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Navy Case No. 77347

MULTI-LAYER TILED ARRAY

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to planar sonar arrays. More particularly, the invention relates to the arrangement of transducer elements in planar sonar arrays.

(2) Description of the Prior Art

Conventional planar sonar array designs typically comprise ceramic or polyvinylidene fluoride (PVDF) transducer elements arranged in a single plane according to a required inter-element spacing. The inter-element spacing is based on the half wavelength dimension of acoustic signals at the desired operating frequency. There are several disadvantages associated with this conventional array design. First, the inter-element spacing places an upper bound on the center to center distance between adjacent elements. If this upper bound is violated, beamformed acoustic energy will be allowed to fold back spatially, resulting in false indications of received energy. This is analogous to frequency domain aliasing where the Nyquist criteria has been violated, but in the case of a beamformer or spatial filter, the independent variable is bearing instead of frequency.

Furthermore, because the inter-element spacing constrains the maximum separation distance between elements, there is a corresponding upper bound on element size. That is, as the inter-element spacing is decreased, the area available for the element face decreases as a function of the square of the linear dimension of the element's side. Element signal-to-noise ratio is proportional to the volume of an element and decreases as the elements get smaller. Furthermore, since the PVDF transducer elements used in conventional array construction are essentially flat plate capacitors, the capacitance of any element is directly proportional to the electrode area of the element. As the area available for the element electrode decreases, the capacitance is lowered, thereby increasing electronic noise floor levels. Elevated noise floor levels can mask acoustic signals of interest. Furthermore, the effects of the increased noise floor levels can be exacerbated by the fact that at certain operating frequencies, the deep ocean ambient sound pressure level has a notch making it the quietest region in the usable spectrum. It is at these frequencies that problems resulting from the limited capacitance of the elements are most noticeable.

In addition to the sensitivity and detection problems, elevated noise floor levels complicate the fabrication of conventional arrays. To keep the electronic noise floor level as low as possible, the capacitive loading of the elements must be kept at a minimum. The capacitive loading at the elements is kept at a minimum by keeping the lead lengths of any signal conditioners (preamplifiers) as short as possible. However, this requirement complicates fabrication and provides little space to connect the preamplifiers.

Two alternatives have been considered to increase the capacitance in a flat plate capacitor without increasing the area of the electrodes. One approach is to decrease the spacing between the two electrodes of the capacitor. The second approach is to increase the dielectric constant of the material between the electrodes. However, neither of these approaches has proven feasible for use in elements within a sonar array. The first approach decreased the element sensitivity greatly and alternative dielectric materials considered in the second approach either decreased the element sensitivity or increased the thermal noise of the array.

Thus, what is needed is a planar array with an arrangement for the individual elements that increases the capacitance of the elements by increasing their surface area while maintaining the inter-element spacing required to avoid spatial aliasing in the received signals.

SUMMARY OF THE INVENTION

Accordingly, it is a general purpose and object of the present invention to provide a sonar array that maximizes the capacitance of the array elements while maintaining the required inter-element spacing.

Another object of the present invention is to increase the distance between the array element preamplifiers and the elements.

A further object of the present invention is to reduce the electronic noise floor levels of the array element and preamplifier combinations.

These and other objects made apparent hereinafter are accomplished with the present invention by providing a multi-layer tiled arrangement for the individual elements that increases the capacitance of the elements by increasing their surface area while maintaining a required inter-element spacing. The array comprises an outer array and an inner array of transducer elements which convert an acoustic pressure to an electrical response. The transducer elements of the outer array are positioned so as to form a grid of isolation spaces separating each one of the transducer elements. Similarly, the inner array also has transducer elements arranged in a two dimensional matrix with a grid of isolation spaces separating each one of the transducer elements. When an acoustic signal reaches the array, a portion of the signal strikes the transducer elements of the outer array and a portion of the signal propagates through the outer array and strikes the transducer elements of the inner array. The electrical response generated by the transducer elements are conditioned by preamplifiers that are coupled to a beamformer. The beamformer combines and post-processes the conditioned signals from the elements of the outer and inner arrays as signals from a single array of transducers.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein like reference numerals and symbols designate identical or corresponding parts throughout the several views and wherein:

FIG. **1** is a block diagram of a multi-layer tiled array;

FIG. **2** is a diagram showing an arrangement of transducer elements for a section of a multi-layer tiled array; and

FIG. **3** shows a cross-sectional view of a multi-layer tiled array.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, there is shown in FIG. **1** a block diagram of a multi-layer tiled array **10** in accordance with the present invention. Array **10** comprises an outer array **12a** of transducer elements **14a** and an inner array **12b** of transducer elements **14b**. Each of the elements **14a** and **14b** within arrays **12a** and **12b**, respectively, are electrically independent; thus, each of the elements **14a** and **14b** are shown separated from their neighboring elements by a space **28**. Each of the elements **14a** and **14b** convert acoustic signals incident upon the element to an electrical response such as a change in voltage, a change in current or the like. Transducer elements **14a** and **14b** can comprise any conventional acoustically transparent material such as polyvinylidene fluoride (PVDF) or the like. The electrical signals generated by transducer elements **14a** and **14b** are conditioned by preamplifiers **16** and coupled to beamformer **18**. Such coupling of preamplifiers **16** to an array **10** is well-known in the art. Using well known techniques, beamformer **18** processes the conditioned signals from preamplifiers **16** to generate an output signal **20**. Such techniques can include beamforming, match filter, or the like.

Processing only the signals from elements **14a** of array **12a**, results in a conventional array having an inter-element spacing **22** measured from element center to element center. However, processing the signals from elements **14a** and **14b** as a single array creates a multi-layer array having a reduced inter-element spacing **22'** measured between an element **14a** of array **12a** and a neighboring element **14b** of array **12b** without reducing the size of the elements.

In operation, a sound source **24** which in the present instance may represent either an active source or an echo from a source located elsewhere, generates acoustic signals **26** which propagate through the water to array **10**. When signal **26** reaches array **10** it strikes the transducer elements **14a** of outer array **12a** and propagates through transducer elements **14a** and spaces **28** to strike transducer elements **14b** of inner array **12b**. The electrical response generated by transducer elements **14a** and **14b** of outer array **12a** and inner array **12b**, respectively, are conditioned by preamplifiers **16** that are coupled to beamformer **18**. The signals generated by elements **14a** and **14b** of arrays **12a** and **12b** are processed as a single array by beamformer **18** to produce output signal **20**.

Referring now to FIG. **2**, there is shown a diagram illustrating an arrangement of transducer elements for a section of a multi-layer tiled array **10**. A section of array **10** comprising outer array **12a** represented by the solid lines and inner array **12b** represented by the dashed lines is shown. Outer array **12a** and inner array **12b** each comprise a plurality of electrically independent transducer elements **14a** and **14b**, respectively, arranged in a two-dimensional matrix. The elements **14a** of outer array **12a** are arranged such that each element **14a** is separated from its neighboring elements within array **12a** by a distance of "W_1"; thereby forming a grid of isolation spaces **28** of width "W_1" separating each of the elements **14a**. Similarly, elements **14b** of inner array **12b** are arranged so as to form a grid of isolation spaces **30** of width "W_2" separating each of the elements **14b**. Widths "W1" and "W2" are negligible in size in comparison to the size of transducer elements **14a** and **14b**.

Transducer elements **14b** of inner array **12b** are positioned such that the center of each transducer element **14b** is aligned with an isolation space **28** of outer array **12a**. Preferably, elements **14b** are positioned such that the center of each element **14b** in array **12b** is substantially aligned with the intersection of two of the isolation spaces **28** of outer array **12a** thereby maximizing the inter-element spacing **22'**.

Preferably, both arrays **12a** and **12b** are oriented at angle α of approximately 45 degrees relative to the horizontal to maintain the conventional azimuthal and elevation angle orientation for the inter-element spacing **22'**. Because of the square shape of the individual physical elements **14a** and **14b** and the 45 degree orientation, Bartlett shading is imposed on the individual elements. The elements may take other shapes such as rectangular, circular, or the like; however, the square shape will maximize the element capacitance. Optionally, conventional shading techniques, such as Hamming or the like, can be employed either electronically or computationally to the entire array in addition to any shading technique imposed during fabrication resulting from the shape of the elements.

Referring now to FIG. **3**, there is shown a cross-sectional view of array **10** according to one embodiment of the present invention. In the embodiment shown in FIG. **3**, transducer elements **14a** of outer array **12a** comprise a layer of PVDF film **32** with a top surface **34** and an opposing bottom surface **36** with a plurality of electrically independent electrodes **38** disposed on each of the surfaces **34, 36**. Each electrode **38** can be individually placed on surfaces **34** and **36**, or each electrode can be formed by depositing a thin layer of conductive material such as copper or the like on surfaces **34, 36** and etching away material to form a grid of isolation spaces **28**. Any conventional technique such as spraying or the like can be used to deposit a thin layer of conductive material. Alternatively, array **12a** can comprise a single electrode disposed on surface **34** or **36** with a plurality of individual electrodes disposed on the opposing surface. However, in a preferred embodiment array **12a** comprises individual electrodes **38** disposed on each surface to reduce coupling between adjacent elements. Similarly inner array **12b** can comprise a layer of PVDF film **40** with a top surface **42** and an opposing bottom surface **44** with a plurality of electrically independent electrodes **46** disposed on each of surfaces **42,44**.

A window **48** of acoustically transparent material such as polyurethane or the like can be disposed to outer surface **50** of outer array **12a**. The window **48** allows acoustic signals **26** to propagate to elements **14a, 14b** and keeps water away from array **10**. A non-conductive adhesive **52** can be used to join inner array **12a** to outer array **12b** and to help prevent any misalignment of elements **14a, 14b**. A substrate **54** can be disposed to the lower surface **56** of inner array **12b** to support arrays **12a** and **12b**. Additionally, substrate **54** can be comprised of materials to dampen the acoustic signals propagating through the array thereby reducing any reflection of the signals towards array **10**. Leads **58** receive the electrical signals generated by transducer elements **14a** and **14b**. The signals are then conditioned by preamplifiers **16**. Widths "W1" and "W2" are made large enough to allow for the connection of leads **58** to transducer elements **14a** and **14b** and small enough to obtain the maximum physical size of transducer elements **14a** and **14b**.

In operation, signal **26** propagates through the water until it reaches array **10.** The material used to form transducer elements **14a** and **14b** is acoustically transparent thereby allowing signal **26** to propagate through transducer elements **14a** to transducer elements **14b.**

The multi-layer tiled array of the present invention provides a novel arrangement for the individual elements that increases the capacitance of the elements by increasing their surface area while maintaining the inter-element spacing required to avoid spatial aliasing in the received signals. The array provides significant advantages over prior art arrays. First, the array increases the maximum allowable distance between array elements. Second, it increases the capacitance of the elements which can be utilized to obtain a lower electrical noise floor level thereby improving the sonar system's performance in detecting low level target signals. Furthermore the arrangement eases the fabrication of the array by allowing the preamplifiers to be located a greater distance from the array.

What has thus been described is a sonar sensor array that provides a multi-layer tiled arrangement for the individual array elements. The arrangement increases the capacitance of the array elements while maintaining the required inter-element spacing.

It will be understood that various changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention.

. For example: a different material might be used for the construction of the array to attain better sensitivity or capacitance. Other shading could be implemented readily during fabrication of the inner and outer arrays or additional shading could also be applied after the sensor either electronically or computationally if further improved sidelobe performance of some other shading design is required.

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MULTI-LAYER TILED ARRAY

ABSTRACT OF THE DISCLOSURE

A sonar sensor array having a multi-layer tiling arrangement for the individual elements that increases surface area available for each element while maintaining the inter-element spacing required to avoid spatial aliasing when the received signals are combined to form a sonar beam. The array comprises outer and inner arrays of transducer elements for converting an acoustic signal to an electrical response. The transducer elements of the outer array are positioned such than a grid of isolation spaces separates each of the transducer elements. The transducer elements of the inner array are also positioned such that a grid of isolation spaces separates each one of the transducer elements. The electrical response generated by the transducer elements of the inner and outer arrays are coupled to a beamformer which processes the responses to produce an output signal.

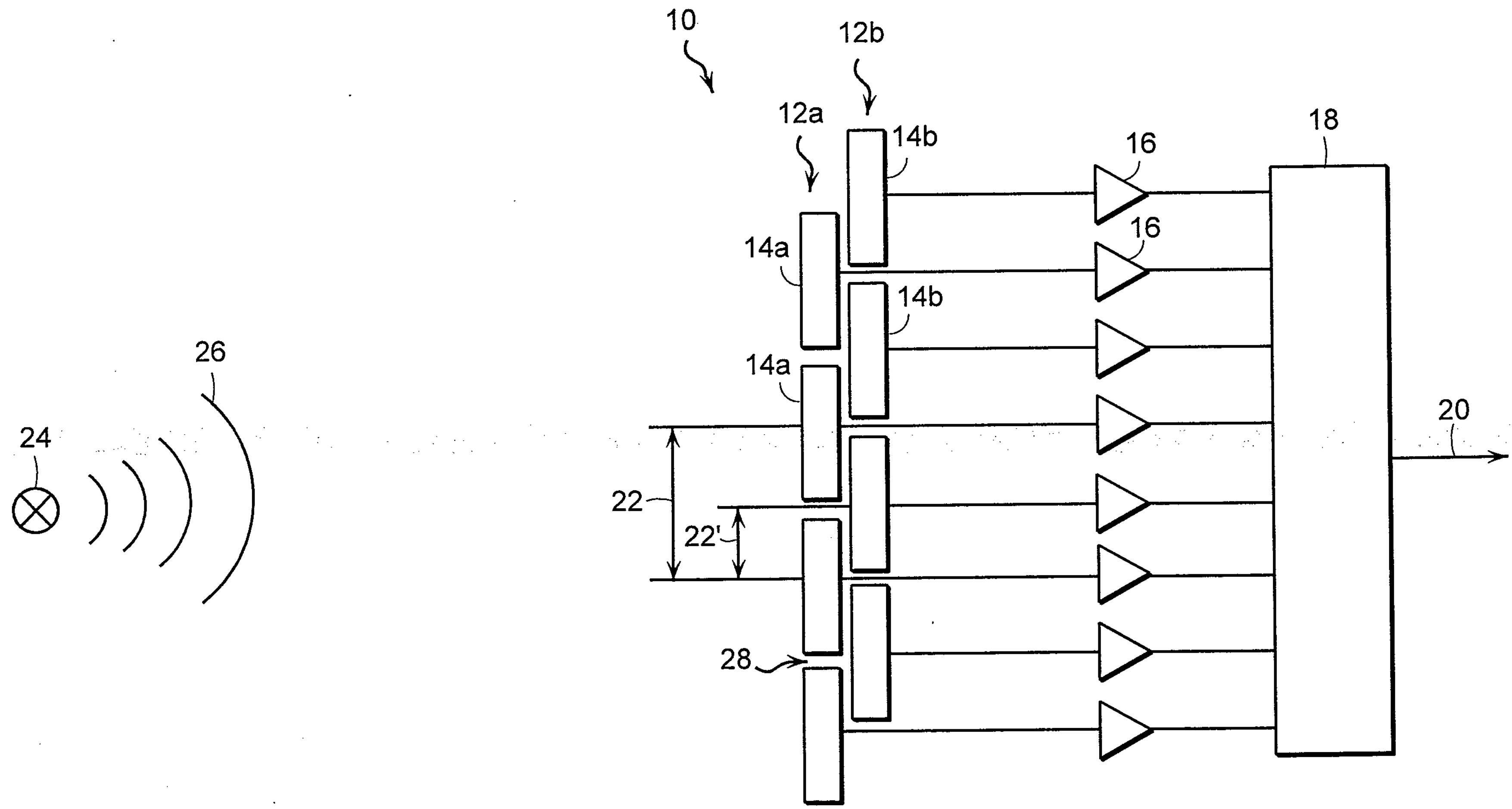


FIG. 1

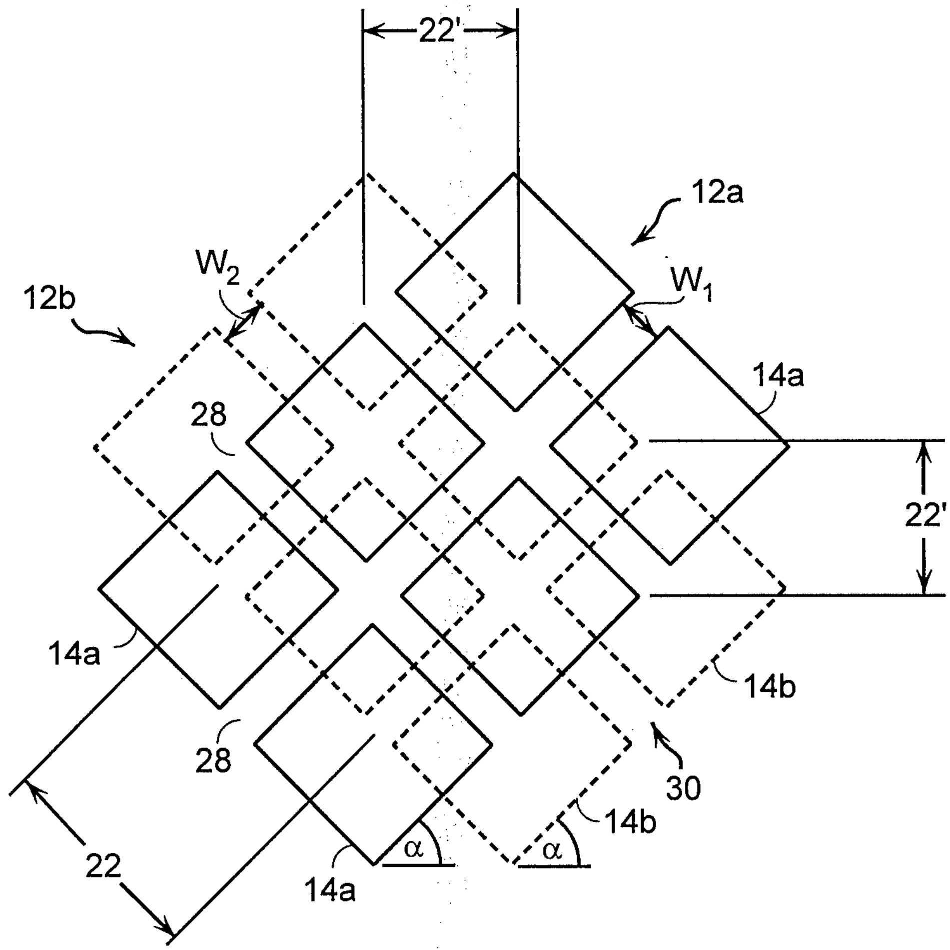
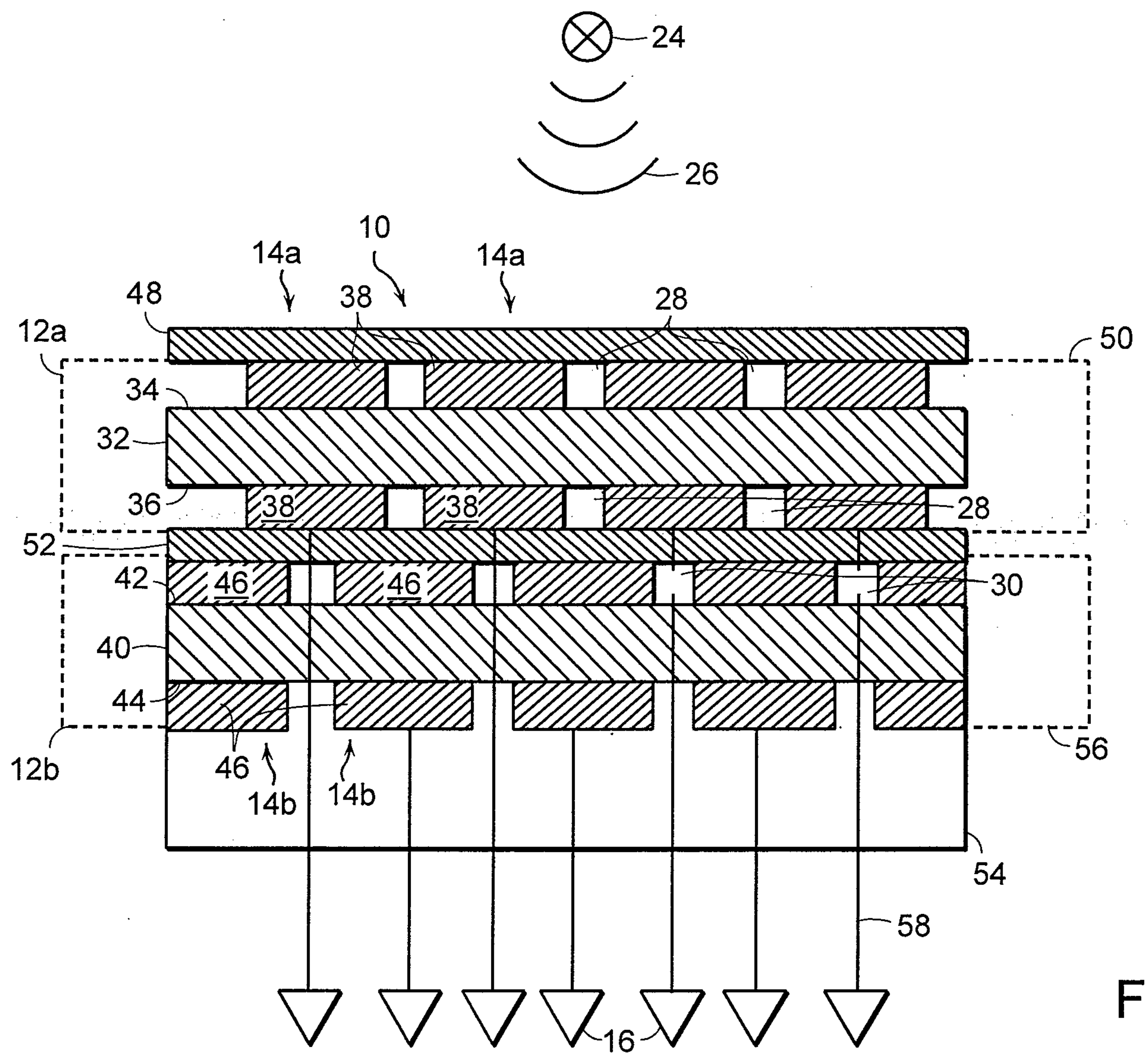


FIG. 2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14a
14a
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38
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12a
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46
46
30
40
44
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12b
14b
14b
56
54
58
16

FIG. 3