is located over substantially the entire printed wiring board, a radio-frequency "RF" transition system comprising a stripline trace section with openings in ground planes and forms a quarter wavelength resonator; and an electromagnetic mechanism to couple the RF energy from the stripline trace section to a connector, wherein the RF signal energy is transferred from inside the printed wiring board to an antenna back plane with minimal RF losses, and a plurality of connectors located on the backside of the printed wiring board that allows for expansion of the system.

[0012] According to another embodiment, a method for transferring radio-frequency "RF" signal energy includes forming a quarter-wavelength resonator, and coupling the RF signal energy from a stripline trace section to a connector, wherein the RF signal energy is transferred from inside a beam forming network printed wiring board to an antenna back plane with minimal RF losses.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

FIG. 1A is a mechanical schematic of one embodiment of a beam forming network within a printed wiring distribution board which has a rhombic shape, according to an embodiment.

FIG. 1B illustrates the layers associated with the printed wiring board of Figure 1A.

FIG. 2 is a mechanical schematic of the receive phased array antenna system with two subarrays of the beam forming network as shown in Fig. 1A.
FIG. 3A is a diagram view of the beam forming network RF circuits inside the beam former printed wiring board, according to an embodiment.
FIG. 3B shows the octagonal arrangement of clock lines on the beam former printed wiring board, according to an embodiment.
FIG. 3C shows the octagonal arrangement of data lines on the beam former printed wiring board, according to an embodiment.
FIG. 4 is a diagram of a receive phased array antenna assembly, according to an embodiment.
FIG. 5 illustrates the back side of the phased array antenna system that shows the back side connectors for DC power and logic, and the coaxial connectors for radio frequency (RF) signals, according to an embodiment.
Figure 6 is a perspective view of a stripline to waveguide transition module in accordance with an embodiment.
FIG. 7A shows a side view of an RF transition module, according to an embodiment.
FIG. 7B shows an isometric view of the RF transition module.
FIG. 7C shows a plan view of the RF transition module.
FIG. 7D shows an electromagnetic field distribution inside the RF transition module.
FIG. 8 represents the results of a finite-element electromagnetic field simulation within the waveguide transition module shown in FIG. 6.
FIG. 9A shows a perspective view of a stripline to coaxial module which also includes a coaxial interface.
FIG. 9B shows a side view of the stripline to coaxial module which includes a coaxial interface.
FIG 9C shows the performance comparison of the stripline to waveguide module and the stripline to coaxial module.

DETAILED DESCRIPTION

[0014] The present embodiment relates generally to beam forming networks and more particularly to phased array antennas utilizing such networks. The following description is presented to enable one of ordinary skill in the art to make and use the embodiment and is provided in the context of a patent application and its requirements.

[0015] Every phased array antenna system includes a beam forming network to coherently combine the signals from all of its many elements. It is this signal combining ability that forms the electromagnetic beam. A beam forming distribution board for a conventional phased array antenna system has a rectangular shape for the beam forming network. As is known the rectangular shape provides problems because it is easily observable electronically due to its electronic signature. Hence it is desirable for the phased array antenna system to be rhombic in shape to allow for low observability.

[0016] Active electronically scanned phased arrays have been produced that contain a large number of phased array elements. For example, The Boeing Company has produced such a phased array antenna system that contains 4,096 elements in 8 subarrays arranged in a 2x4 configuration.

[0017] In a conventional receive phased array antenna system all of the DC power and logic interconnections are placed at the outside edges of the subarray. One cannot add more subarray columns to increase the size without having large gaps in-between adjacent subarrays. In conventional phased array antenna systems such as K-band arrays, the rhombic shape of aperture for phased array antennas were accomplished by either using the metal plate itself, (which offered only the minimum benefit to the low observability), or having passive dummy elements placed around the rectangular shape of active elements.

[0018] There are four critical features in that distinguish the beam forming network of the present embodiment over conventional beam forming networks:

(1) A rhombic shape of the beam forming network subarray that accommodates requirements for low observability and utilizes beam forming elements over substantially the entire array.

(2) Reduced the column and row gaps in between the subarray panels, with improved results on the antenna beam patterns.

(3) Improved RF bandwidth and mechanical tolerances in the RF transition from the beam forming network to the backside of the array.

(4) Back side interconnections that allow the array architecture to expand to include more subarrays and thus more elements in a full size array.

[0019] A phased array antenna system in accordance with an embodiment expands the capabilities of phased array antenna systems in two critical areas: (1) providing a low observability compliant phased array aperture with reduced size, weight and cost; and (2) providing a beam forming network scalability to large full- size arrays. Both capabilities allow for the enhanced phased array antennas utilized for a variety of applications. To describe the features of the phased array antenna system refer now to the following description in conjunction with the accompanying figures.

[0020] FIG. 1A is a mechanical schematic of one embodiment of a beam forming network 100 within a printed wiring board 102. The beam forming network 100 is formed inside a rhombic shape printed wiring board (PWB) 102, so that two or more of such identical boards

can be put together to form a larger sized array without compromising the low observability characteristics. In this embodiment, the rhombic shape of the aperture is covered with active beam forming elements for a maximum cost effective benefit to the antenna system. In an embodiment, the PWB 102 includes nine layers as shown in Figure 1B.

[0021] FIG. 2 is a mechanical schematic of the receive phased array antenna system 200 with two subarrays 202a and 202b of the beam forming network, according to an embodiment. One critical feature is the narrowing of the non-active-element gaps around each board when two or more identical PWBs are put together to form large arrays. FIG. 2 shows that the edge gaps 204 in-between the adjacent boards are of only one element spacing, as compared with two element spacing in the conventional phased arrays. This reduction in the gap width improves the antenna beam patterns. The reduction of gap width is accomplished by laying out the beam forming circuits of the subarrays 202a and 202b in a more efficient manner. Also, by placing all of the circuitry and connectors on the backside adjacent subarrays, the subarrays can be placed closer together than the subarrays utilized in a conventional phased array antenna system.

[0022] FIG. 3A is a diagram of a portion of the beam forming network circuits 200 inside the PWB 202. FIG. 3A shows stripline traces 302 on the RF layer 300 embedded inside the printed wiring board 202. These stripline traces 302 form the RF distribution network for the beam forming function. As is seen in FIGs. 3B and 3C, the data and clock lines are arranged in an orthogonal style to provide a more efficient layout on the PWB 202 and more robust signal integrity for array's beam steering control.

[0023] The array assembly and the backside interconnections for the phased array antenna system are shown in FIG. 4 and FIG. 5. FIG. 4 is a diagram of a receive phased array antenna assembly 400. In this embodiment one subarray 410a is shown assembled and one subarray 410b is shown in exploded view. As is seen the subarray 410b includes a plurality of subarray elements 412, a module shim 414, a multilayer wiring board (MLWB) 416, an elastomer connector shim 418 and a pressure plate with thermal transfer material 420. The MWLB is utilized advantageously to provide the RF, power and logic distribution for the phased array antenna. These elements are coupled together as shown in subarray 410a to provide the rhombic shaped array.

[0024] FIG. 5 illustrates the back side of the phased array antenna system showing the back side connectors for DC/logic connector 502, and the RF port coaxial connector 504 for the RF signals. By including these connectors on the back side of the board the subarrays can be placed closer together. The RF port connector provides for an RF transition for the beam forming network printed wiring board and the array housing. As before mentioned, in conventional subarrays, the connectors are placed on the sides of the PWB thereby causing adjacent subarrays to be placed at a distance from each other based upon the size of the connectors. In one embodiment there is one port per each subarray. A phased array antenna system in accordance with an embodiment expands the capabilities of phased array antenna systems in two critical areas: (1) providing a low observability compliant phased array aperture with reduced size, weight and cost; and (2) providing a beam forming network scalability to large full size arrays. Both capabilities allow for the enhanced phased array antennas utilized for a variety of applications. The embodiment includes a RF transition module that two key improvements over the previous RF transition modules:

(1) improved RF bandwidth with more tuning range by selecting the optimum material dielectric constant for the tuning block.

(2) more relaxed mechanical tolerances in the RF transition from the beam forming network to the backside of the array, thus making the board more manufacturable, with lower cost. To describe the features of the RF transition module in more detail refer now to the following description in conjunction with the accompanying figures.

[0025] The RF distribution network constructed inside the PWB for the beam forming function is shown in FIG. 3A. The RF traces are connected at each 256-element level to the transition module 600 shown above in FIG. 6.

[0026] FIG. 6 is a perspective view of a stripline to waveguide RF transition module 600 or system in accordance with one or more embodiments. FIG. 7A shows a side view of the RF transition module 600. FIG. 7B shows an isometric view of the RF transition module 600. FIG. 7C shows a plan view of the RF transition module 600. FIG. 7D shows an electromagnetic field distribution inside the RF transition module 600. As is seen, the RF energy comes in along the stripline 602 (Port 1) and is coupled into the rectangular waveguide 604 (Port 2). The rectangular block 606 placed above the trace represents the dielectric material that is inserted in a can (not shown). The dielectric material 606 tunes the transition coupling performance by varying the material dielectric properties. In one embodiment, the RF transition module comprises a stripline trace section with openings in the nearby ground planes forming a quarter-wavelength resonator. The RF energy from the stripline is electromagnetically coupled to either a rectangular wavelength piece or a coaxial contact.

[0027] This RF transition module 600 is integrated in the beam-forming-network-printed-wiring-board. The rhombic shape beam forming network printed wiring board is shown in FIG. 1A. Inside each PWB, two RF transition modules are integrated with the phased array. The transition modules are responsible for combining the elements in one subarray. In one embodiment the subarray includes 256 elements.

[0028] FIG. 8 represents the results of a finite-element electromagnetic field simulation within the RF waveguide transition structure shown in FIG. 6. The insert material simulated includes Teflon, Taconic, Rexolite, Rogers Duroid, and Arlon Coefficient of Linear Thermal Expansion (CLTE). The insert material is simulated by varying its dielectric constant and the return losses for the RF transition are plotted as a function of the RF frequency. All materials within the numerical analysis result in a "double null" pattern across the frequency band of interest - this is a desirable characteristic because it means less reflection, better impedance matching, and wider bandwidth in the desired frequency range. FIG. 8 indicates that a return loss of 20 dB or better has been achieved over more than 2 GHz frequency range - better than 10% bandwidth at K-band (20 GHz). This is a significant improvement in operation bandwidth from previous designs.

[0029] Another RF transition design comprising a low cost commercial off-the-shelf (COTS), surface mount coaxial connector has also been used for the same stripline matching network, i.e., the coaxial matching has been successfully simulated and compared. For the coaxial cases, the compact impedance match circuit occupies less than one-half the space as for the waveguide case. The waveguide transition module occupies four times the width, but about the same height as the coaxial connector. FIGs. 9A and 9C show a perspective view and side view of a stripline to coaxial module 900 which also includes a coaxial interface. Figure 9B shows the performance of the stripline to waveguide module and the stripline to coaxial connector transition module

[0030] As is seen, desirable characteristics of these transition modules display wide bandwidth while having a below -25 dB return loss. The waveguide transition module is less sensitive to trace width / length variance, representing manufacturing tolerance fluctuation. Overall, the above-identified modules are simpler structures and less costly than conventional transition modules. Also, the new coaxial transition module is easier to manufacture thereby reducing the cost and the schedule risk associated with manufacturing of the beam forming network.

[0031] A phased array antenna system in accordance with an embodiment expands the capabilities of phased array antenna systems in two critical areas: (1) providing a low observability compliant phased array aperture with reduced size, weight and cost; and (2) providing a beam forming network scalability to large full size arrays. Both capabilities allow for the enhanced phased array antennas utilized for a variety of applications.

Claims

1. A phased array antenna system (200), comprising:

a printed wiring board (102) formed in rhombic shape;

a beam forming network (100) located within the printed wiring board, wherein the beam forming network is located over substantially the entire printed wiring board, wherein the beam forming network includes at least one subarray (202a, 202b) of a plurality of beam forming elements, wherein data and clock lines of the beam forming elements are arranged in an orthogonal style to provide an efficient layout of the printed wiring board and robust signal integrity for the array beam steering control, and wherein the subarray comprises a plurality of subarray elements (412), a module shim (414) coupled to the plurality of subarray elements, a multilayer wiring board (416) coupled to the module shim, a connector shim (418) coupled to the multilayer wiring board; and a pressure plate (420) coupled to the connector shim, wherein two or more subarrays are coupled together to provide a rhombic shaped array, a plurality of connectors (502, 504) located on the backside of the printed wiring board configured to allow for expansion of the system.

2. The phased array antenna system (200) of claim 1, further comprising

a radio-frequency "RF" transition system (600) comprising a stripline trace section (602) with openings in ground planes and forms a quarter wavelength resonator; and an electromagnetic mechanism (604) to couple the RF energy from the stripline trace section to a connector, wherein the RF signal energy is transferred from inside the printed wiring board to an antenna back plane with minimal RF losses.

3. The phased array antenna system of claim 2, wherein the connector comprises one of a rectangular waveguide and a coaxial contact.

4. The phased array antenna system of claim 2, wherein the electromagnetic mechanism comprises a dielectric material which is inserted in a can for tuning the transition system; wherein the coupling performance is a function of the material's dielectric properties.

5. The phased array antenna system of claim 2, wherein the dielectric material is Teflon.

6. A method for forming a phased array beam, the method comprising:

providing a printed wiring board (102) formed in a rhombic shape;

providing a beam forming network (100) located within the printed wiring board, wherein the beam-forming network is located over substan-

tially the entire printed wiring board, wherein the beam forming network includes at least one subarrays (202a, 202b) of a plurality of beam forming elements, wherein data and clock lines of the beam forming elements are arranged in an orthogonal style to provide an efficient layout of the printed wiring board and robust signal integrity for the array beam steering control, and wherein each subarray comprises a plurality of subarray elements (412), a module shim (414) coupled to the plurality of subarray elements, a multilayer wiring board (416) coupled to the module shim, a connector shim (418) coupled to the multilayer wiring board; and a pressure plate (420) coupled to the connector shim, wherein two or more subarrays are coupled together to provide a rhombic shaped array, providing a plurality of connectors (502, 504) only on the back side of the printed wiring board to allow for expansion of the phased array beams.

Patentansprüche

1. Phased-Array-Antennensystem (200), das aufweist:

eine Leiterplatte (102), die rautenförmig ausgebildet ist;
ein strahlbildendes Netzwerk (100), das sich innerhalb der Leiterplatte befindet, wobei sich das strahlbildende Netzwerk im Wesentlichen über die gesamte Leiterplatte erstreckt, wobei das strahlbildende Netzwerk zumindest ein Subarray (202a, 202b) aus mehreren strahlbildenden Elementen umfasst, wobei Daten- und Taktleitungen der strahlbildenden Elemente in einer orthogonalen Form angeordnet sind, um eine effiziente Gestaltung der Leiterplatte und eine robuste Signalintegrität für die Arraystrahlschwenksteuerung zu ermöglichen, und wobei das Subarray mehrere Subarrayelemente (412), eine Modulabschirmung (414), die an die mehreren Subarrayelemente gekoppelt ist, eine mehrlagige Leiterplatte (416), die an die Modulabschirmung gekoppelt ist, eine Verbinderabschirmung (418), die an die mehrlagige Leiterplatte gekoppelt ist, und eine Druckplatte (420) aufweist, die an die Verbinderabschirmung gekoppelt ist, wobei zwei oder mehrere Subarrays gekoppelt sind, um ein rautenförmiges Array auszubilden,
mehrere Verbinder (502, 504), die sich an der Rückseite der Leiterplatte befinden und so ausgebildet sind, dass sie eine Erweiterung des Systems zulassen.

2. Phased-Array-Antennensystem (200) nach Anspruch 1, das ferner aufweist:

ein Hochfrequenz "HF"-Überleitungssystem (600), das eine Streifenleitungsleiterbahnsektion (602) mit Öffnungen in Masseebenen aufweist und einen Viertelwellenlängenresonator bildet; und einen elektromagnetischen Mechanismus (604) zum Koppeln der HF-Energie von der Streifenleitungsleiterbahnsektion an einen Verbinder, wobei die HF-Signalenergie vom Inneren der Leiterplatte mit minimalen HF-Verlusten zu einer Antennenbackplane transferiert wird.

3. Phased-Array-Antennensystem nach Anspruch 2, wobei der Verbinder einen rechteckförmigen Wellenleiter oder einen koaxialen Anschluss aufweist.

4. Phased-Array-Antennensystem nach Anspruch 2, wobei der elektromagnetische Mechanismus ein dielektrisches Material umfasst, das zum Abstimmen des Überleitungssystems in eine Dose eingesetzt ist, wobei die Kopplungsleistung eine Funktion der dielektrischen Eigenschaften des Materials ist.

5. Phased-Array-Antennensystem nach Anspruch 2, wobei es sich bei dem dielektrischen Material um Teflon handelt.

6. Verfahren zum Bilden eines Phased-Array-Strahls, wobei das Verfahren umfasst:

Bereitstellen einer Leiterplatte (102), die rautenförmig ausgebildet ist;
Bereitstellen eines strahlbildenden Netzwerks (100), das sich innerhalb der Leiterplatte befindet, wobei sich das strahlbildende Netzwerk im Wesentlichen über die gesamten Leiterplatte erstreckt, wobei das strahlbildende Netzwerk zumindest ein Subarray (202a, 202b) aus mehreren strahlbildenden Elementen umfasst, wobei Daten- und Taktleitungen der strahlbildenden Elemente in einer orthogonalen Form angeordnet sind, um eine effiziente Gestaltung der Leiterplatte und eine robuste Signalintegrität für die Arraystrahlschwenksteuerung zu ermöglichen, und
wobei jedes Subarray mehrere Subarrayelemente (412), eine Modulabschirmung (414), die an die mehreren Subarrayelemente gekoppelt ist, eine mehrlagige Leiterplatte (416), die an die Modulabschirmung gekoppelt ist, eine Verbinderabschirmung (418), die an die mehrlagige Leiterplatte gekoppelt ist, und eine Druckplatte (420) aufweist, die an die Verbinderabschirmung gekoppelt ist, wobei zwei oder mehrere Subarrays gekoppelt sind, um ein rautenförmiges Array auszubilden,
Bereitstellen von mehreren Verbinder (502, 504) ausschließlich an der Rückseite der Leiter-

platte, um eine Erweiterung der Phased-Array-Strahlen zulassen.

Revendications

1. Système d'antennes à réseau de phases (200), comprenant :

   une carte de circuit imprimé (102) de forme rhombique ;
   un réseau de mise en forme de faisceau (100) situé sur la carte de circuit imprimé, dans lequel le réseau de mise en forme de faisceau est situé sensiblement sur l'intégralité de la carte de circuit imprimé, dans lequel le réseau de mise en forme de faisceau comprend au moins un sous-réseau (202a, 202b) d'une pluralité d'éléments de mise en forme de faisceau, dans lequel les lignes de données et d'horloge des éléments de mise en forme de faisceau sont disposées de manière orthogonale afin de garantir un agencement efficace de la carte de circuit imprimé et une solide intégrité de signal pour la commande de direction du faisceau de réseau, et dans lequel le sous-réseau comprend une pluralité d'éléments de sous-réseau (412), une cale de module (414) reliée à la pluralité d'éléments de sous-réseau, une carte de circuit imprimé à plusieurs couches (416) reliée à la cale de module, une cale de connecteur (418) reliée à la carte de circuit imprimé à plusieurs couches ; et une plaque de pression (420) reliée à la cale de connecteur, dans lequel deux sous-réseaux ou plus sont reliés ensemble afin d'offrir un réseau de forme rhombique,
   une pluralité de connecteurs (502, 504) situés sur l'arrière de la carte de circuit imprimé et configurés pour permettre l'extension du système.

2. Système d'antennes à réseau de phases (200) selon la revendication 1, comprenant en outre
   un système de transition radiofréquence « RF » (600) comprenant une section de trace de guide d'ondes à ruban (602) avec des ouvertures sur des plans de masse, et qui forme un résonateur à quart de longueur d'onde ; et un mécanisme électromagnétique (604) destiné à relier l'énergie RF qui provient de la section de trace de guide d'ondes à ruban à un connecteur, dans lequel l'énergie du signal RF est transférée de l'intérieur de la carte de circuit imprimé vers un panneau arrière d'antenne avec des pertes RF minimales.

3. Système d'antennes à réseau de phases (200) selon la revendication 2, dans lequel le connecteur comprend l'un d'un guide d'ondes rectangulaire et d'un contact coaxial.

4. Système d'antennes à réseau de phases selon la revendication 2, dans lequel le mécanisme électromagnétique comprend un matériau diélectrique qui est inséré dans une gaine afin de régler le système de transition ; dans lequel les performances de couplage dépendent des propriétés diélectriques du matériau.

5. Système d'antennes à réseau de phases selon la revendication 2, dans lequel le matériau diélectrique est du Téflon.

6. Procédé de mise en forme d'un faisceau à réseau de phases, le procédé comprenant :

   le fait de prévoir une carte de circuit imprimé (102) de forme rhombique ;
   le fait de prévoir un réseau de mise en forme de faisceau (100) situé sur la carte de circuit imprimé ;
   dans lequel le réseau de mise en forme de faisceau est situé sensiblement sur l'intégralité de la carte de circuit imprimé, dans lequel le réseau de mise en forme de faisceau comprend au moins un sous-réseau (202a, 202b) d'une pluralité d'éléments de mise en forme de faisceau, dans lequel les lignes de données et d'horloge des éléments de mise en forme de faisceau sont disposées de manière orthogonale afin de garantir un agencement efficace de la carte de circuit imprimé et une solide intégrité de signal pour la commande de direction du faisceau de réseau, et dans lequel chaque sous-réseau comprend une pluralité d'éléments de sous-réseau (412), une cale de module (414) reliée à la pluralité d'éléments de sous-réseau, une carte de circuit imprimé à plusieurs couches (416) reliée à la cale de module, une cale de connecteur (418) reliée à la carte de circuit imprimé à plusieurs couches ; et une plaque de pression (420) reliée à la cale de connecteur, dans lequel deux sous-réseaux ou plus sont reliés ensemble afin d'offrir un réseau de forme rhombique,
   le fait de prévoir une pluralité de connecteurs (502, 504) uniquement sur l'arrière de la carte de circuit imprimé afin de permettre l'extension des faisceaux de réseau de phases.

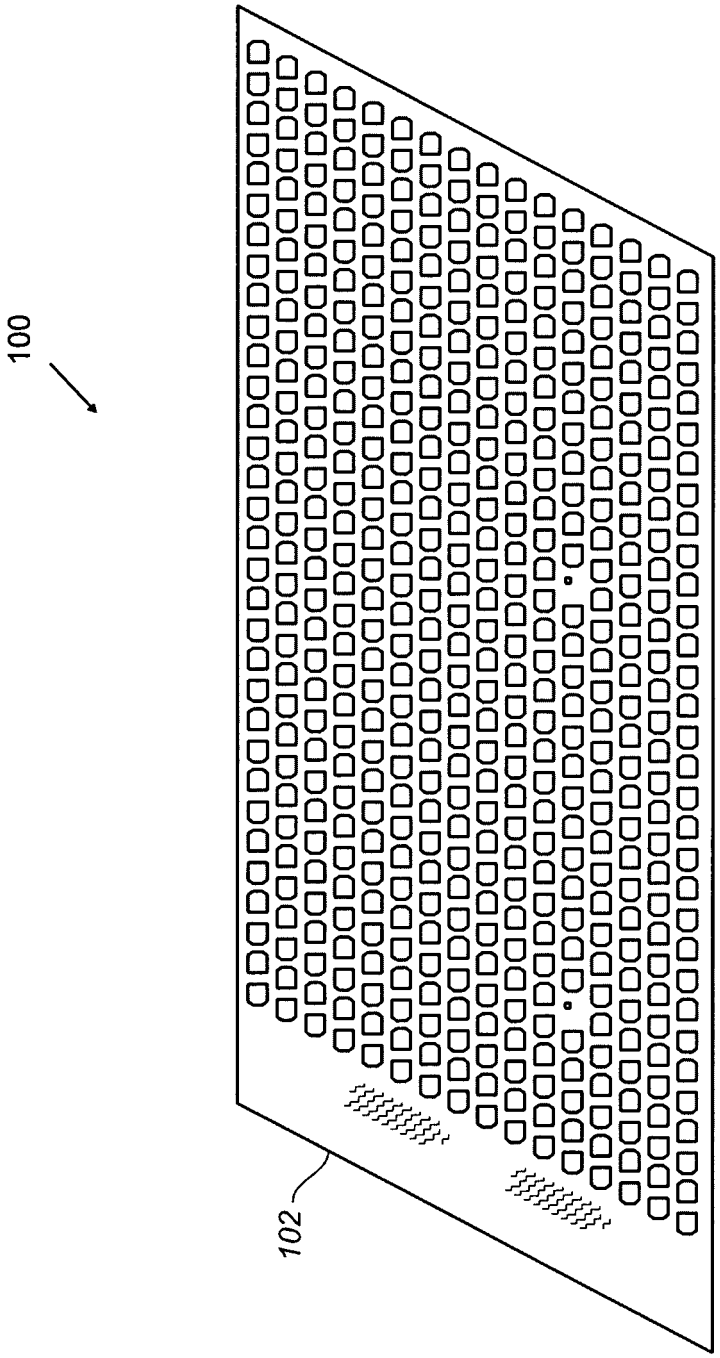


FIG. 1A

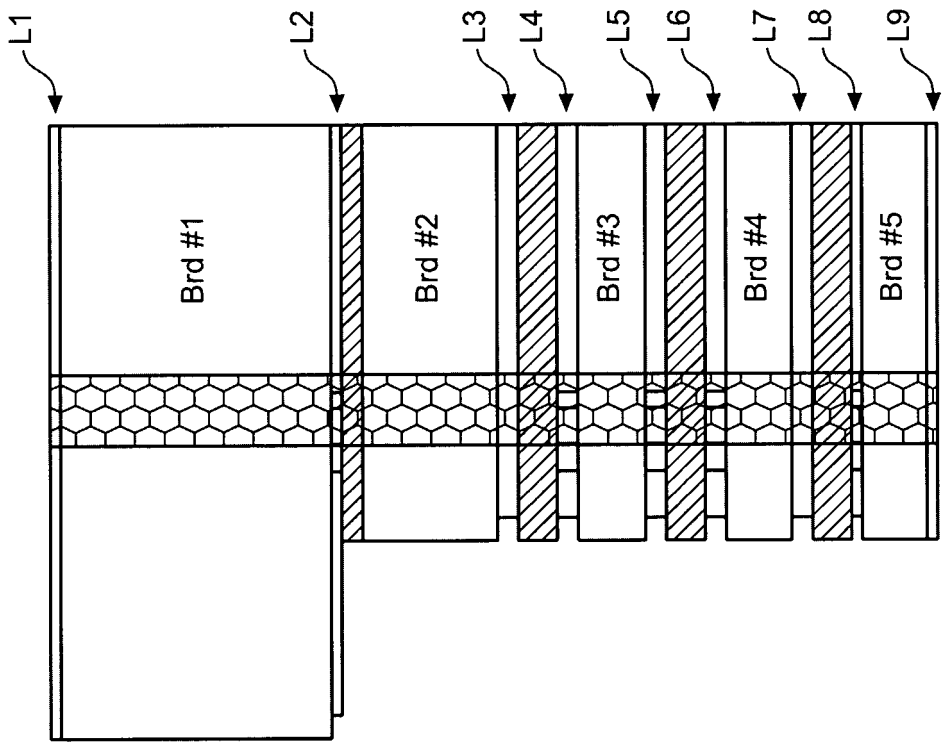


FIG. 1B

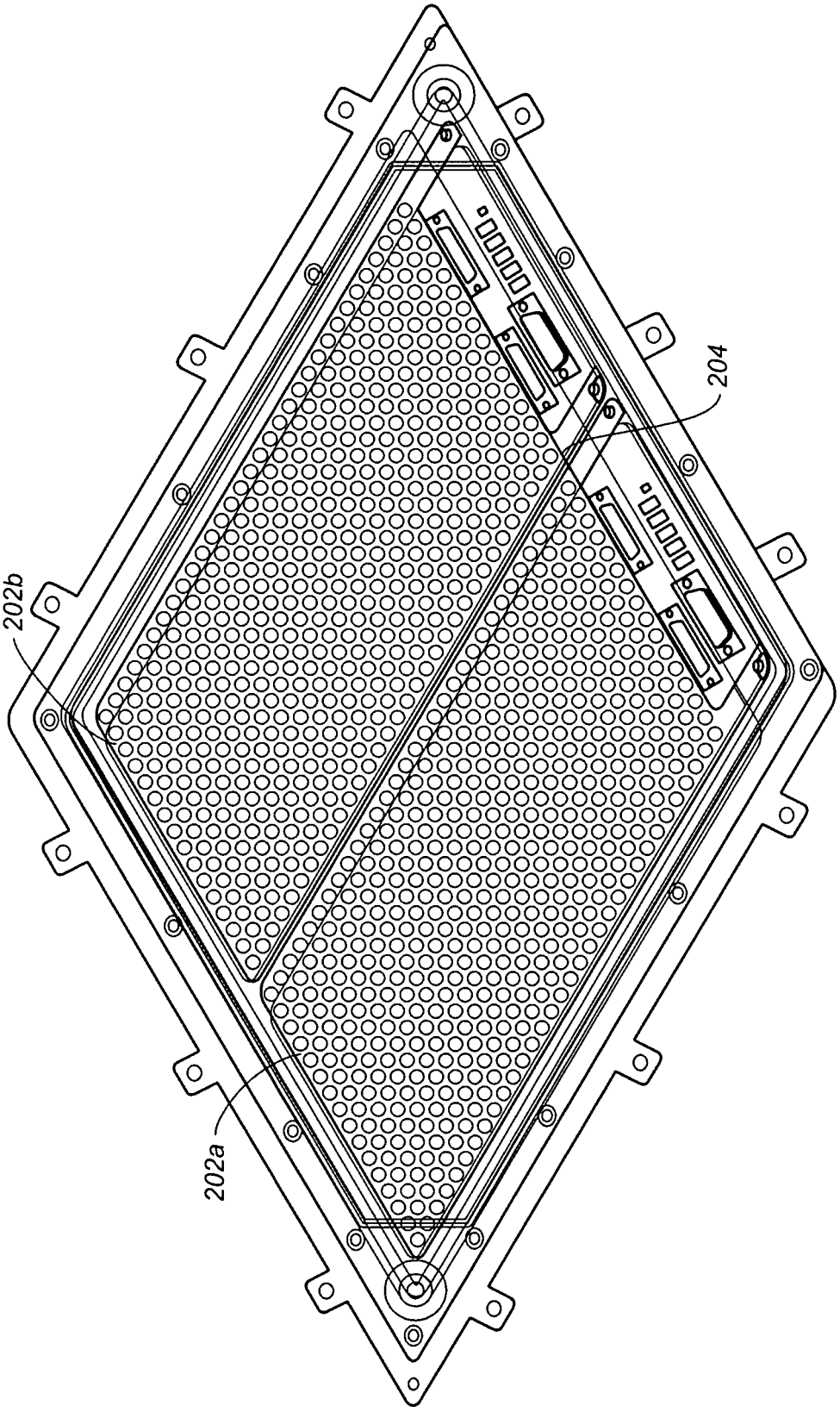


FIG. 2

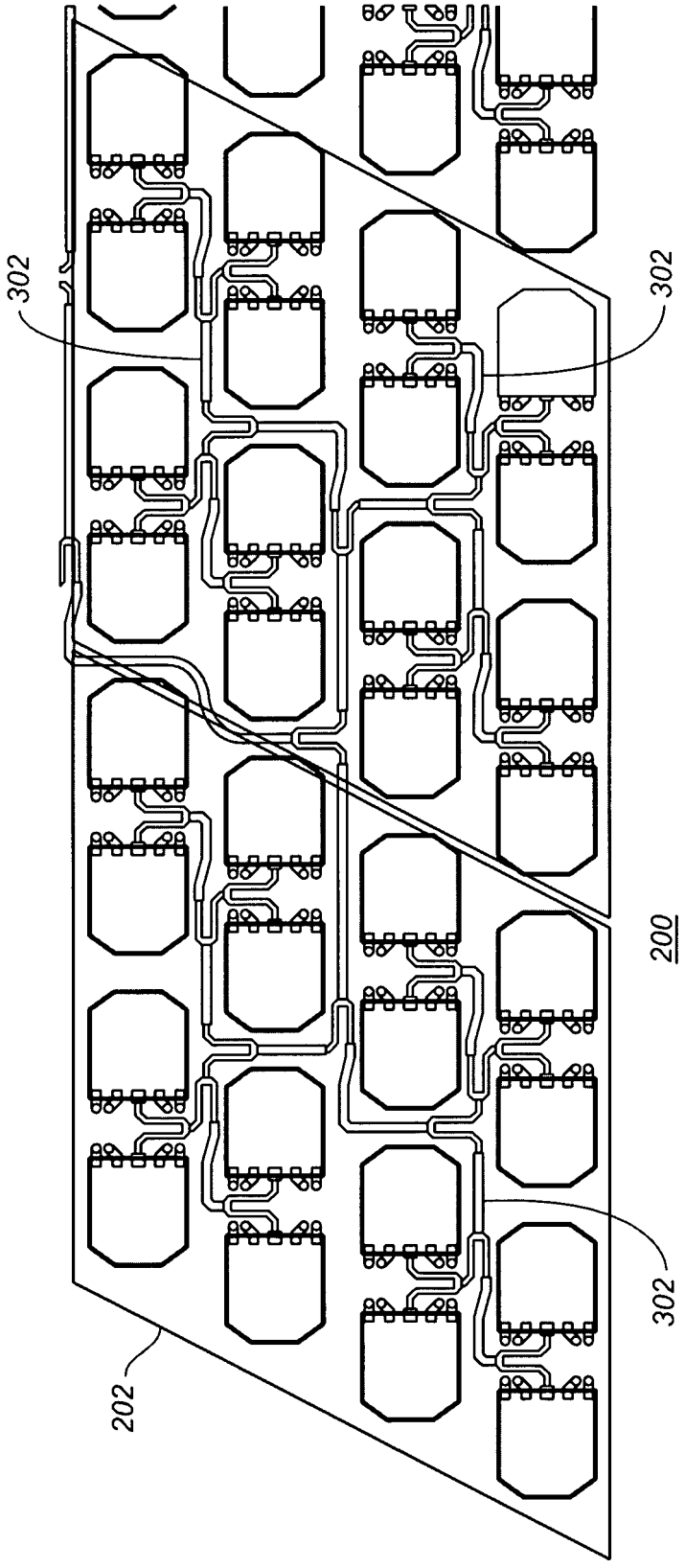


FIG. 3A

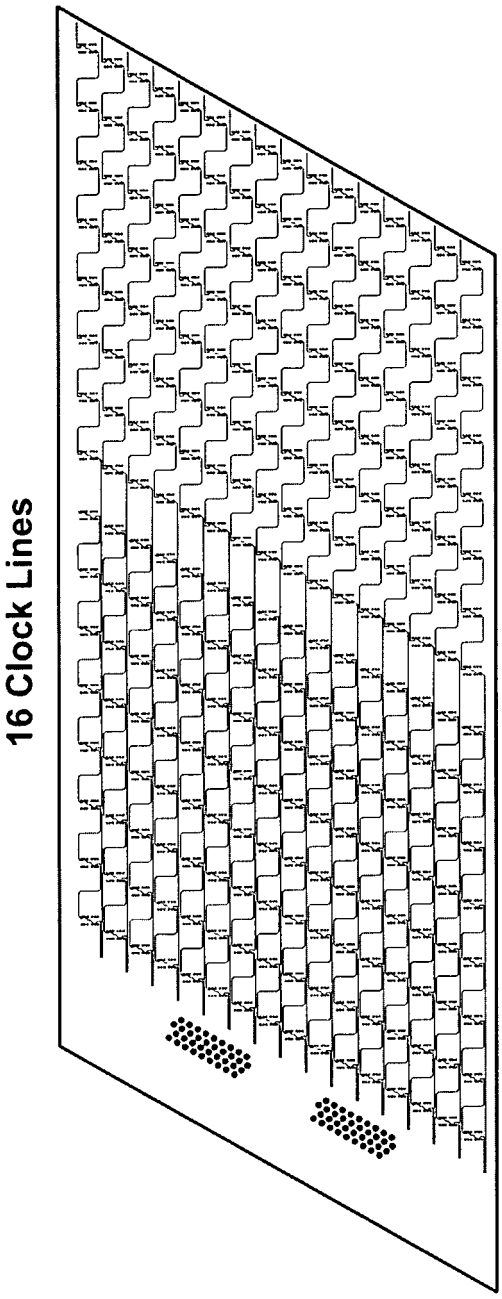


FIG. 3B

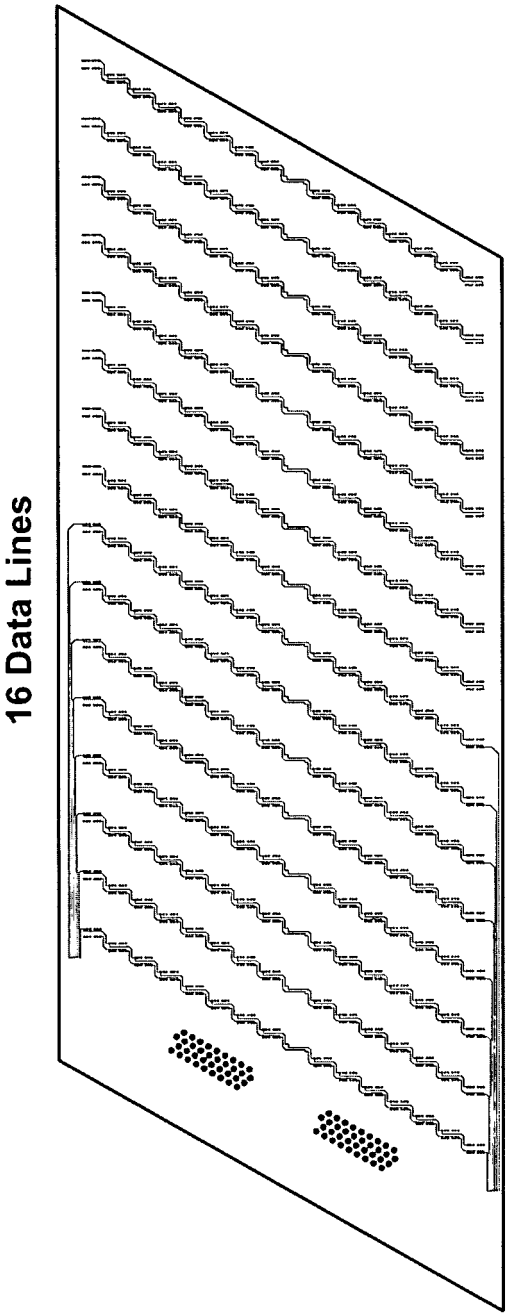


FIG. 3C

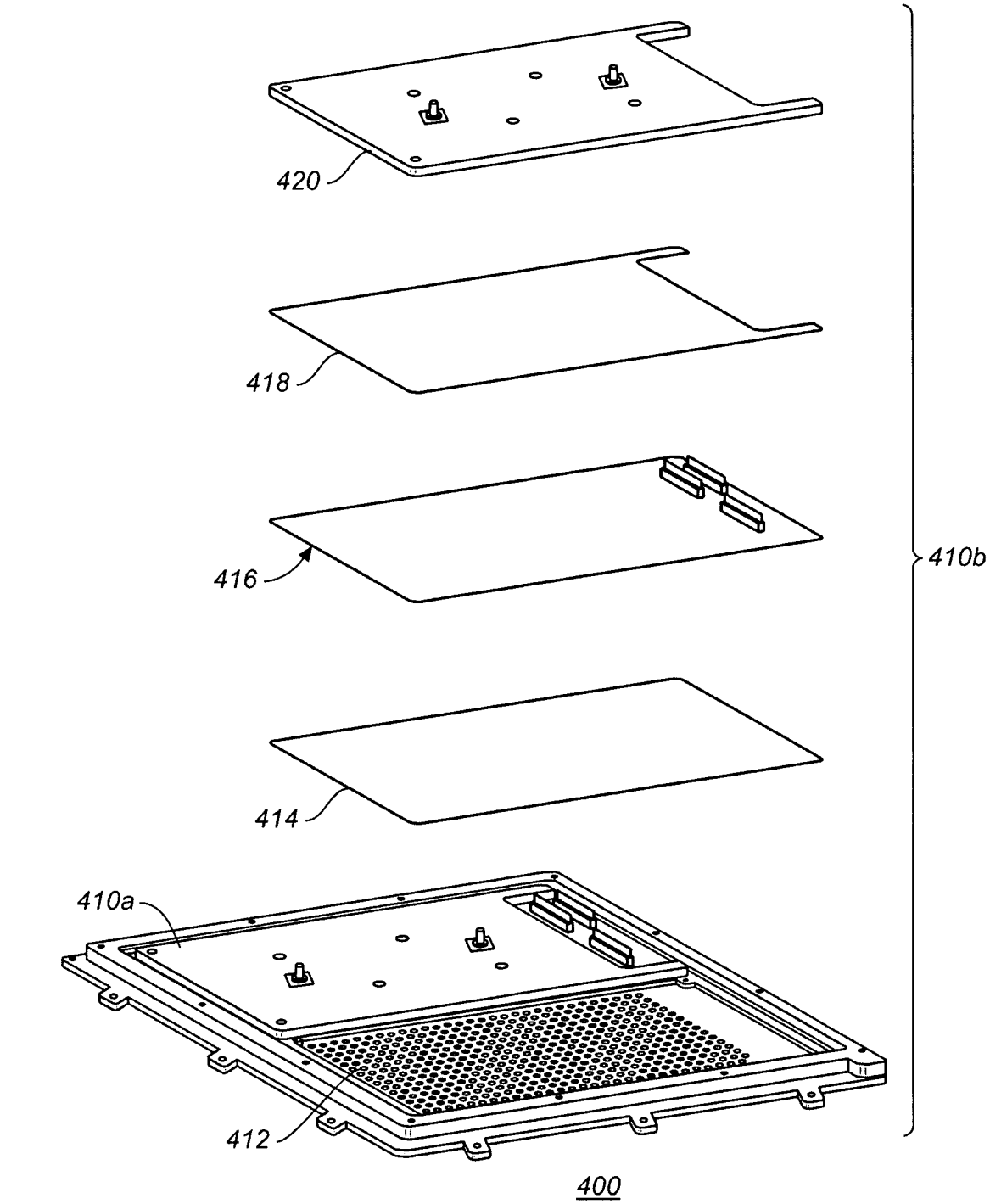


FIG. 4

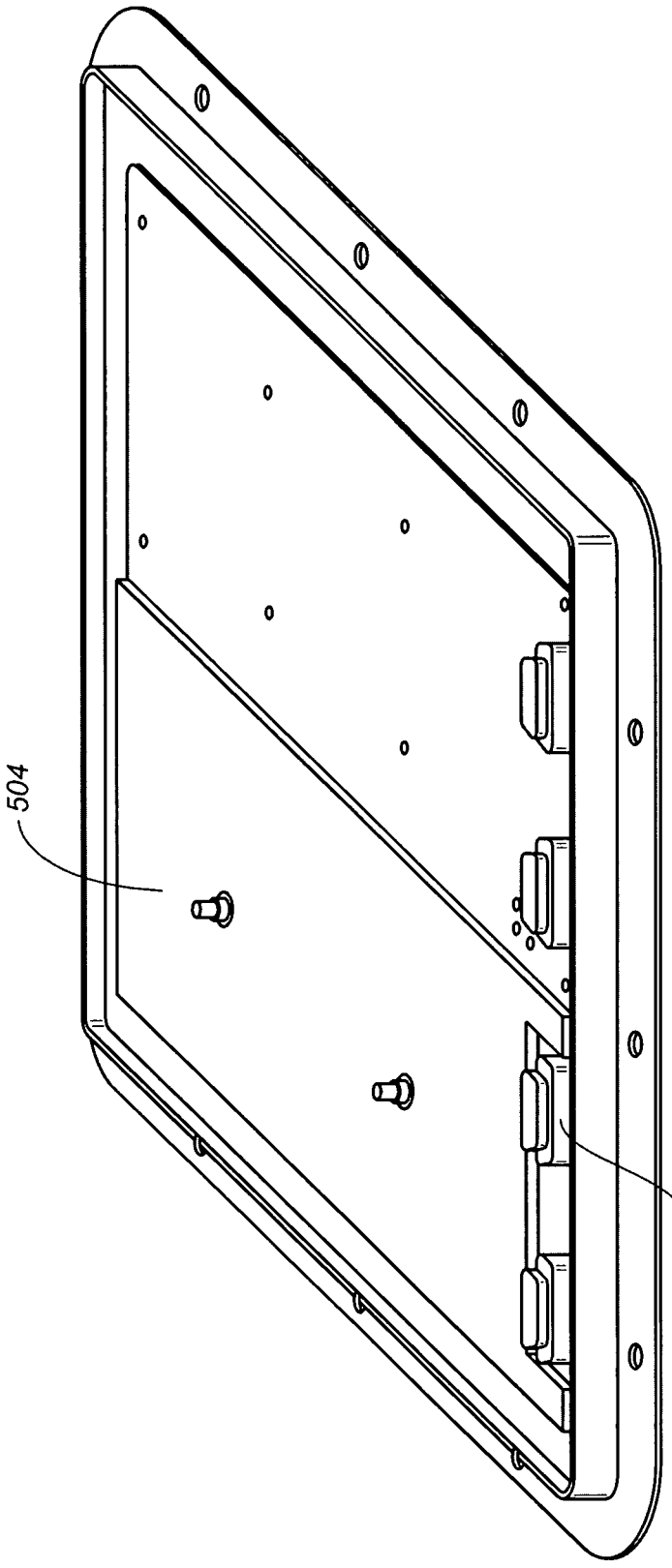


FIG. 5

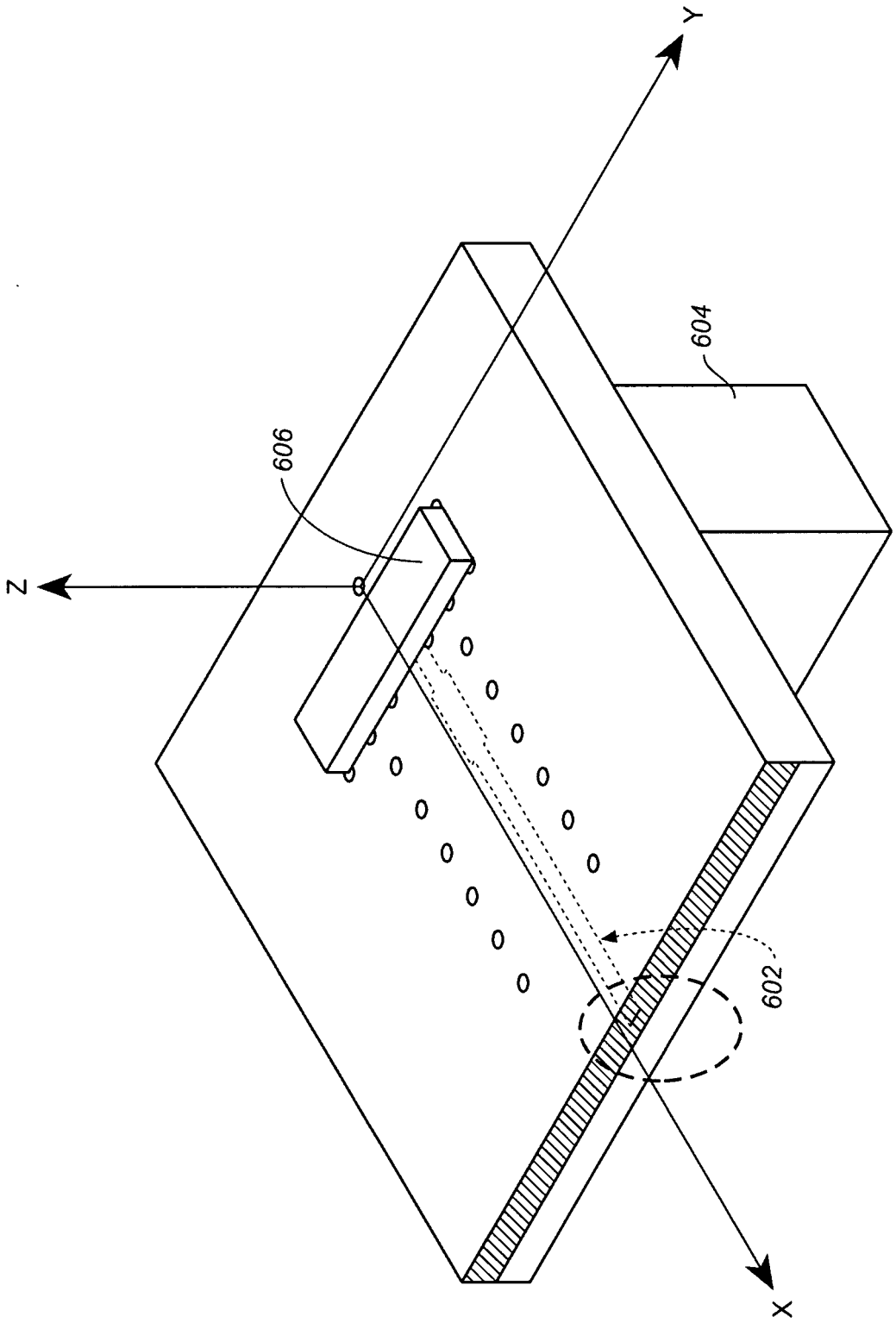


FIG. 6

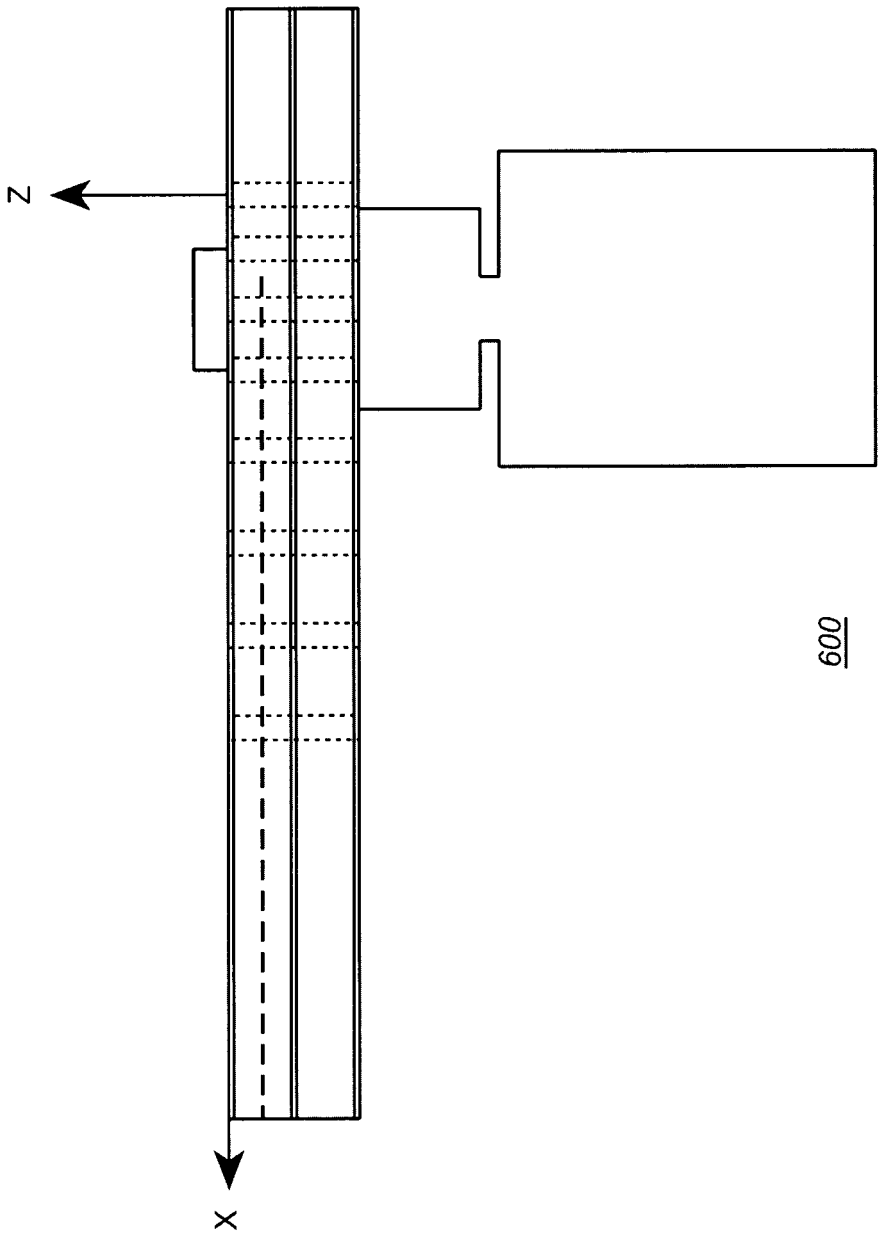


FIG. 7A

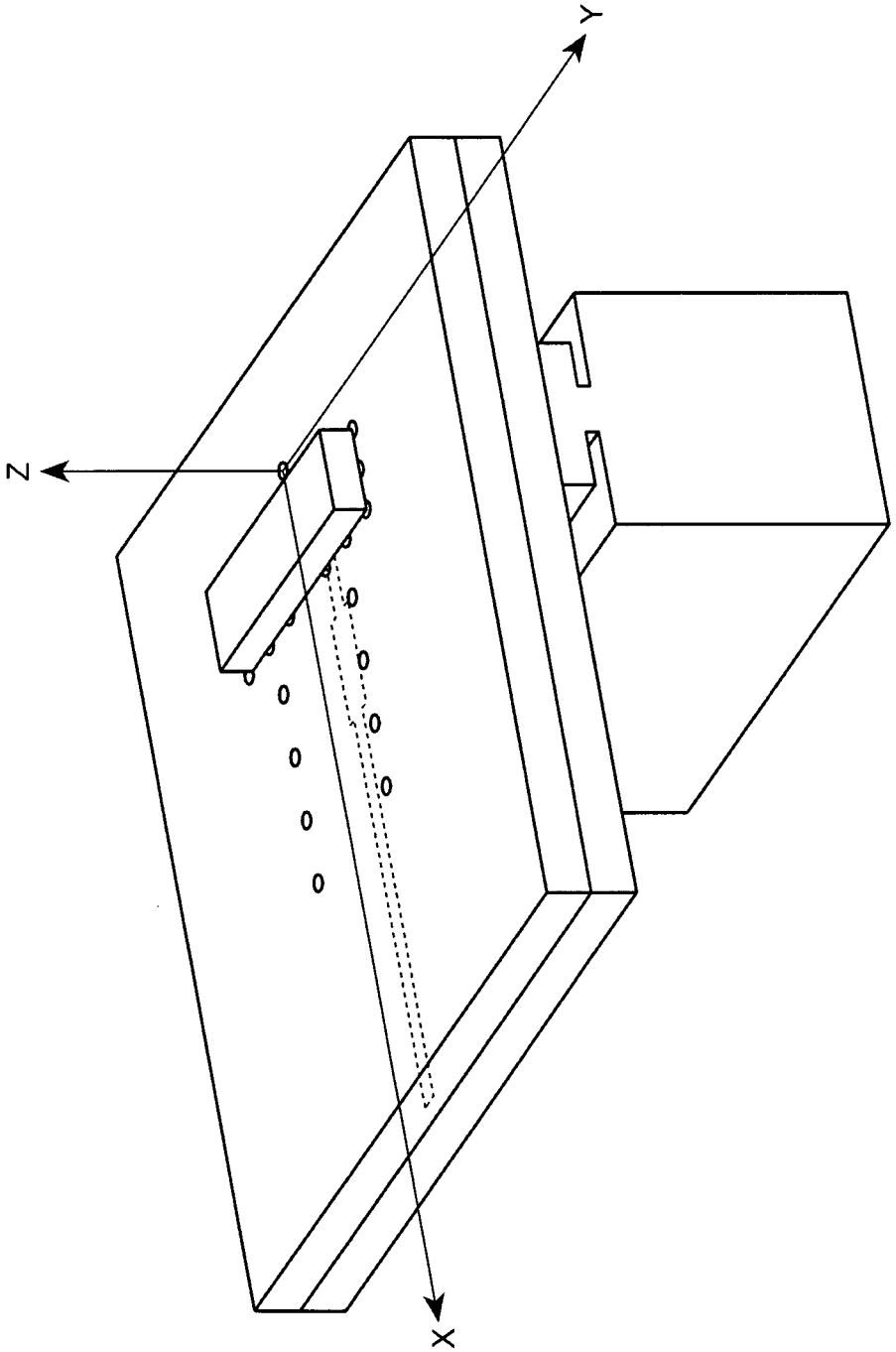


FIG. 7B

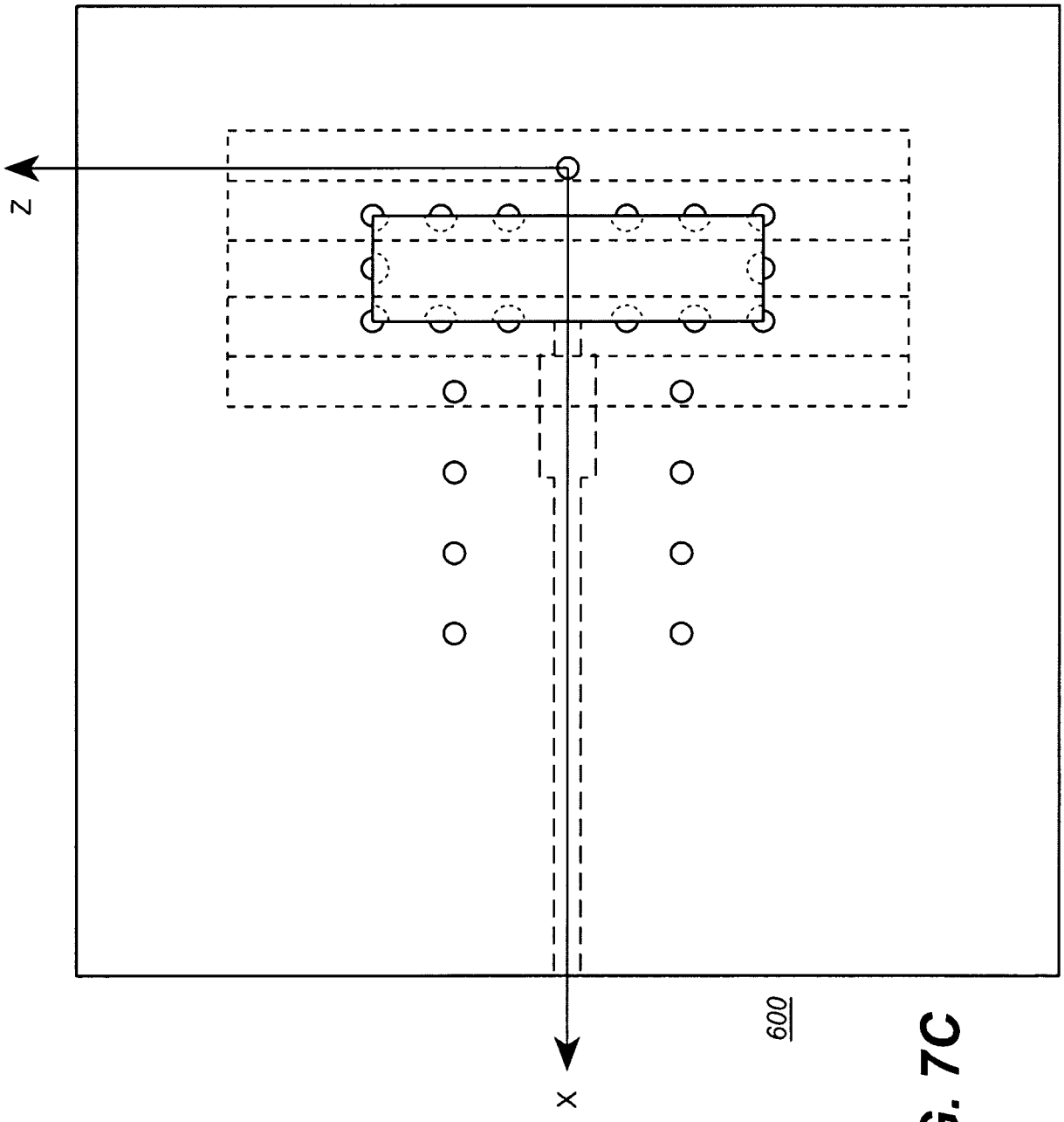


FIG. 7C

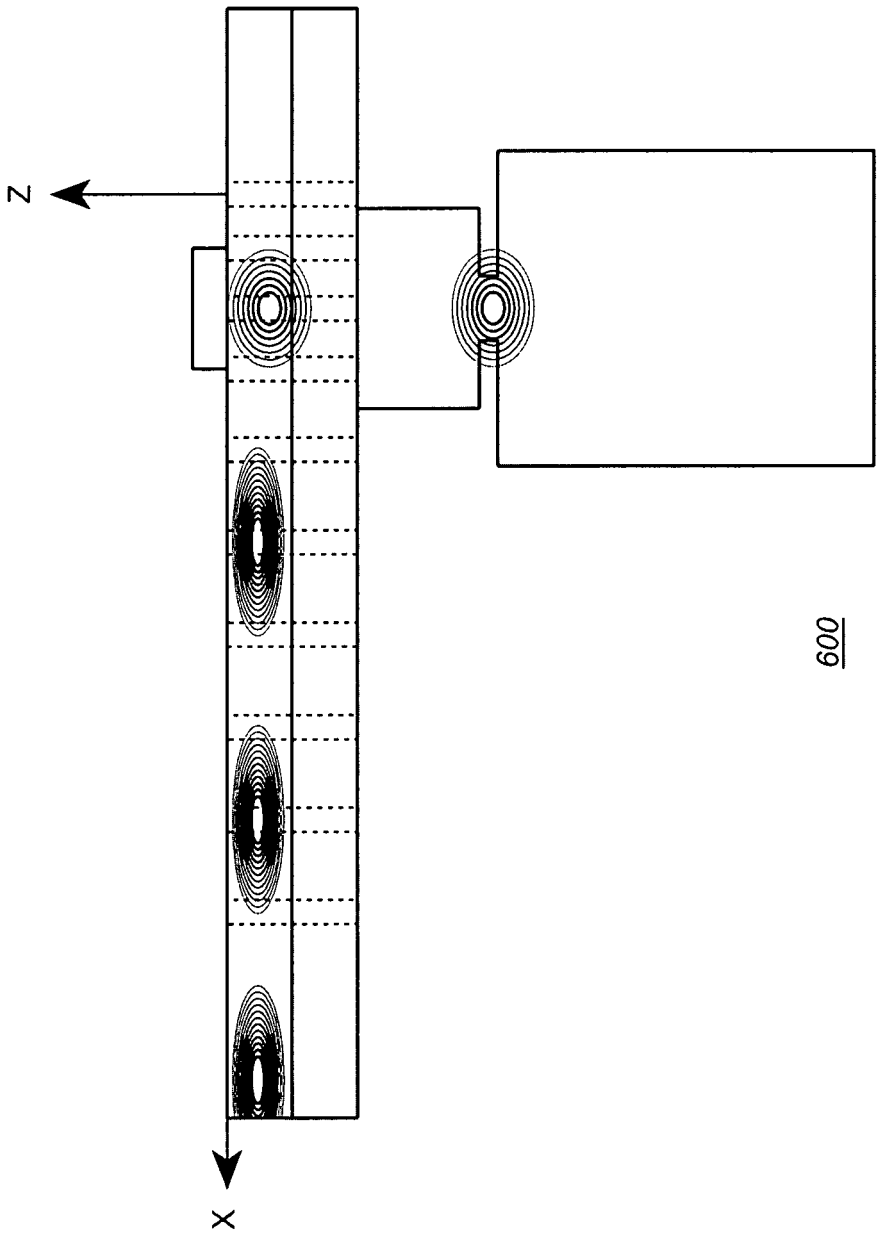


FIG. 7D

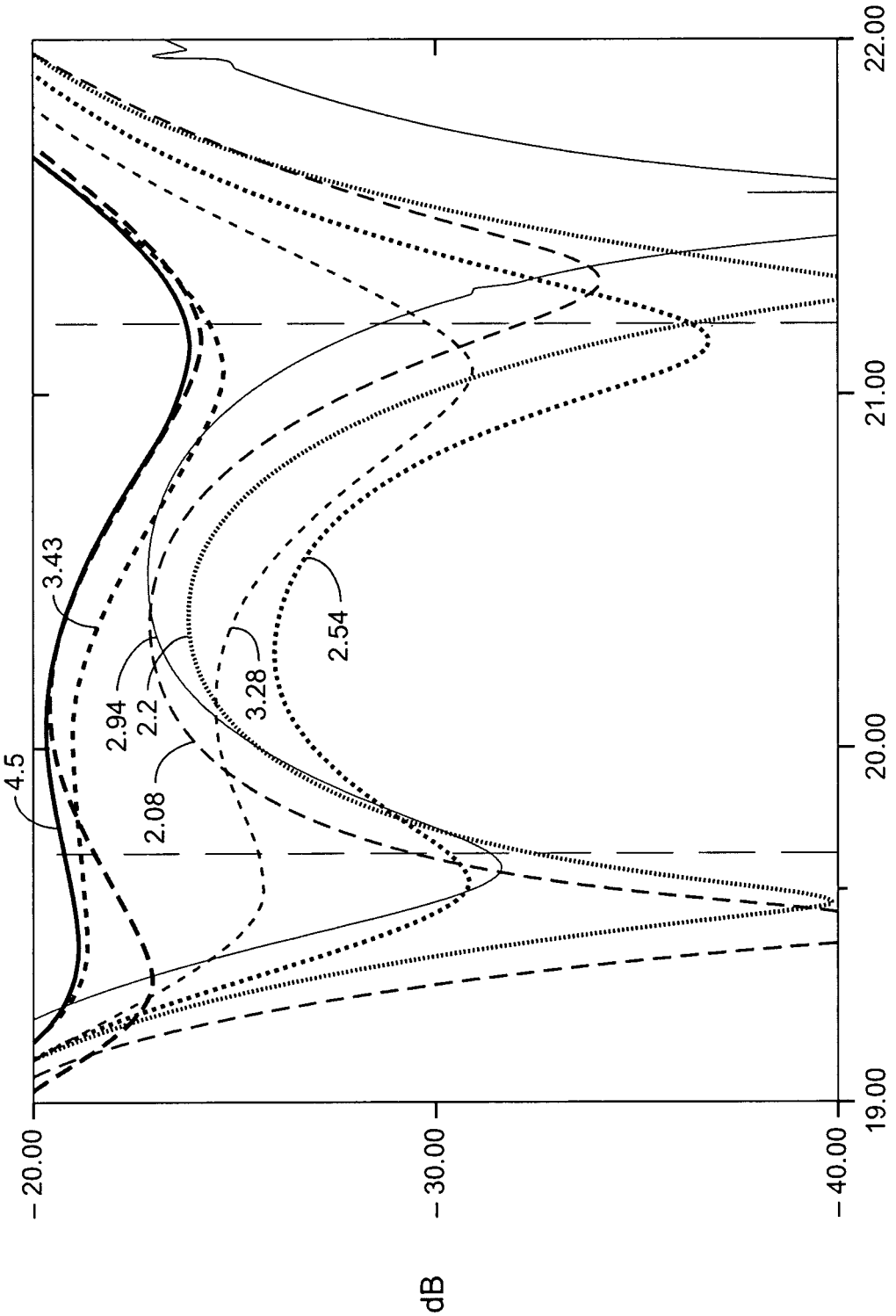

22.00
21.00
20.00
19.00
freq [GHz]
– 20.00
– 30.00
– 40.00
dB
4.5
3.43
2.94
2.2
2.08
3.28
2.54

FIG. 8

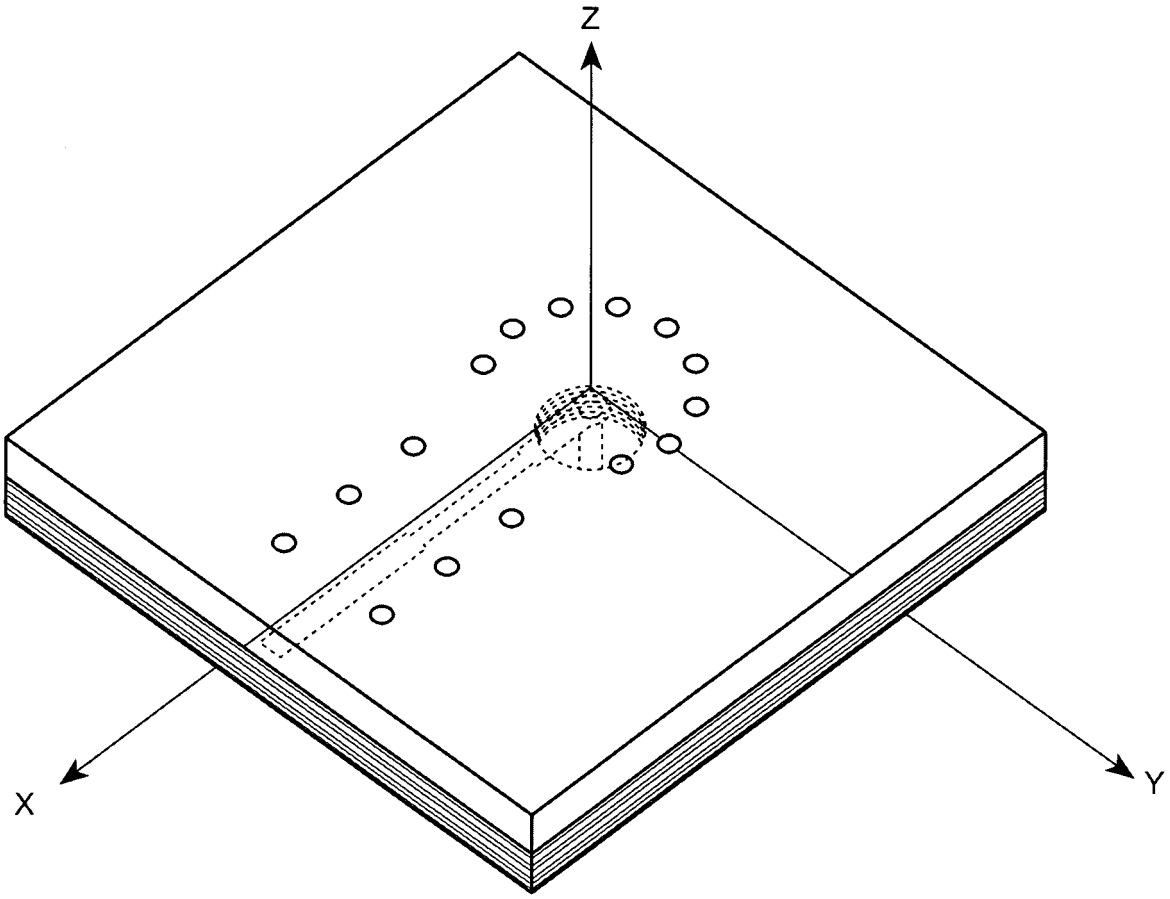


FIG. 9A

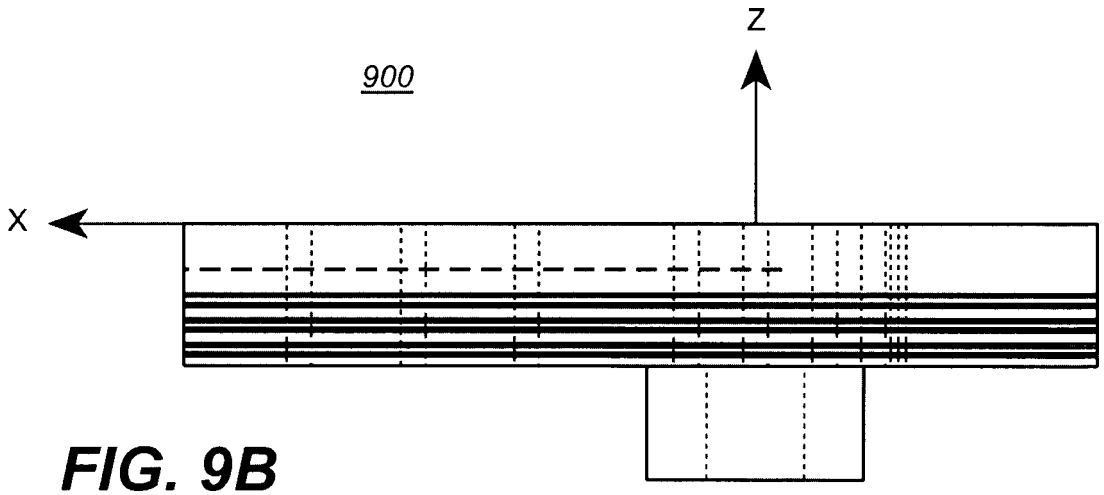


FIG. 9B

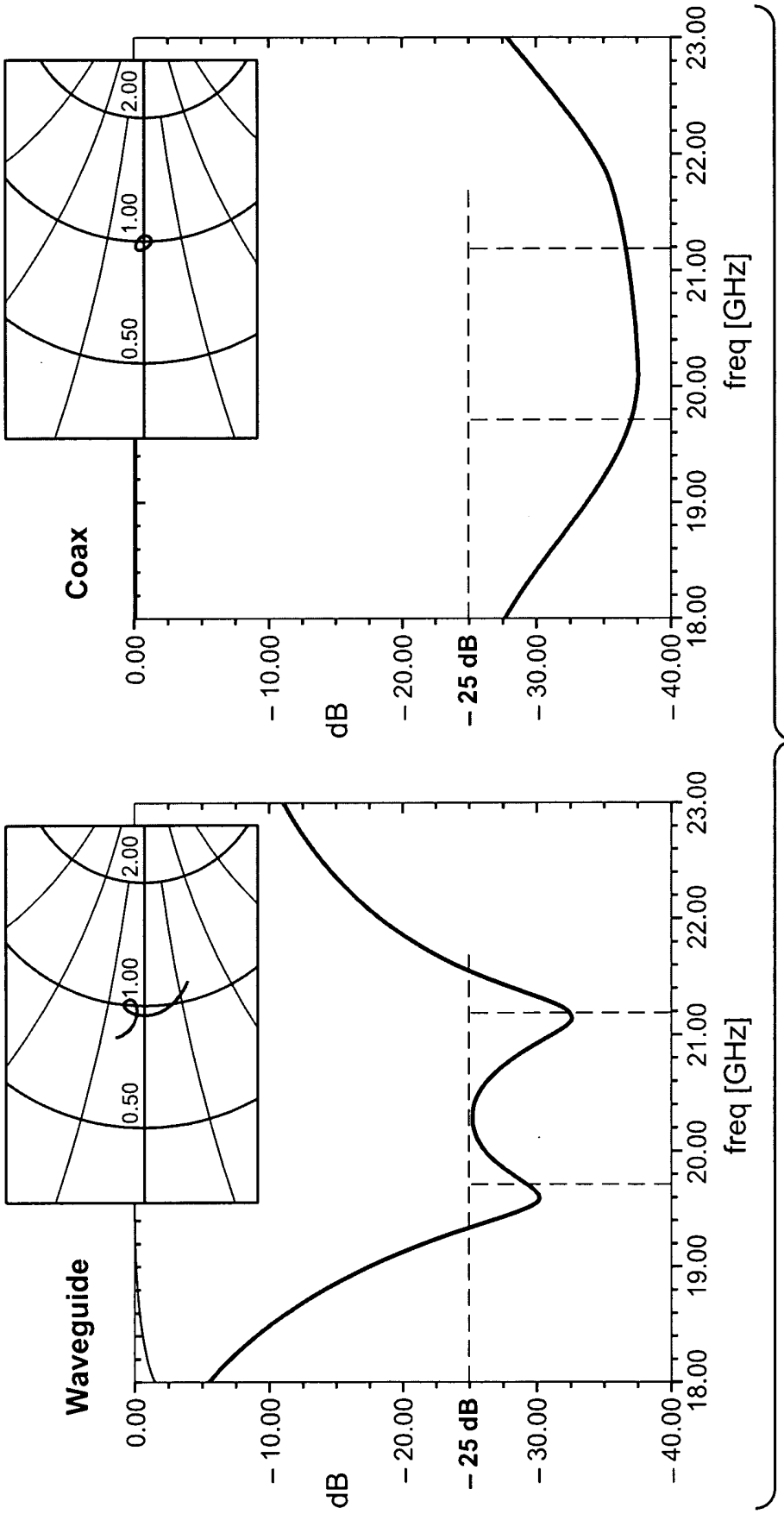

Coax
Waveguide
0.00
– 10.00
– 20.00
– 30.00
– 40.00
dB
– 25 dB
18.00
19.00
20.00
21.00
22.00
23.00
freq [GHz]
0.50
1.00
2.00

FIG. 9C

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 03049231 A **[0007]**