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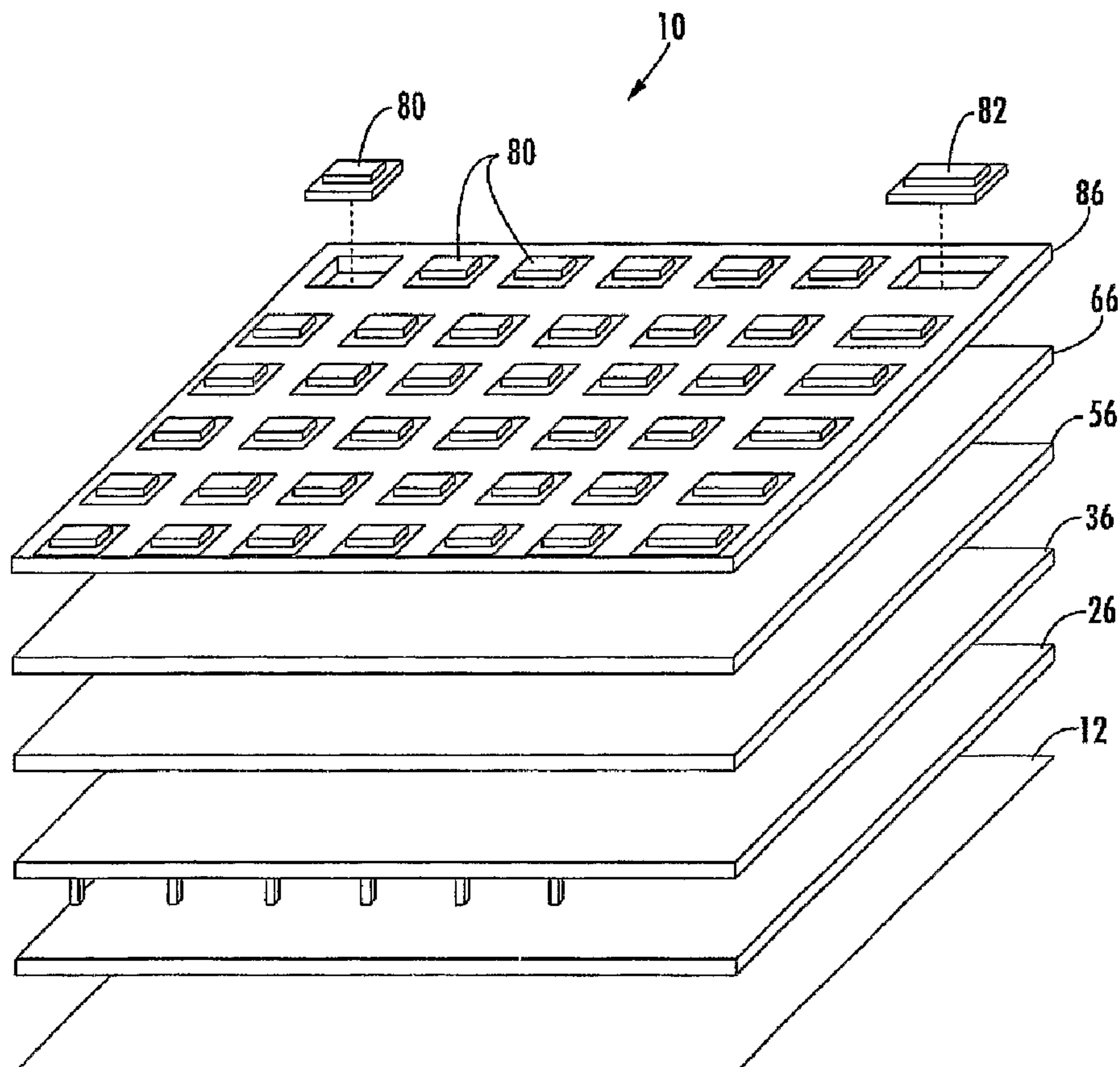
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(54) Titre : ANTENNE RESEAU COMPRENANT UN SYSTEME D'ALIMENTATION D'ANTENNE MONOLITHIQUE ET
PROCEDES ASSOCIES
(54) Title: ARRAY ANTENNA INCLUDING A MONOLITHIC ANTENNA FEED ASSEMBLY AND RELATED METHODS



(57) Abrégé/Abstract:

An antenna (10) includes antenna elements (16-22) , an antenna feed assembly (36) and at least one integrated circuit (80) adjacent the antenna feed assembly (36) on a side thereof opposite the antenna elements (16-22) . The at least one integrated



(57) **Abrégé(suite)/Abstract(continued):**

circuit (80) is connected to the antenna elements (16-22) via the antenna feed assembly (36) . The antenna feed assembly (36) includes a conductive base plate (38) spaced from the antenna elements (16-22) , and has feed openings (40) therein. Spaced apart conductive posts (42) are integrally formed with the conductive base plate (38) as a monolithic unit, and extend outwardly therefrom toward the antenna elements (16-22) . Each conductive post (42) has at least one passageway therethrough (46) aligned with at least one respective feed opening (40) to define at least one antenna feed passageway. A respective elongated feed conductor (50) extends through each antenna feed passageway.

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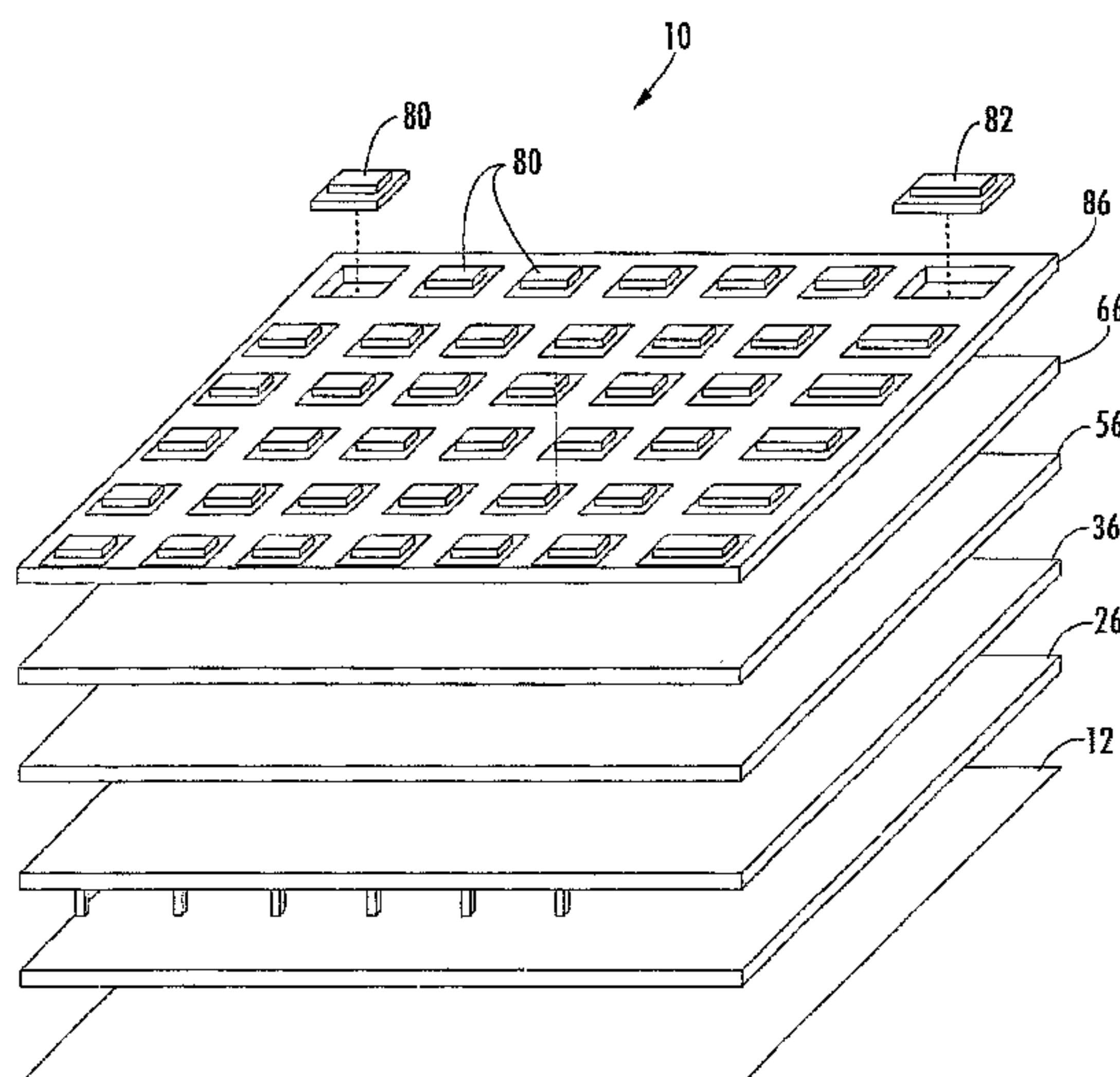
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(54) Title: ARRAY ANTENNA INCLUDING A MONOLITHIC ANTENNA FEED ASSEMBLY AND RELATED METHODS



(57) Abstract: An antenna (10) includes antenna elements (16-22), an antenna feed assembly (36) and at least one integrated circuit (80) adjacent the antenna feed assembly (36) on a side thereof opposite the antenna elements (16-22). The at least one integrated circuit (80) is connected to the antenna elements (16-22) via the antenna feed assembly (36). The antenna feed assembly (36) includes a conductive base plate (38) spaced from the antenna elements (16-22), and has feed openings (40) therein. Spaced apart conductive posts (42) are integrally formed with the conductive base plate (38) as a monolithic unit, and extend outwardly therefrom toward the antenna elements (16-22). Each conductive post (42) has at least one passageway therethrough (46) aligned with at least one respective feed opening (40) to define at least one antenna feed passageway. A respective elongated feed conductor (50) extends through each antenna feed passageway.

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**ARRAY ANTENNA INCLUDING A MONOLITHIC ANTENNA
FEED ASSEMBLY AND RELATED METHODS**

Background of the Invention

5 Existing phased array antennas include a wide variety of configurations for various applications, such as satellite reception and remote broadcasting. The desirable characteristics of low cost, light-weight, low profile and mass producibility are provided in general by printed circuit
10 antennas. Printed circuit antennas are defined by flat conductive elements spaced from a single, essentially continuous ground element by a dielectric sheet of uniform thickness.

 While a printed circuit antenna is advantageous in
15 applications requiring a conformal configuration, e.g., in aerospace systems, mounting the antenna presents challenges. One of these challenges is with respect to the manner in which it is fed such that conformality and satisfactory radiation coverage and directivity are maintained and losses to
20 surrounding surfaces are reduced.

 An antenna feed assembly for a phased array antenna with a wide frequency bandwidth and a wide scan angle is disclosed in U.S. Patent No. 6,483,464. The '464 patent is assigned to the current assignee of the present invention, and
25 is incorporated herein by reference in its entirety. In particular, this antenna can be conformally mounted to a surface, and the antenna feed assembly includes a respective feed line organizer body having passageways therein for receiving the respective coaxial feed lines for a
30 corresponding antenna element. Each respective feed line organizer body is individually coupled to the ground plane using four screws. Although this patent discloses a significant advance in such antennas, individually coupling the feed line organizer bodies to the ground plane is a

tedious and time consuming process, especially when the phased array antenna includes a large number of antenna elements. In addition, manufacturing costs may be increased as a result of this process.

5

Summary of the Invention

In view of the foregoing background, it is therefore an object of the present invention to provide an array antenna that is relatively straightforward to produce, particularly
10 with respect to the antenna feed assembly.

This and other objects, features, and advantages in accordance with the present invention are provided by an antenna comprising a plurality of antenna elements, an antenna feed assembly, and at least one integrated circuit adjacent
15 the antenna feed assembly on a side thereof opposite the antenna elements and connected thereto via the antenna feed assembly.

The antenna feed assembly may comprise a conductive base plate spaced from the plurality of antenna elements, and
20 the conductive base plate has a plurality of feed openings therein. A plurality of spaced apart conductive posts are integrally formed with the conductive base plate as a monolithic unit, and extend outwardly therefrom toward the plurality of antenna elements. Each conductive post may have
25 at least one passageway therethrough aligned with at least one respective feed opening in the conductive base plate to define at least one antenna feed passageway. A respective elongated feed conductor may extend through each antenna feed passageway.

30 The conductive base plate functions as a ground plane for the plurality of antenna elements. Since each conductive post is integrally formed with the conductive base plate as a monolithic unit, this advantageously allows the antenna feed assembly to be formed in a relatively

straightforward manner. For example, the antenna feed assembly may be machined from a block of conductive material. The cost of an antenna with an antenna feed assembly machined from a block of conductive material may be significantly
5 reduced. Moreover, since the conductive posts and the conductive base plate are formed as a monolithic unit, the antenna feed assembly is more reliable, particularly during periods of extreme vibration.

The plurality of antenna elements may comprise first
10 and second sets of orthogonal antenna elements to provide dual polarization. For a dual polarization, each conductive post has four passageways for interfacing with a respective first and second set of orthogonal antenna elements.

The antenna may further comprise a dielectric layer
15 between the plurality of antenna elements and the conductive base plate. The antenna has a desired frequency range, and the dielectric layer has a thickness that is equal to or less than one-half a wavelength of a highest desired frequency.

The at least one integrated circuit may comprise a
20 plurality of active Balun integrated circuits. The active Balun integrated circuits advantageously provide impedance matching with the antenna elements. In addition, the Baluns replace the 0/180 degree hybrid circuits normally used with this type of antenna - which resulted in a 3 dB power loss.
25 Moreover, in addition to overcoming this power loss, the Balun integrated circuits may also comprise low noise amplifiers.

The antenna may further comprise a beam forming network layer coupled to the active Balun integrated circuits so that the antenna is a phased array antenna. The beam
30 forming network layer is based upon strip lines sandwiched between ground planes, and replaces the coaxial cables normally associated with this type of antenna. The advantages are two-fold. First, the thickness of the beam forming network layer is smaller by about a factor of six as compared

to the use of coaxial cables. Second, the strip lines help to dissipate heat away from the antenna elements and the active Balun integrated circuits.

5 The antenna may further comprise at least one time delay integrated circuit coupled to the beam forming network layer. The time delay integrated circuits may be programmable to define a scan angle of about ± 50 degrees.

10 The antenna may further comprise a power and control distribution network layer coupled to the active Balun integrated circuits and the beam forming network layer. The array of antenna elements is sized and relatively positioned so that the antenna is operable over a frequency range of 2 to 18 GHz. The antenna has an overall thickness that is less than or equal to about 1 inch.

15 Another aspect of the present invention is directed to a method for making an antenna as described above. The method comprises forming a plurality of antenna elements, forming an antenna feed assembly, and connecting at least one integrated circuit to the plurality of antenna elements via
20 the antenna feed assembly. The at least one integrated circuit may be adjacent the antenna feed assembly on a side thereof opposite the plurality of antenna elements.

More particularly, forming the antenna feed assembly comprises forming a conductive base plate spaced from the
25 plurality of antenna elements and having a plurality of feed openings therein, and forming as a monolithic unit a plurality of spaced apart conductive posts with the conductive base plate. The plurality of spaced apart conductive posts extend outwardly from the conductive base plate toward the plurality
30 of antenna elements. Each conductive post may have at least one passageway therethrough aligned with at least one respective feed opening to define at least one antenna feed passageway connecting the at least one integrated circuit to

the plurality of antenna elements via the antenna feed assembly.

Brief Description of the Drawings

5 FIG. 1 is a top schematic plan view of a dual polarization phased array antenna in accordance with the present invention.

 FIG. 2 is an exploded perspective view of the dual polarization phased array antenna illustrated in FIG. 1.

10 FIG. 3 is a top plan view of the antenna feed assembly illustrated in FIG. 2.

 FIG. 4 is a side view of the antenna feed assembly illustrated in FIG. 2.

 FIG. 5 is a partial cross-sectional side view of the
15 phase array antenna in accordance with the present invention.

Detailed Description of the Preferred Embodiments

 The present invention will now be described more fully hereinafter with reference to the accompanying drawings,
20 in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and
25 complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

 Referring initially to FIG. 1, an antenna 10 according to the invention includes a plurality of antenna
30 units 12 arranged in an array. The illustrated antenna 10 includes 36 antenna units 12 formed on a printed conductive sheet 14, where each antenna unit includes four adjacent dipole antenna elements 16, 18, 20, 22 arranged in a spaced apart relation from one another about a central feed position

24. The 36 antenna units **12** are for illustrative purposes only, and the antenna **10** may include a larger number of antenna units, such as 250 or more, for example.

5 The four adjacent antenna elements **16-22** for each antenna unit **12** may be arranged as first and second sets of orthogonal antenna elements, e.g., **16/22** and **18/20**, to provide dual polarization. Of course, only a single pair of antenna elements, e.g., **16/22**, may be used to provide for a single polarization embodiment.

10 The array of antenna units **12** are sized and relatively positioned so that the antenna **10** is operable over a desired frequency range, such as 2 to 18 GHz, for example, which is a 9:1 bandwidth. Of course, the antenna units **12** may be sized and positioned to support other frequency bands,
15 including frequency bands with a larger bandwidth. For a more detailed discussion on the different features and embodiments of the antenna units, reference is directed to U.S. Patent No. 6,512,487. The '487 patent discloses dipole antenna elements and is assigned to the current assignee of the present
20 invention, and is incorporated herein by reference in its entirety.

The antenna **10** will now be discussed with reference to FIGS. 2-5. The antenna **10** is made up of a plurality of layers. The different layers are fabricated by standard PCB
25 techniques, and the antenna **10** can be conformally mounted to a desired surface as readily appreciated by those skilled in the art. The outermost layer is the array of antenna units **12** carried by the printed conductive sheet **14**. A dielectric layer **26** is between the printed conductive sheet **14** and an
30 antenna feed assembly **36**. The dielectric layer **26** has a thickness that is typically equal to or less than about one-half a wavelength of a highest desired frequency, e.g., 18 GHz.

The antenna feed assembly **36** comprises a conductive base plate **38** spaced from the array of antenna elements **16-22**, and the conductive base plate has a plurality of feed openings **40** therein. A plurality of spaced apart conductive posts **42** are integrally formed with the conductive base plate **38** as a monolithic unit, and extend outwardly therefrom toward the plurality of antenna elements **16-22**. Each conductive post **42** has a plurality of passageways therethrough **46** that are aligned with a plurality of respective feed opening **40** in the conductive base plate **38** to define a plurality of antenna feed passageways.

A respective elongated feed conductor **50** extends through each antenna feed passageway. For dual polarization, each conductive post **42** has four passageways **46** therethrough for interfacing with a respective first and second set of orthogonal antenna elements **16/22** and **18/20**, and a respective elongated feed conductor **50** extends through each passageway **46**. A distance that each conductive post **42** extends from the conductive base plate **38** is based on the highest operating frequency of the antenna **10**, i.e., one-half the wavelength of the highest desired frequency. The thickness of the dielectric layer **24** and the distance the conductive posts **42** extend from the conductive base plate **38** are substantially equal.

The conductive base plate **38** functions as a ground plane for the plurality of antenna elements **16-22**. Since each conductive post **42** is integrally formed with the conductive base plate **38** as a monolithic unit, this advantageously allows the antenna feed assembly **36** to be formed in a relatively straightforward manner. For example, the antenna feed assembly **36** may be machined from a solid block of conductive material, such as brass.

The cost of an antenna **10** with an antenna feed assembly **36** that is machined from a solid block of conductive

material may be significantly reduced. The weight is also reduced. Moreover, since the conductive posts 42 and the conductive base plate 38 are formed as a monolithic unit, the antenna feed assembly 36 is more reliable, particularly during
5 periods of extreme vibration. The common mode normally associated with multiple feed structures is also reduced.

Each conductive post 42 is illustrated as being rectangular shaped, although other shapes are acceptable. An example diameter d of each respective passageway 46
10 therethrough is 0.028 inches. An example distance x between a center of any two passageways 46 is 0.048 inches. A corresponding width w of the sides 43 of each conductive post 42 is 0.100 inches. The antenna feed assembly 36 also includes a plurality of alignment posts 52 used in assembling
15 together the plurality of layers of the antenna 10.

A DC power and control distribution network layer 56 is adjacent the antenna feed assembly 36. The DC power and control distribution network layer 56 includes a ground plane 58 and typically 2 or more DC/control layers 60, as best
20 illustrated in FIG. 5.

A beam forming network layer 66 is adjacent the DC power and control distribution network layer 56, and a plurality of integrated circuits 80 are connected to the beam forming network layer so that the antenna 10 is a phased array
25 antenna. The beam forming network layer 66 includes couplers, i.e., a summing network, for summing the signals from the antenna elements 16-22. The beam forming network layer 66 is based upon strip lines 68 sandwiched between ground planes 70 and 72, as illustrated in FIG. 5, and replaces the coaxial
30 cables normally associated with this type of antenna. The advantages are two-fold. First, the thickness of the beam forming network layer 66 is smaller by about a factor of six as compared to the use of coaxial cables. Second, the strip

lines help to dissipate heat away from the antenna elements **16-22** and the integrated circuits **80**.

The integrated circuits **80** comprise a plurality of active MMIC Balun integrated circuits. The Balun integrated circuits **80** advantageously provide impedance matching, e.g., 50 ohms, between the antenna elements **16-22** and the beam forming network layer **66**. Each Balun integrated circuit may further comprise a low noise amplifier for amplifying signals. There is an active Balun integrated circuit **80** for each antenna unit **12**.

In addition, the Balun integrated circuits **80** replace the 0/180 degree hybrid circuits normally used with this type of antenna. The 0/180 degree hybrid circuits are passive devices, and there was typically a 3 dB power loss associated with these circuits. Not only do the active MMIC Balun integrated circuits **80** avoid this 3 dB power loss, but they also reduce the effects of any losses associated with the strip lines **68** in the beam forming network layer **66**. Insertion loss is also reduced and the active Balun integrated circuits **80** also provide an improved noise figure because of the low noise amplifiers included therein.

The antenna **10** may further comprise a plurality of time delay integrated circuits **82** coupled to the beam forming network layer **66**. The time delay integrated circuits add up in phase all the signals arriving at each individual antenna element **16-22**. The time delay integrated circuits **82** may be programmable so that the phased array antenna is operable over a scan angle of about ± 50 degrees, for example. The time delay integrated circuits **82** may be 6 bit integrated circuits, for example. A ribbon **90** connects the integrated circuits **80**, **82** to the DC power and control distribution network layer **56**.

The illustrated antenna **10** is compact, and has an overall thickness that is less 1 inch, and more particularly, is about 0.7 inches. The 0.7 inches overall thickness is

based upon the integrated circuits **80**, **82** being recessed within the dielectric layer **86** carrying the integrated circuits so that the upper surface of these integrated circuits is flush with the upper surface of the dielectric layer.

Another aspect of the present invention is directed to a method for making an antenna **10** as described above. The method comprises forming a plurality of antenna elements **16-22**, forming an antenna feed assembly **36**, and connecting at least one integrated circuit **80** to the plurality of antenna elements via the antenna feed assembly. The at least one integrated circuit **80** is adjacent the antenna feed assembly **36** on a side thereof opposite the plurality of antenna elements **16-22**.

More particularly, forming the antenna feed assembly **36** comprises forming a conductive base plate **38** spaced from the plurality of antenna elements **16-22** and having a plurality of feed openings **40** therein, and forming as a monolithic unit a plurality of spaced apart conductive posts **42** with the conductive base plate. The plurality of spaced apart conductive posts **42** extend outwardly from the conductive base plate **38** toward the plurality of antenna elements **16-22**. Each conductive post **42** has at least one passageway **46** therethrough aligned with at least one respective feed opening **40** to define at least one antenna feed passageway connecting the at least one integrated circuit **80** to the plurality of antenna elements **16-22** via the antenna feed assembly **36**.

THAT WHICH IS CLAIMED IS:

1. An antenna comprising:
a plurality of antenna elements;
5 an antenna feed assembly comprising
a conductive base plate spaced from said
plurality of antenna elements and having a plurality
of feed openings therein,
a plurality of spaced apart conductive
10 posts integrally formed with said conductive base
plate as a monolithic unit and extending outwardly
therefrom toward said plurality of antenna elements,
each conductive post having at least one passageway
therethrough aligned with at least one respective
15 feed opening to define at least one antenna feed
passageway, and
a respective elongated feed conductor
extending through each antenna feed passageway; and
at least one integrated circuit adjacent said
20 antenna feed assembly on a side thereof opposite said
plurality of elements and connected thereto via said antenna
feed assembly.
2. An antenna according to Claim 1 wherein said
25 at least one integrated circuit comprises a plurality of
active Balun integrated circuits.
3. An antenna according to Claim 1 wherein said
at least one integrated circuit comprises an amplifier.
- 30 4. An antenna according to Claim 1 further
comprising a beam forming network layer coupled to said at
least one integrated circuit.

5. An antenna according to Claim 4 further comprising at least one time delay integrated circuit coupled to said beam forming network layer.

5 6. A method for making an antenna comprising:
forming a plurality of antenna elements;
forming an antenna feed assembly comprising
forming a conductive base plate spaced
from the plurality of antenna elements and having a
10 plurality of feed openings therein,
forming as a monolithic unit a plurality
of spaced apart conductive posts with the conductive
base plate, the plurality of spaced apart conductive
posts extending outwardly from the conductive base
15 plate toward the plurality of antenna elements,
each conductive post having at least one passageway
therethrough aligned with at least one respective
feed opening to define at least one antenna feed
passageway, and
20 extending a respective elongated feed
conductor through each antenna feed passageway; and
connecting at least one integrated circuit to the
plurality of antenna elements via the antenna feed assembly,
the at least one integrated circuit being adjacent the antenna
25 feed assembly on a side thereof opposite the plurality of
elements.

7. A method according to Claim 6 wherein the at least one integrated circuit comprises a plurality of active
30 Balun integrated circuits.

8. A method according to Claim 6 wherein the at least one integrated circuit comprises an amplifier.

9. A method according to Claim 6 further comprising coupling a beam forming network layer to the at least one integrated circuit.

5 10. A method according to Claim 9 further comprising coupling at least one time delay integrated circuit to the beam forming network layer.

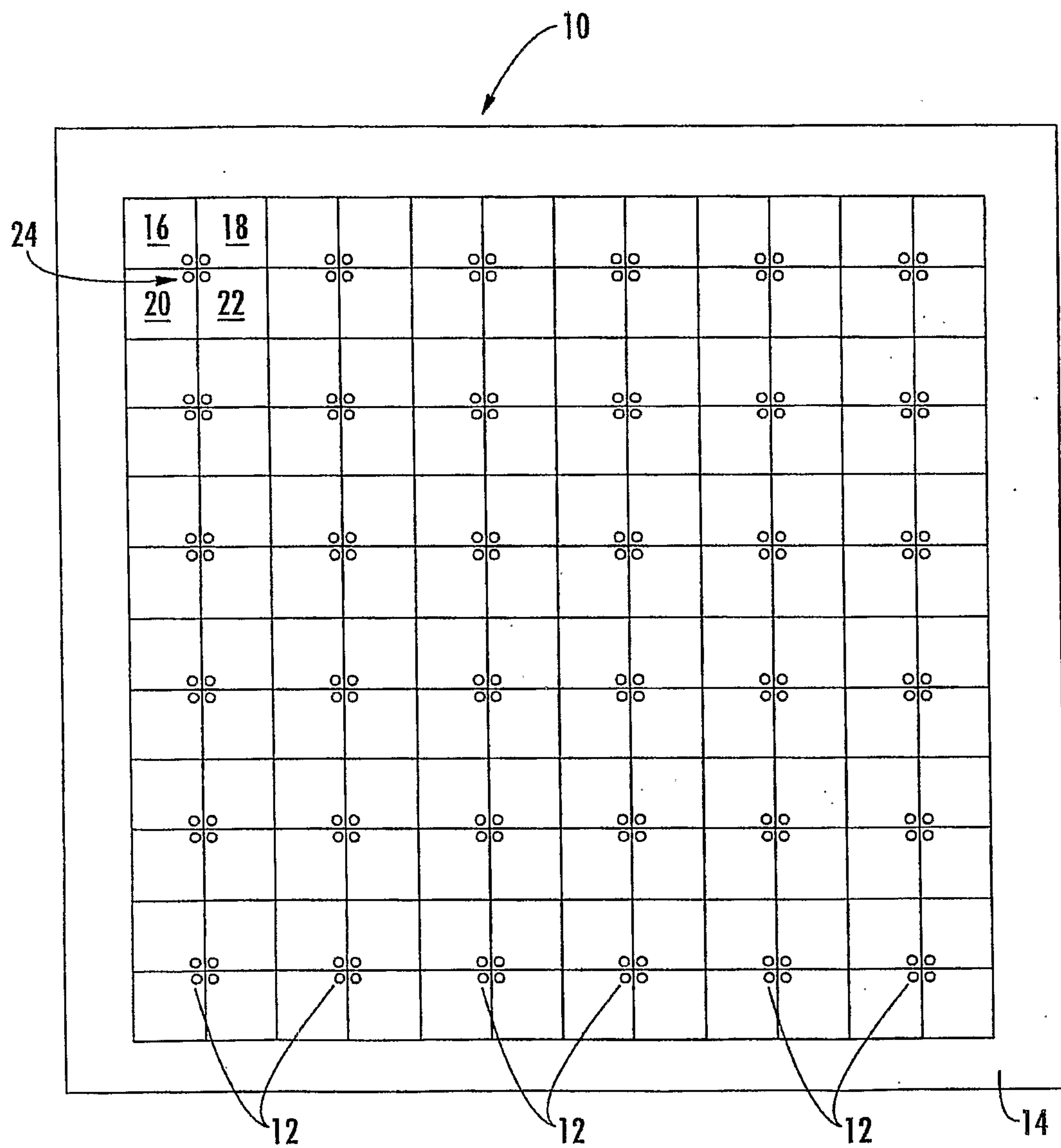


FIG. 1

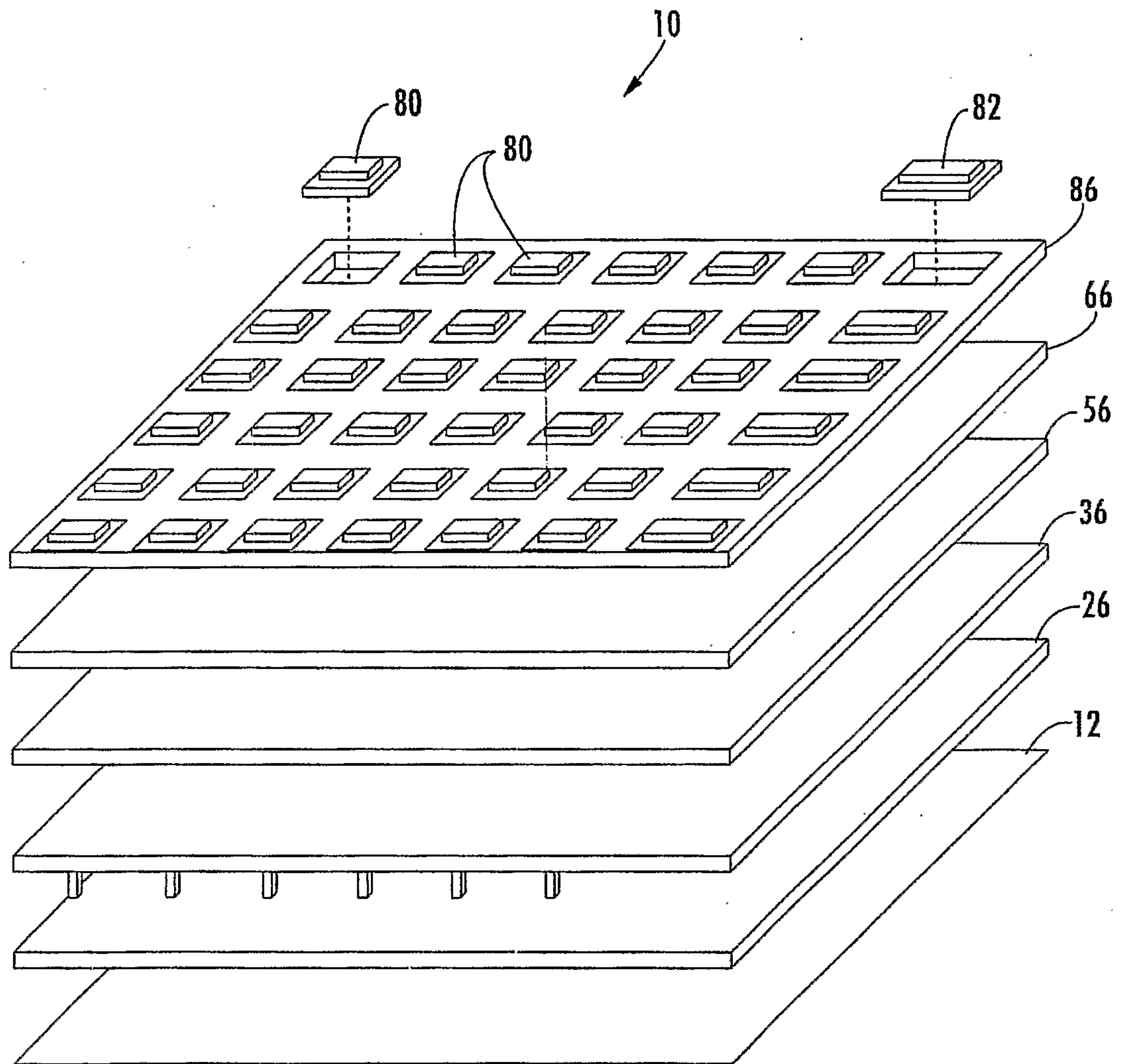


FIG. 2

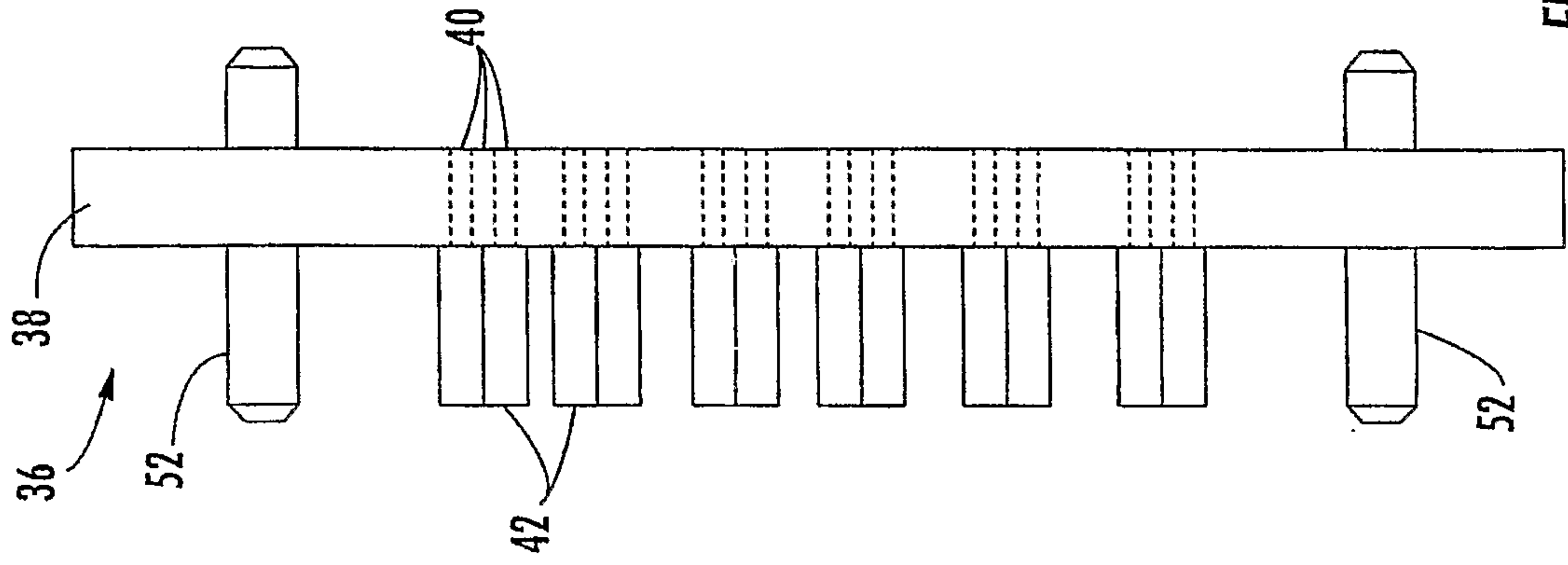


FIG. 4

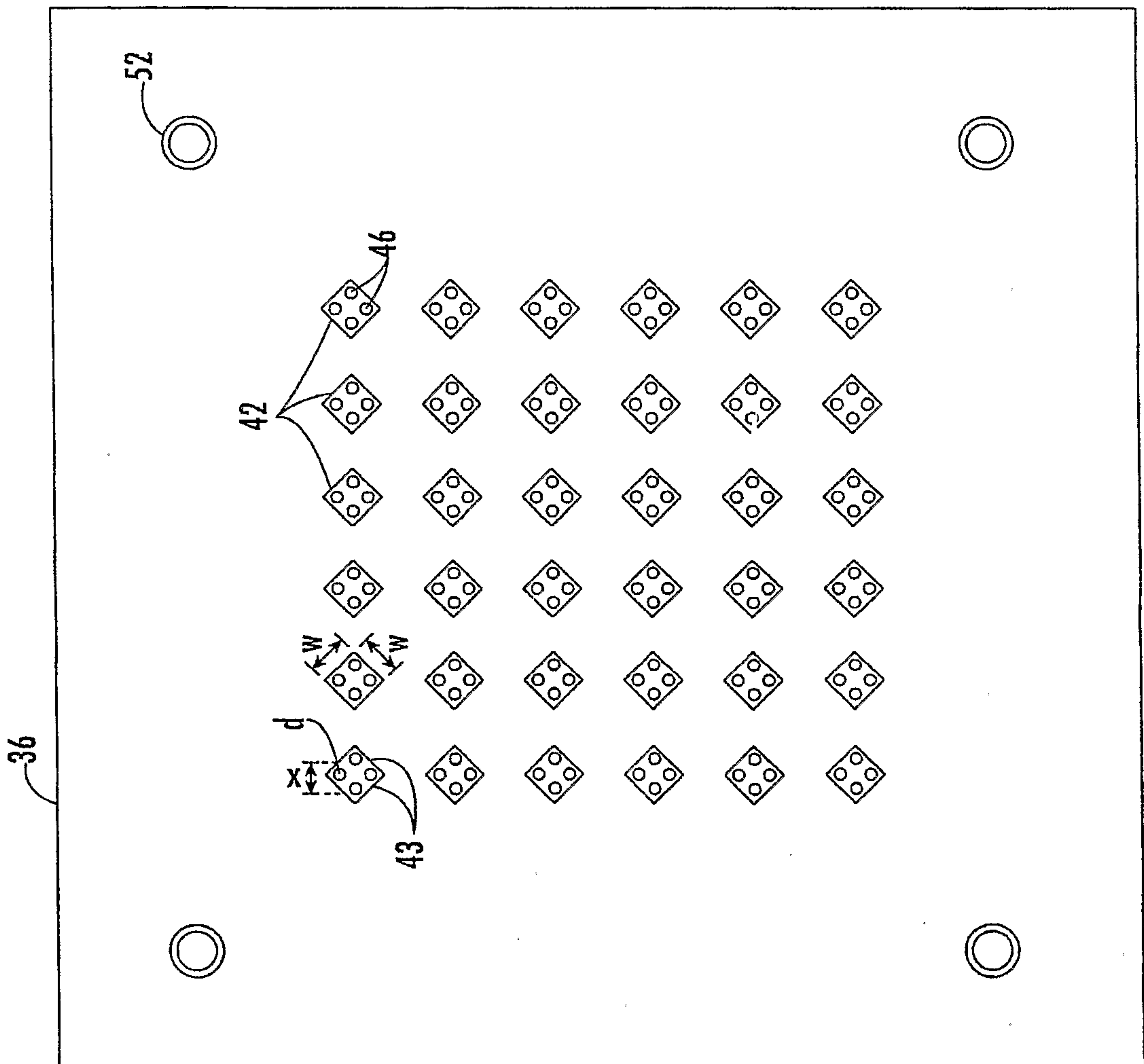


FIG. 3

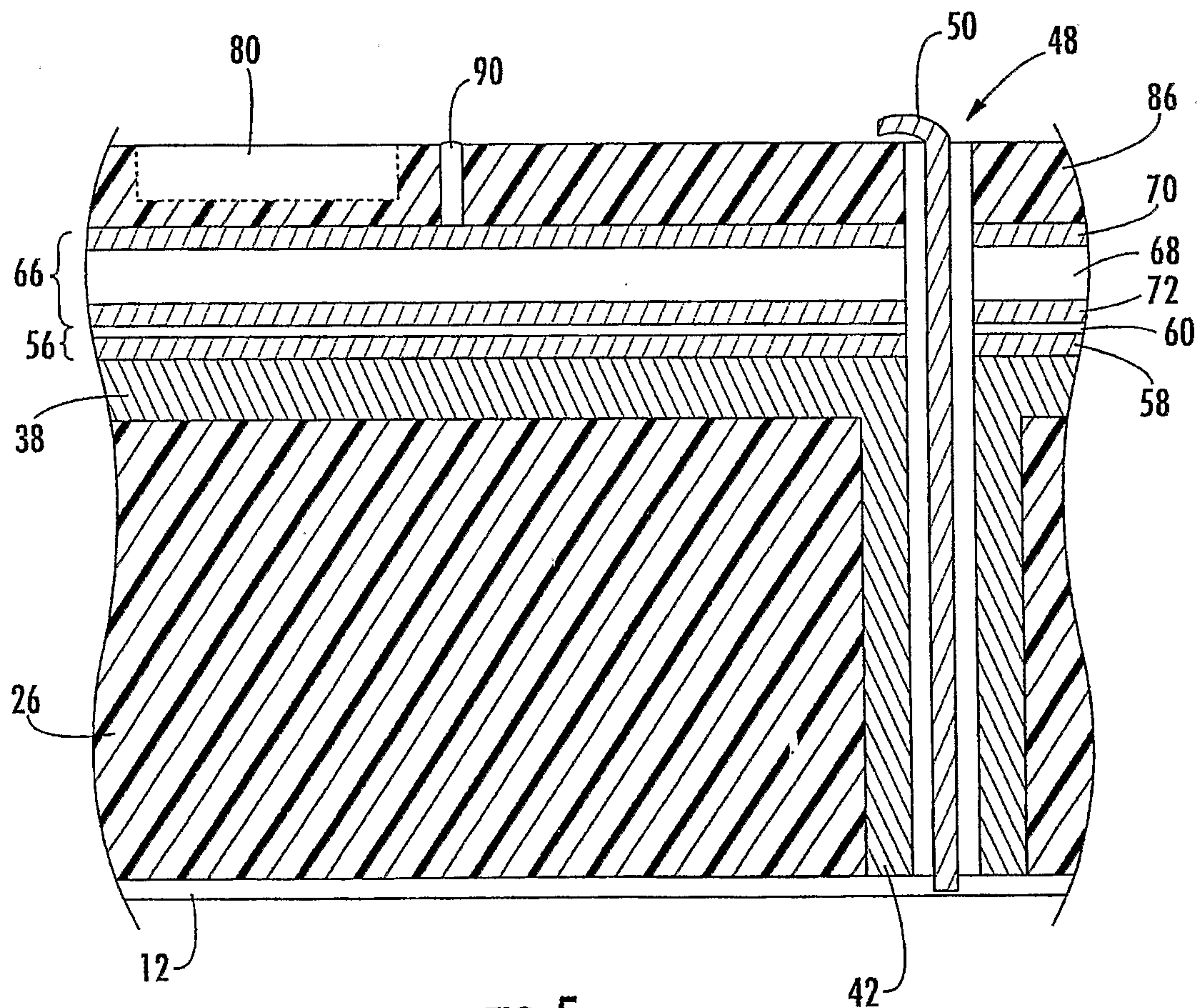


FIG. 5

