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(54) APPARATUSES, SYSTEMS, AND METHODS FOR REDUCING TRANSMISSION LINE INSERTION LOSS USING TRIMMING LINES

(57) A disclosed system may include (1) a coplanar waveguide that includes a signal region and a ground region, (2) a first trimming line positioned in the signal region of the coplanar waveguide, and (3) a second trimming line positioned in the ground region of the coplanar waveguide, (4) wherein the first trimming line and the second trimming line form a floating region in the coplanar waveguide that is configured to receive an input radio frequency signal. Various other apparatuses, systems, and methods of manufacture are also disclosed.

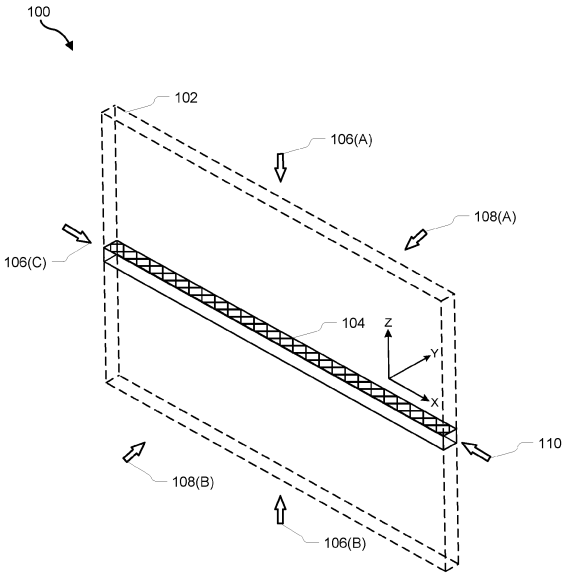

FIG. 1

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Description

TECHNICAL FIELD

[0001] The present disclosure is generally directed to apparatuses, systems, and methods that may implement one or more trimming lines to reduce transmission line insertion loss.

BACKGROUND

[0002] Modern mobile and artificial reality devices (e.g., augmented reality (AR) and/or virtual reality glasses) continue to grow smaller over time. As such, some of these form factors may attempt to move the existing antennas from being located in frames of the augmented reality devices to being located on one or more lenses of the augmented reality devices. In such cases, transparent conductive (e.g., metal) meshes may be implemented as antennas on the surface of, for example, AR glass lenses.

[0003] In cases where transparent metal meshes are used to create antennas on AR glass lens surfaces, antenna feed energy may be met with a large insertion loss into the conductive mesh. This may, in turn, reduce the effectiveness of the antennas. Hence, the present disclosure identifies and addresses a need for additional apparatuses, systems, and methods for reducing insertion loss into conductive mesh of antenna feed energy.

SUMMARY

[0004] According to a first aspect, there is provided a coplanar waveguide comprising: a signal region and a ground region; a first trimming line positioned on the signal region; and a second trimming line positioned on the ground region, wherein the first trimming line and the second trimming line form a floating region in the coplanar waveguide that is configured to receive an input radio frequency (RF) signal.

[0005] The floating region in the coplanar waveguide may receive the input RF signal at a reduced insertion loss below a predetermined threshold.

[0006] At least one of the first trimming line or the second trimming line may be etched into the coplanar waveguide at a specified location.

[0007] The etching may remove at least a portion of mesh wire along the position of the first or second trimming lines.

[0008] At least one of the first or second trimming lines may be additively applied by placing nonconductive material over a wire mesh affixed to the coplanar waveguide.

[0009] The wire mesh may be part of a transparent metal mesh antenna.

[0010] The coplanar waveguide may further comprise at least a portion of fill material configured to return a metal density of the transparent metal mesh antenna to a previously established level of prior to an implementation of the trimming lines.

[0011] According to a second aspect, there is provided a system comprising the coplanar waveguide of the first aspect.

[0012] The system may further comprise an augmented reality device. The coplanar waveguide may be included in a lens of the augmented reality device.

[0013] According to a third aspect, there is provided a method comprising: positioning, within a signal region included in a coplanar waveguide, a first trimming line; and positioning, within a ground region included in the coplanar waveguide, a second trimming line, wherein positioning the first trimming line and the second trimming line forms a floating region in the coplanar waveguide that is configured to receive an input radio frequency (RF) signal.

[0014] Positioning the first trimming line within the signal region included in the coplanar waveguide may comprise etching the first trimming line into the coplanar waveguide at a specified location within the signal region included in the coplanar waveguide.

[0015] Positioning the second trimming line within the ground region included in the coplanar waveguide may comprise etching the second trimming line into the coplanar waveguide at an additional specified location within the ground region included in the coplanar waveguide.

[0016] Positioning the first trimming line within the signal region included in the coplanar waveguide may comprise additively applying the first trimming line by placing nonconductive mesh over a wire mesh affixed to the coplanar waveguide.

[0017] Positioning the second trimming line within the ground region included in the coplanar waveguide may comprise additively applying the first trimming line by placing nonconductive mesh over the wire mesh affixed to the coplanar waveguide.

[0018] The method may further comprise including the coplanar waveguide in a lens of an augmented reality device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The accompanying drawings illustrate a number of examples and are a part of the specification. Together with the following description, these drawings demonstrate and explain various principles of the instant disclosure.

FIG. 1 is a perspective view of a simulation model for a coplanar waveguide (CPW) in accordance with some of the embodiments disclosed herein.

FIG. 2 is a detailed perspective view of a simulation model that includes a CPW in accordance with some embodiments described herein.

FIG. 3 includes views of diagrams that illustrate and/or describe various relationships and/or attributes of an example mesh.

FIG. 4 includes equations and tables that further il-

lustrate and/or describe possible relationships between and/or values for an example mesh.

FIG. 5 includes a view of a block diagram that generally illustrates the use of a trimming line with an example mesh in accordance with some embodiments described herein.

FIG. 6 includes additional views of block diagrams that generally illustrate possible uses of trimming lines with example meshes in accordance with some embodiments described herein.

FIG. 7 illustrates various views of some meshes that may include dummy fill material in accordance with some embodiments described herein.

FIGS. 8-13 show various views of hexagonal meshes that may be configured in accordance with some embodiments described herein.

FIGS. 14-16 show various views of square meshes that may be configured in accordance with some embodiments described herein.

FIG. 17 is a flow diagram of an example method 1700 of manufacture for apparatuses or systems for reducing transmission line insertion loss using trimming lines in accordance with some embodiments described herein.

FIG. 18 is an illustration of exemplary augmented-reality glasses that may be used in connection with embodiments of this disclosure.

FIG. 19 is an illustration of an exemplary virtual-reality headset that may be used in connection with embodiments of this disclosure.

FIG. 20 is an illustration of an example smartwatch that may be used in connection with embodiments of this disclosure.

[0020] Throughout the drawings, identical reference characters and descriptions indicate similar, but not necessarily identical, elements. While the example embodiments described herein are susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. However, the example embodiments described herein are not intended to be limited to the particular forms disclosed. Rather, the instant disclosure covers all modifications, equivalents, and alternatives falling within the scope of the appended claims.

DETAILED DESCRIPTION

[0021] In some cases, the one or more trimming lines (i.e., regions of non-conductive or conductorless material) may be used in transparent conductive meshes to reduce insertion loss in the antennas that are formed thereby. Embodiments of the present disclosure may reduce transmission line insertion loss by implementing one or more trimming lines (alternatively referred to herein as "nonconductive regions"). In some cases, the trimming lines may be implemented in conjunction with a transparent metal mesh that is embedded within or is otherwise affixed to a CPW.

[0022] In some embodiments, a trimming line may be implemented on a signal region of the CPW, and an additional trimming line may be implemented on a ground region. This may create a floating region or branch region in the CPW between a signal current and a ground current. This floating region may reduce insertion loss in the CPW. As such, when a signal is applied to the transparent conductive mesh, the signal may experience a much lower insertion loss than would otherwise be experienced without the trimming lines and without the floating region. In some cases, the embodiments herein may define the signal and ground regions, and then define their outlines so that few or no metal branches grow out of them. For instance, if the signal and ground are in the same plane, such as in a CPW and/or slot antennas, the outline of the signal and ground may be defined so that there is a branch between the signal and ground that is at least partially or entirely floating. This may improve insertion loss when the branch is fully suspended compared to when the branch extends from the signal or ground. Then, in some embodiments, conductors may be added to keep the conductor density constant.

[0023] The trimming lines may be applied to the CPW and/or the conductive mesh in a variety of ways. In some embodiments, for instance, the trimming lines may be applied by etching or cutting the CPW in specific locations in the ground and signal regions. This may remove small portions of the transparent conductive mesh. In additional or alternative embodiments, trimming lines may be applied additively by placing nonconductive material over portions of conductive mesh wires. Implementing trimming lines in this manner may greatly reduce insertion loss and may thus greatly enhance the operating efficiency of the transparent metal mesh antenna. Additional or alternative embodiments may place dummy fill material in the conductive mesh to return the metal density of the mesh to the level of metal density that existed before the trimming lines were etched out or before the trimming lines were positioned onto the metal mesh.

[0024] In one embodiment, a system may be provided. The system may include a CPW that has a signal region and a ground region. The system may also include a first trimming line positioned on the signal region of the CPW, and a second trimming line positioned on the ground region of the CPW. The first and second trimming lines may thereby establish a floating region in the CPW that configured to receive an input radio frequency (RF) signal. The floating region in the CPW may exhibit characteristics that allow it to receive the input RF signal at a reduced insertion loss. This reduced insertion loss may improve the functionality of the transparent antenna or other similar transmission line.

[0025] In some cases, the trimming lines may be etched into the CPW in specified locations. In such cases, the etching process may remove at least a portion of mesh wire along the position of the trimming lines. This

removed wire may create the floating regions in the CPW. In other cases, the trimming lines may be additively applied by placing nonconductive material over the wire mesh that is affixed to the CPW. Thus, nonconductive material may be placed on top of portions of a wire mesh that is part of a transparent metal mesh antenna. The nonconductive material may prevent current from flowing past the trimming lines, thereby creating a floating region that provides reduced insertion loss for incoming signals. In at least some cases, one or more portions of fill material may be implemented to restore a metal mesh's density. As such, fill material may be added to a conductive mesh to return the metal density of a transparent mesh antenna to a previously established level before trimming lines were implemented. Restoring the metal density may improve the operating functionality of the conductive mesh. This conductive mesh may be used with various mobile electronic devices including augmented reality glasses, smart watches, or other similar devices.

[0026] The following will provide, with reference to FIGS. 1-16 and 18-20, detailed descriptions of apparatuses and systems for reducing transmission line insertion loss using trimming lines. Detailed descriptions of methods of manufacture of apparatuses and systems for reducing transmission line insertion loss using trimming lines will also be provided in connection with FIG. 17.

[0027] FIG. 1 is a perspective view 100 of a simulation model 102 for a CPW 104 (CPW 104) in accordance with some of the embodiments disclosed herein. As shown in FIG. 1, simulation model 102 includes CPW 104, which simulation model 102 defines in terms of perfect electrical conductor (PEC) regions 106 (e.g., PEC 106(A), PEC 106(B), and PEC 106(C)), periodic boundary condition (PBC) regions 108 (e.g., PBC region 108(A) and PBC region 108(B)). As further shown in FIG. 1, simulation model 102 simulates CPW 104 as including or comprising a perfect magnetic conductor (PMC) region 110.

[0028] FIG. 2 is a detailed perspective view 200 of simulation model 102 that includes CPW 104. As shown, CPW 104 includes a mesh 202 positioned, affixed to, mounted to, placed upon, etched into, and/or formed from a base material 204. In some examples, mesh 202 may include a transparent conductive metal mesh. Mesh 202 may include any suitable metal, metal alloy, or other electrically conductive material including, without limitation, copper, silver, tin, indium tin oxide (ITO), zinc, zinc oxide (ZnO), and so forth.

[0029] In the example shown in FIG. 2, CPW 104 and/or mesh 202 may include a signal region 206 and a ground region 208 that may be separated and/or defined by a trimming line 210. Trimming line 210 may be any suitable conductorless region that separates conductive regions of mesh 202 from one another. As shown, trimming line 210 transects mesh 202 along a y-axis of CPW 104. As trimming line 210 represents a conductorless region, trimming line 210 may therefore prevent current from passing from signal region 206 to ground region 208 and vice versa. In additional or alternative embodiments, trimming line 210 may, at least partially, electrically and/or magnetically separate and/or isolate at least a portion of signal region 206 from at least a portion of ground region 208 and vice versa.

[0030] FIG. 3 includes a view 300 of a diagram that illustrates and/or describes various relationships and/or attributes of an example mesh 302. In some examples, example mesh 302 may include or represent attributes of a possible implementation of mesh 202. As shown, example mesh 302 may include or be comprised of a plurality of example segments 304. Each example segment 304 may have a length *ML*, a width of *ML*, and a depth of *t*. Furthermore, each example segment 304 may have an electrical conductivity represented by σ. In the configuration shown in FIG. 3, example mesh 302 has a square aperture and may have a pitch *MP* (measured from the center of each example segment 304 of example mesh 302) equal to *ML*.

[0031] FIG. 4 includes a view 400 of equations 402 and table 404 that further illustrates and/or describes possible relationships between and/or values for an example mesh 302. As shown by equations 402, example mesh 302 may have an aperture percentage *Ap* such that:

$$Ap = \frac{(MP - MW)^2}{MP^2}$$

where, as mentioned above, *MP* = *ML*.

[0032] Furthermore, example mesh 302 may have a cross sectional area *AC* such that $AC = MP^2$ and an overall resistance *R* such that:

$$R = \frac{1}{\sigma}\frac{MP}{tMW}$$

[0033] Table 404 indicates possible values that may be included in and/or may describe a possible implementation of an example mesh (e.g., example mesh 302). As shown, an example mesh may have a σ value of 20% of 5.8×10^7 siemens per meter, a t of 1 μm, a value of *MP* = *ML* of 80 μm, a value of *MW* of 2 μm, a value of *Ap* of 95.1 %, and a sheet resistivity (R_s) of 3.45 ohms per square. Table 404 further indicates possible values of a dielectric constant (BM Dk) of 2.25 and a dissipation factor (BM Df) of 1/1000.

[0034] FIG. 5 includes a view 500 of a block diagram that generally illustrates the use of a trimming line with an example mesh in accordance with some embodiments described herein. As shown, in FIG. 5, mesh 502 is disposed upon and/or within a suitable base material (e.g., a substrate). Trimming line 504 transects mesh 502, dividing mesh 502 into signal region 506 and ground region 508. Signal region 506 may conduct signal current 510 (e.g., signal current 510(A) and signal current 510(B)) and ground region 508 may conduct ground current 512 (e.g., ground current 512(A) and ground current

512(B)). Trimming line 504 may cause at least a partial disruption and/or interruption in transmission of signal current 510 and/or ground current 512 by mesh 502 via signal sections 514 (signal section 514(A), signal section 514(B), and signal section 514(C)) and/or ground sections 516 (e.g., ground section 516(A), ground section 516(B), and/or ground section 516(C)). This disruption or interruption may effectively create "floating" sections 518 (e.g., floating section 518(A), floating section 518(B), and/or floating section 518(C)) that may be electrically isolated from signal sections 514 and/or ground sections 516.

[0035] Furthermore, trimming line 504 may create branches of mesh 502 that may be electrically isolated from signal current and/or ground current, such as signal branches 520 (e.g., ground branch 520(A) and ground branch 520(B)) and signal branches 522 (e.g., signal branch 522(A) and signal branch 522(B)).

[0036] The configuration shown in FIG. 5 is provided only by way of example or illustration. Additional possible configurations are shown in FIG. 6. In the configurations shown in FIG. 6, trimming lines are noted as regions shaded with downward diagonal lines, ground sections, signal sections, and floating sections are noted by letters "G", "S", and "F" respectively.

[0037] Configuration 600 shows a trimming line that intersects with a cross point or junction in an example mesh. Configuration 610 shows a trimming line that intersects with two wires in a single grid of an example mesh. Configuration 620 shows a trimming line that intersects with two cross points or junctions in an example mesh, and configuration 630 shows two trimming lines positioned as in configuration 600 and configuration 620, respectively. Each of these configurations may result in different configurations for ground branches ($b(G)$), singal branches, and/or floating branches ($b(G)$, $b(S)$, and $b(F)$ in FIG. 6, respectively). Each of these configurations may impact insertion loss to varying degrees. In some experimental results, configuration 630 may have an improved loss in comparison to other possible configurations.

[0038] Configuration 610 also shows a possible orthogonal trimming line 612. This alternative configuration may be more robust in comparison to other configurations with respect to machining accuracy (e.g., laser processing accuracy) and may be less likely to damage important signal (SIG) and ground (GND) patterns. Cutting in a zig-zag pattern (e.g., orthogonal to mesh wires) may provide more margin for machining of trimming lines.

[0039] As mentioned above, some embodiments may include dummy fill material in the conductive mesh. This dummy fill material may adjust and/or return a metal density of the conductive mesh to a level of metal density that may have existed prior to positioning and/or etching of the trimming lines relative to the conductive mesh. FIG. 7 illustrates various views of some embodiments that may include dummy fill material. As shown in FIG. 7, view 700 shows a configuration that includes a mesh 702, a first trimming line 704, and a second trimming line 706. The configuration shown in view 700 also includes dummy fill material 708 (e.g., dummy fill material 708(A), dummy fill material 708(B), dummy fill material 708(C), and dummy fill material 708(D)) within trimming lines. This may be referred to as a "floating" or "totally floating" configuration.

[0040] View 710 shows a configuration that includes a mesh 712, a first trimming line 714, and a second trimming line 716. The configuration shown in view 710 also includes dummy fill material 718 (e.g., dummy fill material 718(A), dummy fill material 718(B), dummy fill material 718(C), and dummy fill material 718(D)). In this configuration, dummy fill material 718 may be included in and/or connected to a "floating" portion of mesh 712.

[0041] View 720 shows a configuration that includes a mesh 722, a first trimming line 724, and a second trimming line 726. The configuration shown in view 720 also includes dummy fill material 728 (e.g., dummy fill material 728(A), dummy fill material 728(B), dummy fill material 728(C), and dummy fill material 728(D)). In this configuration, dummy fill material 728 may be included in ant/or connected to a signal portion of mesh 722 and/or a ground portion of mesh 722.

[0042] FIGS. 8-16 illustrate views of example implementations, embodiments, and/or configurations of meshes as described herein. FIGS. 8-10 illustrate an example that may be implemented using hexagonal mesh having an aperture of 200 μm. FIG. 8 shows a view 800 of a hexagonal mesh 802 that includes a floating region 804 (denoted by dashed lines) that divides hexagonal mesh 802 into a signal region 806 and a ground region 808. As shown, floating region 804 may have a width across hexagonal mesh 802 of 802.0 μm, and may be bounded, formed, and/or defined by one or more trimming lines. Hexagonal mesh 802 is shown in FIG. 8 as having a length of 5000.0 μm.

[0043] Hexagonal mesh 802 may further include, be joined to, and/or abut an additional mesh 810. In FIG. 8, additional mesh 810 is shown as having a width of 1000 μm. Additional mesh 810 may vary from hexagonal mesh 802 in one or more ways, such as having different aperture dimensions, a different compositional structure, one or more different electrical properties, and so forth.

[0044] FIG. 9 shows a detailed view 900 of hexagonal mesh 802. As shown in FIG. 8 and FIG. 9, hexagonal mesh 802 may have an aperture size of 200.0 μm. FIG. 10 includes a detailed view 1000 of a first possible configuration for a node in a mesh (e.g., hexagonal mesh 802) that joins a first region 1002 of a hexagonal mesh (e.g., floating region 804, signal region 806, and/or ground region 808) to a second region 1002 of a hexagonal mesh (e.g., floating region 804, signal region 806 and/or ground region 808).

[0045] In this configuration, a discontinuity 1006 having a length of 5.0 μm is formed in the mesh at a point where a wire in region 1004 meets a node and a discontinuity 1008 having a length of 5.0 μm is formed in the

mesh of second region 1002 at a point between nodes. In this example, dummy fill material 1010 and dummy fill material 1012, each having a length of 5.0 μm, may be placed within a predetermined distance of the wire (e.g., 5.0 μm in view 1000) of first region 1004 in an orientation parallel to the wire in first region 1004. This may adjust and/or return a metal density of the mesh to a level of metal density that may have existed prior to the forming of discontinuity 1006 and/or discontinuity 1008.

[0046] FIG. 10 also includes a detailed view 1020 of a second possible configuration for a node in a mesh (e.g., hexagonal mesh 802) that joins a first region 1002 of a hexagonal mesh (e.g., floating region 804, signal region 806, and/or ground region 808) to a second region 1004 of a hexagonal mesh (e.g., floating region 804, signal region 806 and/or ground region 808). In this configuration, dummy fill material 1010 is positioned parallel to a wire in region 1002 that adjoins a node that joins first region 1002 to second region 1004.

[0047] FIGS. 11-13 illustrate an example that may be implemented using hexagonal mesh having an aperture of 200 μm. In this example, the apertures of the mesh are rotated ninety degrees from the apertures of the mesh shown in the examples illustrated in FIGS. 8-10. FIG. 11 shows a view 1100 of a hexagonal mesh 1102 that includes a floating region 1104 (denoted by dashed lines) that divides hexagonal mesh 1102 into a signal region 1106 and a ground region 1108. As shown, floating region 1104 may have a width across hexagonal mesh 1102 of 926.1 μm, and may be bounded, formed, and/or defined by one or more trimming lines. Hexagonal mesh 1102 is shown in FIG. 11 as having a length of 5000.0 μm.

[0048] Hexagonal mesh 1102 may further include, be joined to, and/or abut an additional mesh 1110. In FIG. 11, additional mesh 1110 is shown as having a width of 1000 μm. Additional mesh 1110 may vary from hexagonal mesh 1102 in one or more ways, such as having different aperture dimensions, a different compositional structure, one or more different electrical properties, and so forth.

[0049] FIG. 12 shows a detailed view 1200 of hexagonal mesh 1102. As shown in FIG. 11 and FIG. 12, hexagonal mesh 1102 may have an aperture size of 200.0 μm. FIG. 13 includes a detailed view 1300 of a first possible configuration for a node in a mesh (e.g., hexagonal mesh 1102) that joins a first region 1302 of a hexagonal mesh (e.g., floating region 1104, signal region 1106, and/or ground region 1108) to a second region 1304 of a hexagonal mesh (e.g., floating region 1104, signal region 1106 and/or ground region 1108).

[0050] In this configuration, a discontinuity 1306 having a length of 5.0 μm is formed in the mesh at a point where a wire in region 1304 meets a node and a discontinuity 1308 having a length of 5.0 μm is formed in the mesh of second region 1302 at a point between nodes. In this example, dummy fill material 1310 and dummy fill material 1312, each having a length of 5.0 μm, may be placed within a predetermined distance of the wire (e.g., 5.0 μm in view 1300) of first region 1304 in an orientation parallel to the wire in first region 1304. This may adjust and/or return a metal density of the mesh to a level of metal density that may have existed prior to the forming of discontinuity 1306 and/or discontinuity 1308.

[0051] FIG. 13 also includes a detailed view 1320 of a second possible configuration for a node in a mesh (e.g., hexagonal mesh 1102) that joins a first region 1302 of a hexagonal mesh (e.g., floating region 1104, signal region 1106, and/or ground region 1108) to a second region 1304 of a hexagonal mesh (e.g., floating region 1104, signal region 1106 and/or ground region 1108). In this configuration, dummy fill material 1310 is positioned parallel to a wire in region 1302 that adjoins a node that joins first region 1302 to second region 1304.

[0052] FIGS. 14-16 illustrate an example that may be implemented using diamond mesh having an aperture of 200 μm. In this example, the apertures of the mesh are square and rotated forty-five degrees. FIG. 14 shows a view 1400 of a square mesh 1402 that includes a floating region 1404 (denoted by dashed lines) that divides square mesh 1402 into a signal region 1406 and a ground region 1408. As shown, floating region 1404 may have a width across square mesh 1402 of 851.4 μm, and may be bounded, formed, and/or defined by one or more trimming lines. Square mesh 1402 is shown in FIG. 14 as having a length of 5000.0 μm.

[0053] Square mesh 1402 may further include, be joined to, and/or abut an additional mesh 1410. In FIG. 14, additional mesh 1410 is shown as having a width of 1000 μm. Additional mesh 1410 may vary from square mesh 1402 in one or more ways, such as having different aperture dimensions, a different compositional structure, one or more different electrical properties, and so forth.

[0054] FIG. 15 shows a detailed view 1500 of square mesh 1402. As shown in FIG. 14 and FIG. 15, square mesh 1402 may have an aperture size of 200.0 μm. FIG. 16 includes a detailed view 1600 of a first possible configuration for a node in a mesh (e.g., square mesh 1402) that joins a first region 1602 of a square mesh (e.g., floating region 1404, signal region 1406, and/or ground region 1408) to a second region 1604 of a square mesh (e.g., floating region 1404, signal region 1406 and/or ground region 1408).

[0055] In this configuration, a discontinuity 1606 having a length of 5.0 μm is formed in the mesh at a point where a wire in region 1604 meets a node and a discontinuity 1608 having a length of 5.0 μm is formed in the mesh of second region 1602 at a point between nodes. In this example, dummy fill material 1610(A), dummy fill material 1610(B), and dummy fill material 1612, each having a length of 5.0 μm, may be placed within a predetermined distance of the wire (e.g., 5.0 μm in view 1600) of first region 1604 in an orientation parallel to wire in first region 1604. This may adjust and/or return a metal density of the mesh to a level of metal density that may have existed prior to the forming of discontinuity 1606 and/or discontinuity 1608.

[0056] FIG. 16 also includes a detailed view 1620 of a second possible configuration for a node in a mesh (e.g., square mesh 1402) that joins a first region 1602 of a square mesh (e.g., floating region 1404, signal region 1406, and/or ground region 1408) to a second region 1604 of a square mesh (e.g., floating region 1404, signal region 1406 and/or ground region 1408). In this configuration, dummy fill material 1610(A) and dummy fill material 1610(B) are each positioned parallel to a wire in region 1602 that adjoins a node that joins first region 1602 to second region 1604.

[0057] FIG. 17 is a flow diagram of an example method 1700 of manufacture for apparatuses or systems for reducing transmission line insertion loss using trimming lines in accordance with some embodiments described herein. The steps shown in FIG. 17 may be performed by any suitable instrumentality including, without limitation, a person, a device, a machine, portions of one or more of the same, variations or combinations of one or more of the same, and so forth. In at least one example, each of the steps shown in FIG. 17 may represent an algorithm whose structure includes and/or is represented by multiple sub-steps, examples of which are provided in greater detail herein.

[0058] As illustrated in FIG. 17, at step 1710, one or more suitable instrumentalities may position, within a signal region included in a CPW, a first trimming line. At step 1720, one or more suitable instrumentalities may position, within a ground region included in the CPW, a second trimming line, wherein positioning the first trimming line and the second trimming line forms a floating region in the CPW that is configured to receive an input RF signal.

[0059] The trimming lines may be applied to and/or positioned within the CPW and/or the conductive mesh in a variety of ways. In some embodiments, for instance, as described above, the trimming lines may be applied by etching or cutting the CPW in specific locations in the ground and signal regions. This may remove small portions of the transparent conductive mesh. In additional or alternative embodiments, trimming lines may be applied additively by placing nonconductive material over portions of conductive mesh wires.

[0060] The first and second trimming lines may establish or define a floating region in the CPW that is configured to receive an input radio frequency (RF) signal. The floating region in the CPW may exhibit characteristics that allow it to receive the input RF signal at a reduced insertion loss. This reduced insertion loss may improve the functionality of the transparent antenna or other similar transmission line.

[0061] In some cases, as also mentioned above, the trimming lines may be etched into the CPW in specified locations. In such cases, the etching process may remove at least a portion of mesh wire along the position of the trimming lines. This removed wire may create the floating regions in the CPW. In other cases, the trimming lines may be additively applied by placing nonconductive material over the wire mesh that is affixed to the CPW. Thus, nonconductive material may be placed on top of portions of a wire mesh that is part of a transparent metal mesh antenna. The nonconductive material may prevent current from flowing past the trimming lines, thereby creating a floating region that provides reduced insertion loss for incoming signals. In at least some cases, one or more portions of fill material may be implemented to restore a metal mesh's density.

[0062] As may be apparent from the foregoing, embodiments of the apparatuses, systems, and methods disclosed herein may have many benefits. For example, embodiments of the apparatuses, systems and methods disclosed herein may reduce insertion loss of antenna feed energy into one or more antennas implemented by a transparent conductive mesh. As such, when a signal is applied to the transparent conductive mesh, the signal may experience a much lower insertion loss than would otherwise be experienced absent embodiments of the apparatuses, systems, and methods disclosed herein. This reduced insertion loss may improve functionality of the transparent antenna or other similar transmission line.

[0063] Furthermore, in some examples of the apparatuses, systems, and methods described herein, fill material may be incorporated into a conductive mesh to return a metal density of a transparent mesh antenna to a previously established level before trimming lines were implemented. Restoring the metal density may improve an operating functionality of the conductive mesh. This conductive mesh may be used with various mobile electronic devices including augmented reality glasses, smart watches, or other similar devices.

[0064] Embodiments of the present disclosure may include or be implemented in - conjunction with various types of artificial-reality systems. Artificial reality is a form of reality that has been adjusted in some manner before presentation to a user, which may include, for example, a virtual reality, an augmented reality, a mixed reality, a hybrid reality, or some combination and/or derivative thereof. Artificial-reality content may include completely computer-generated content or computer-generated content combined with captured (e.g., real-world) content. The artificial-reality content may include video, audio, haptic feedback, or some combination thereof, any of which may be presented in a single channel or in multiple channels (such as stereo video that produces a three-dimensional (3D) effect to the viewer). Additionally, in some embodiments, artificial reality may also be associated with applications, products, accessories, services, or some combination thereof, that are used to, for example, create content in an artificial reality and/or are otherwise used in (e.g., to perform activities in) an artificial reality.

[0065] Artificial-reality systems may be implemented in a variety of different form factors and configurations. Some artificial-reality systems may be designed to work without near-eye displays (NEDs). Other artificial-reality

systems may include an NED that also provides visibility into the real world (such as, e.g., augmented-reality system 1800 in FIG. 18) or that visually immerses a user in an artificial reality (such as, e.g., virtual-reality system 1900 in FIG. 19). While some artificial-reality devices may be self-contained systems, other artificial-reality devices may communicate and/or coordinate with external devices to provide an artificial-reality experience to a user. Examples of such external devices include handheld controllers, mobile devices, desktop computers, devices worn by a user, devices worn by one or more other users, and/or any other suitable external system.

[0066] Turning to FIG. 18, augmented-reality system 1800 may include an eyewear device 1802 with a frame 1810 configured to hold a left display device 1815(A) and a right display device 1815(B) in front of a user's eyes. Display devices 1815(A) and 1815(B) may act together or independently to present an image or series of images to a user. While augmented-reality system 1800 includes two displays, embodiments of this disclosure may be implemented in augmented-reality systems with a single NED or more than two NEDs.

[0067] In some embodiments, augmented-reality system 1800 may include one or more sensors, such as sensor 1840. Sensor 1840 may generate measurement signals in response to motion of augmented-reality system 1800 and may be located on substantially any portion of frame 1810. Sensor 1840 may represent one or more of a variety of different sensing mechanisms, such as a position sensor, an inertial measurement unit (IMU), a depth camera assembly, a structured light emitter and/or detector, or any combination thereof. In some embodiments, augmented-reality system 1800 may or may not include sensor 1840 or may include more than one sensor. In embodiments in which sensor 1840 includes an IMU, the IMU may generate calibration data based on measurement signals from sensor 1840. Examples of sensor 1840 may include, without limitation, accelerometers, gyroscopes, magnetometers, other suitable types of sensors that detect motion, sensors used for error correction of the IMU, or some combination thereof.

[0068] In some examples, augmented-reality system 1800 may also include a microphone array with a plurality of acoustic transducers 1820(A)-1820(J), referred to collectively as acoustic transducers 1820. Acoustic transducers 1820 may represent transducers that detect air pressure variations induced by sound waves. Each acoustic transducer 1820 may be configured to detect sound and convert the detected sound into an electronic format (e.g., an analog or digital format). The microphone array in FIG. 18 may include, for example, ten acoustic transducers: 1820(A) and 1820(B), which may be designed to be placed inside a corresponding ear of the user, acoustic transducers 1820(C), 1820(D), 1820(E), 1820(F), 1820(G), and 1820(H), which may be positioned at various locations on frame 1810, and/or acoustic transducers 1820(I) and 1820(J), which may be positioned on a corresponding neckband 1805.

[0069] In some embodiments, one or more of acoustic transducers 1820(A)-(J) may be used as output transducers (e.g., speakers). For example, acoustic transducers 1820(A) and/or 1820(B) may be earbuds or any other suitable type of headphone or speaker.

[0070] The configuration of acoustic transducers 1820 of the microphone array may vary. While augmented-reality system 1800 is shown in FIG. 18 as having ten acoustic transducers 1820, the number of acoustic transducers 1820 may be greater or less than ten. In some embodiments, using higher numbers of acoustic transducers 1820 may increase the amount of audio information collected and/or the sensitivity and accuracy of the audio information. In contrast, using a lower number of acoustic transducers 1820 may decrease the computing power required by an associated controller 1850 to process the collected audio information. In addition, the position of each acoustic transducer 1820 of the microphone array may vary. For example, the position of an acoustic transducer 1820 may include a defined position on the user, a defined coordinate on frame 1810, an orientation associated with each acoustic transducer 1820, or some combination thereof.

[0071] Acoustic transducers 1820(A) and 1820(B) may be positioned on different parts of the user's ear, such as behind the pinna, behind the tragus, and/or within the auricle or fossa. Or, there may be additional acoustic transducers 1820 on or surrounding the ear in addition to acoustic transducers 1820 inside the ear canal. Having an acoustic transducer 1820 positioned next to an ear canal of a user may enable the microphone array to collect information on how sounds arrive at the ear canal. By positioning at least two of acoustic transducers 1820 on either side of a user's head (e.g., as binaural microphones), augmented-reality system 1800 may simulate binaural hearing and capture a 3D stereo sound field around about a user's head. In some embodiments, acoustic transducers 1820(A) and 1820(B) may be connected to augmented-reality system 1800 via a wired connection 1830, and in other embodiments acoustic transducers 1820(A) and 1820(B) may be connected to augmented-reality system 1800 via a wireless connection (e.g., a BLUETOOTH connection). In still other embodiments, acoustic transducers 1820(A) and 1820(B) may not be used at all in conjunction with augmented-reality system 1800.

[0072] Acoustic transducers 1820 on frame 1810 may be positioned in a variety of different ways, including along the length of the temples, across the bridge, above or below display devices 1815(A) and 1815(B), or some combination thereof. Acoustic transducers 1820 may also be oriented such that the microphone array is able to detect sounds in a wide range of directions surrounding the user wearing the augmented-reality system 1800. In some embodiments, an optimization process may be performed during manufacturing of augmented-reality system 1800 to determine relative positioning of each acoustic transducer 1820 in the microphone array.

[0073] In some examples, augmented-reality system 1800 may include or be connected to an external device (e.g., a paired device), such as neckband 1805. Neckband 1805 generally represents any type or form of paired device. Thus, the following discussion of neckband 1805 may also apply to various other paired devices, such as charging cases, smart watches, smart phones, wrist bands, other wearable devices, hand-held controllers, tablet computers, laptop computers, other external compute devices, etc.

[0074] As shown, neckband 1805 may be coupled to eyewear device 1802 via one or more connectors. The connectors may be wired or wireless and may include electrical and/or non-electrical (e.g., structural) components. In some cases, eyewear device 1802 and neckband 1805 may operate independently without any wired or wireless connection between them. While FIG. 18 illustrates the components of eyewear device 1802 and neckband 1805 in example locations on eyewear device 1802 and neckband 1805, the components may be located elsewhere and/or distributed differently on eyewear device 1802 and/or neckband 1805. In some embodiments, the components of eyewear device 1802 and neckband 1805 may be located on one or more additional peripheral devices paired with eyewear device 1802, neckband 1805, or some combination thereof.

[0075] Pairing external devices, such as neckband 1805, with augmented-reality eyewear devices may enable the eyewear devices to achieve the form factor of a pair of glasses while still providing sufficient battery and computation power for expanded capabilities. Some or all of the battery power, computational resources, and/or additional features of augmented-reality system 1800 may be provided by a paired device or shared between a paired device and an eyewear device, thus reducing the weight, heat profile, and form factor of the eyewear device overall while still retaining desired functionality. For example, neckband 1805 may allow components that would otherwise be included on an eyewear device to be included in neckband 1805 since users may tolerate a heavier weight load on their shoulders than they would tolerate on their heads. Neckband 1805 may also have a larger surface area over which to diffuse and disperse heat to the ambient environment. Thus, neckband 1805 may allow for greater battery and computation capacity than might otherwise have been possible on a standalone eyewear device. Since weight carried in neckband 1805 may be less invasive to a user than weight carried in eyewear device 1802, a user may tolerate wearing a lighter eyewear device and carrying or wearing the paired device for greater lengths of time than a user would tolerate wearing a heavy standalone eyewear device, thereby enabling users to more fully incorporate artificial-reality environments into their day-to-day activities.

[0076] Neckband 1805 may be communicatively coupled with eyewear device 1802 and/or to other devices. These other devices may provide certain functions (e.g., tracking, localizing, depth mapping, processing, storage, etc.) to augmented-reality system 1800. In the embodiment of FIG. 18, neckband 1805 may include two acoustic transducers (e.g., 1820(I) and 1820(J)) that are part of the microphone array (or potentially form their own microphone subarray). Neckband 1805 may also include a controller 1825 and a power source 1835.

[0077] Acoustic transducers 1820(I) and 1820(J) of neckband 1805 may be configured to detect sound and convert the detected sound into an electronic format (analog or digital). In the embodiment of FIG. 18, acoustic transducers 1820(I) and 1820(J) may be positioned on neckband 1805, thereby increasing the distance between the neckband acoustic transducers 1820(I) and 1820(J) and other acoustic transducers 1820 positioned on eyewear device 1802. In some cases, increasing the distance between acoustic transducers 1820 of the microphone array may improve the accuracy of beamforming performed via the microphone array. For example, if a sound is detected by acoustic transducers 1820(C) and 1820(D) and the distance between acoustic transducers 1820(C) and 1820(D) is greater than, e.g., the distance between acoustic transducers 1820(D) and 1820(E), the determined source location of the detected sound may be more accurate than if the sound had been detected by acoustic transducers 1820(D) and 1820(E).

[0078] Controller 1825 of neckband 1805 may process information generated by the sensors on neckband 1805 and/or augmented-reality system 1800. For example, controller 1825 may process information from the microphone array that describes sounds detected by the microphone array. For each detected sound, controller 1825 may perform a direction-of-arrival (DOA) estimation to estimate a direction from which the detected sound arrived at the microphone array. As the microphone array detects sounds, controller 1825 may populate an audio data set with the information. In embodiments in which augmented-reality system 1800 includes an inertial measurement unit, controller 1825 may compute all inertial and spatial calculations from the IMU located on eyewear device 1802. A connector may convey information between augmented-reality system 1800 and neckband 1805 and between augmented-reality system 1800 and controller 1825. The information may be in the form of optical data, electrical data, wireless data, or any other transmittable data form. Moving the processing of information generated by augmented-reality system 1800 to neckband 1805 may reduce weight and heat in eyewear device 1802, making it more comfortable to the user.

[0079] Power source 1835 in neckband 1805 may provide power to eyewear device 1802 and/or to neckband 1805. Power source 1835 may include, without limitation, lithium-ion batteries, lithium-polymer batteries, primary lithium batteries, alkaline batteries, or any other form of power storage. In some cases, power source 1835 may be a wired power source. Including power source 1835 on neckband 1805 instead of on eyewear device 1802 may help better distribute the weight and heat generated by power source 1835.

[0080] As noted, some artificial-reality systems may, instead of blending an artificial reality with actual reality, substantially replace one or more of a user's sensory perceptions of the real world with a virtual experience. One example of this type of system is a head-worn display system, such as virtual-reality system 1900 in FIG. 19, that mostly or completely covers a user's field of view. Virtual-reality system 1900 may include a front rigid body 1902 and a band 1904 shaped to fit around a user's head. Virtual-reality system 1900 may also include output audio transducers 1906(A) and 1906(B). Furthermore, while not shown in FIG. 19, front rigid body 1902 may include one or more electronic elements, including one or more electronic displays, one or more inertial measurement units (IMUs), one or more tracking emitters or detectors, and/or any other suitable device or system for creating an artificial-reality experience.

[0081] Artificial-reality systems may include a variety of types of visual feedback mechanisms. For example, display devices in augmented-reality system 1800 and/or virtual-reality system 1900 may include one or more liquid crystal displays (LCDs), light emitting diode (LED) displays, microLED displays, organic LED (OLED) displays, digital light project (DLP) micro-displays, liquid crystal on silicon (LCoS) micro-displays, and/or any other suitable type of display screen. These artificial-reality systems may include a single display screen for both eyes or may provide a display screen for each eye, which may allow for additional flexibility for varifocal adjustments or for correcting a user's refractive error. Some of these artificial-reality systems may also include optical subsystems having one or more lenses (e.g., concave or convex lenses, Fresnel lenses, adjustable liquid lenses, etc.) through which a user may view a display screen. These optical subsystems may serve a variety of purposes, including to collimate (e.g., make an object appear at a greater distance than its physical distance), to magnify (e.g., make an object appear larger than its actual size), and/or to relay (to, e.g., the viewer's eyes) light. These optical subsystems may be used in a non-pupil-forming architecture (such as a single lens configuration that directly collimates light but results in so-called pincushion distortion) and/or a pupil-forming architecture (such as a multi-lens configuration that produces so-called barrel distortion to nullify pincushion distortion).

[0082] In addition to or instead of using display screens, some of the artificial-reality systems described herein may include one or more projection systems. For example, display devices in augmented-reality system 1800 and/or virtual-reality system 1900 may include microLED projectors that project light (using, e.g., a waveguide) into display devices, such as clear combiner lenses that allow ambient light to pass through. The display devices may refract the projected light toward a user's pupil and may enable a user to simultaneously view both artificial-reality content and the real world. The display devices may accomplish this using any of a variety of different optical components, including waveguide components (e.g., holographic, planar, diffractive, polarized, and/or reflective waveguide elements), light-manipulation surfaces and elements (such as diffractive, reflective, and refractive elements and gratings), coupling elements, etc. Artificial-reality systems may also be configured with any other suitable type or form of image projection system, such as retinal projectors used in virtual retina displays.

[0083] The artificial-reality systems described herein may also include various types of computer vision components and subsystems. For example, augmented-reality system 1800 and/or virtual-reality system 1900 may include one or more optical sensors, such as two-dimensional (2D) or 3D cameras, structured light transmitters and detectors, time-of-flight depth sensors, single-beam or sweeping laser rangefinders, 3D LiDAR sensors, and/or any other suitable type or form of optical sensor. An artificial-reality system may process data from one or more of these sensors to identify a location of a user, to map the real world, to provide a user with context about real-world surroundings, and/or to perform a variety of other functions.

[0084] The artificial-reality systems described herein may also include one or more input and/or output audio transducers. Output audio transducers may include voice coil speakers, ribbon speakers, electrostatic speakers, piezoelectric speakers, bone conduction transducers, cartilage conduction transducers, tragus-vibration transducers, and/or any other suitable type or form of audio transducer. Similarly, input audio transducers may include condenser microphones, dynamic microphones, ribbon microphones, and/or any other type or form of input transducer. In some embodiments, a single transducer may be used for both audio input and audio output.

[0085] In some embodiments, the artificial-reality systems described herein may also include tactile (i.e., haptic) feedback systems, which may be incorporated into headwear, gloves, body suits, handheld controllers, environmental devices (e.g., chairs, floormats, etc.), and/or any other type of device or system. Haptic feedback systems may provide various types of cutaneous feedback, including vibration, force, traction, texture, and/or temperature. Haptic feedback systems may also provide various types of kinesthetic feedback, such as motion and compliance. Haptic feedback may be implemented using motors, piezoelectric actuators, fluidic systems, and/or a variety of other types of feedback mechanisms. Haptic feedback systems may be implemented independent of other artificial-reality devices, within other artificial-reality devices, and/or in conjunction with other artificial-reality devices.

[0086] By providing haptic sensations, audible content, and/or visual content, artificial-reality systems may create an entire virtual experience or enhance a user's real-world experience in a variety of contexts and environments. For instance, artificial-reality systems may assist or extend a user's perception, memory, or cognition within a particular environment. Some systems may enhance

a user's interactions with other people in the real world or may enable more immersive interactions with other people in a virtual world. Artificial-reality systems may also be used for educational purposes (e.g., for teaching or training in schools, hospitals, government organizations, military organizations, business enterprises, etc.), entertainment purposes (e.g., for playing video games, listening to music, watching video content, etc.), and/or for accessibility purposes (e.g., as hearing aids, visual aids, etc.). The embodiments disclosed herein may enable or enhance a user's artificial-reality experience in one or more of these contexts and environments and/or in other contexts and environments.

[0087] As mentioned above, one or more of the systems described herein may include a smartwatch, which may include a wearable computer in the form of a wristwatch. FIG. 20 shows a view 2000 of an example smartwatch 2002. As shown, example smartwatch 2002 may include or implement a variety of components that may serve or support various computing functions such as a battery 2004, a central processing unit 2006 ("CPU 2006" in FIG. 20) a speaker 2008, and a display 2010. Additionally, example smartwatch 2002 may include various components that may be used as a sensor such as a microphone 2012 and a thermometer 2014. Although not shown in FIG. 20, example smartwatch 2002 may include any other suitable sensors such as those described herein (e.g., cameras, proximity sensors, motion sensors, etc.).

[0088] As further shown in FIG. 20, example smartwatch 2002 may also include an antenna 2016. Although only shown as a single antenna in FIG. 20, antenna 2016 may include or represent a plurality of antennas that may be configured to transmit and/or receive a variety of electromagnetic signals and/or configured to implement a plurality of wireless standards.

[0089] The process parameters and sequence of the steps described and/or illustrated herein are given by way of example only and can be varied as desired. For example, while the steps illustrated and/or described herein may be shown or discussed in a particular order, these steps do not necessarily need to be performed in the order illustrated or discussed. The various exemplary methods described and/or illustrated herein may also omit one or more of the steps described or illustrated herein or include additional steps in addition to those disclosed.

[0090] The preceding description has been provided to enable others skilled in the art to best utilize various aspects of the exemplary embodiments disclosed herein. This exemplary description is not intended to be exhaustive or to be limited to any precise form disclosed. Many modifications and variations are possible without departing from the spirit and scope of the present disclosure. The embodiments disclosed herein should be considered in all respects illustrative and not restrictive. Reference should be made to any claims appended hereto and their equivalents in determining the scope of the present disclosure.

[0091] Unless otherwise noted, the terms "connected to" and "coupled to" (and their derivatives), as used in the specification and/or claims, are to be construed as permitting both direct and indirect (i.e., via other elements or components) connection. In addition, the terms "a" or "an," as used in the specification and/or claims, are to be construed as meaning "at least one of." Finally, for ease of use, the terms "including" and "having" (and their derivatives), as used in the specification and/or claims, are interchangeable with and have the same meaning as the word "comprising."

Claims

1. A coplanar waveguide comprising:

   a signal region and a ground region;
   a first trimming line positioned on the signal region; and
   a second trimming line positioned on the ground region,
   wherein the first trimming line and the second trimming line form a floating region in the coplanar waveguide that is configured to receive an input radio frequency (RF) signal.

2. The coplanar waveguide of claim 1, wherein the floating region in the coplanar waveguide receives the input RF signal at a reduced insertion loss below a predetermined threshold.

3. The coplanar waveguide of claim 1 or 2, wherein at least one of the first trimming line or the second trimming line is etched into the coplanar waveguide at a specified location.

4. The coplanar waveguide of claim 3, wherein the etching removes at least a portion of mesh wire along the position of the first or second trimming lines.

5. The coplanar waveguide of any preceding claim, wherein at least one of the first or second trimming lines is additively applied by placing nonconductive material over a wire mesh affixed to the coplanar waveguide.

6. The coplanar waveguide of claim 5, wherein the wire mesh is part of a transparent metal mesh antenna.

7. The coplanar waveguide of claim 6, further comprising at least a portion of fill material configured to return a metal density of the transparent metal mesh antenna to a previously established level of prior to an implementation of the trimming lines.

8. A system comprising the coplanar waveguide of any

preceding claim.

9. The system of claim 8, further comprising an augmented reality device.

10. The system of claim 9, wherein the coplanar waveguide is included in a lens of the augmented reality device.

11. A method comprising:

positioning, within a signal region included in a coplanar waveguide, a first trimming line; and
positioning, within a ground region included in the coplanar waveguide, a second trimming line, wherein positioning the first trimming line and the second trimming line forms a floating region in the coplanar waveguide that is configured to receive an input radio frequency (RF) signal.

12. The method of claim 11, wherein positioning the first trimming line within the signal region included in the coplanar waveguide comprises etching the first trimming line into the coplanar waveguide at a specified location within the signal region included in the coplanar waveguide.

13. The method of claim 11 or 12, wherein positioning the second trimming line within the ground region included in the coplanar waveguide comprises etching the second trimming line into the coplanar waveguide at an additional specified location within the ground region included in the coplanar waveguide.

14. The method of any of claims 11 to 13, wherein at least one of:

positioning the first trimming line within the signal region included in the coplanar waveguide comprises additively applying the first trimming line by placing nonconductive mesh over a wire mesh affixed to the coplanar waveguide; and/or
positioning the second trimming line within the ground region included in the coplanar waveguide comprises additively applying the first trimming line by placing nonconductive mesh over the wire mesh affixed to the coplanar waveguide.

15. The method of any of claims 11 to 14, further comprising:
including the coplanar waveguide in a lens of an augmented reality device.

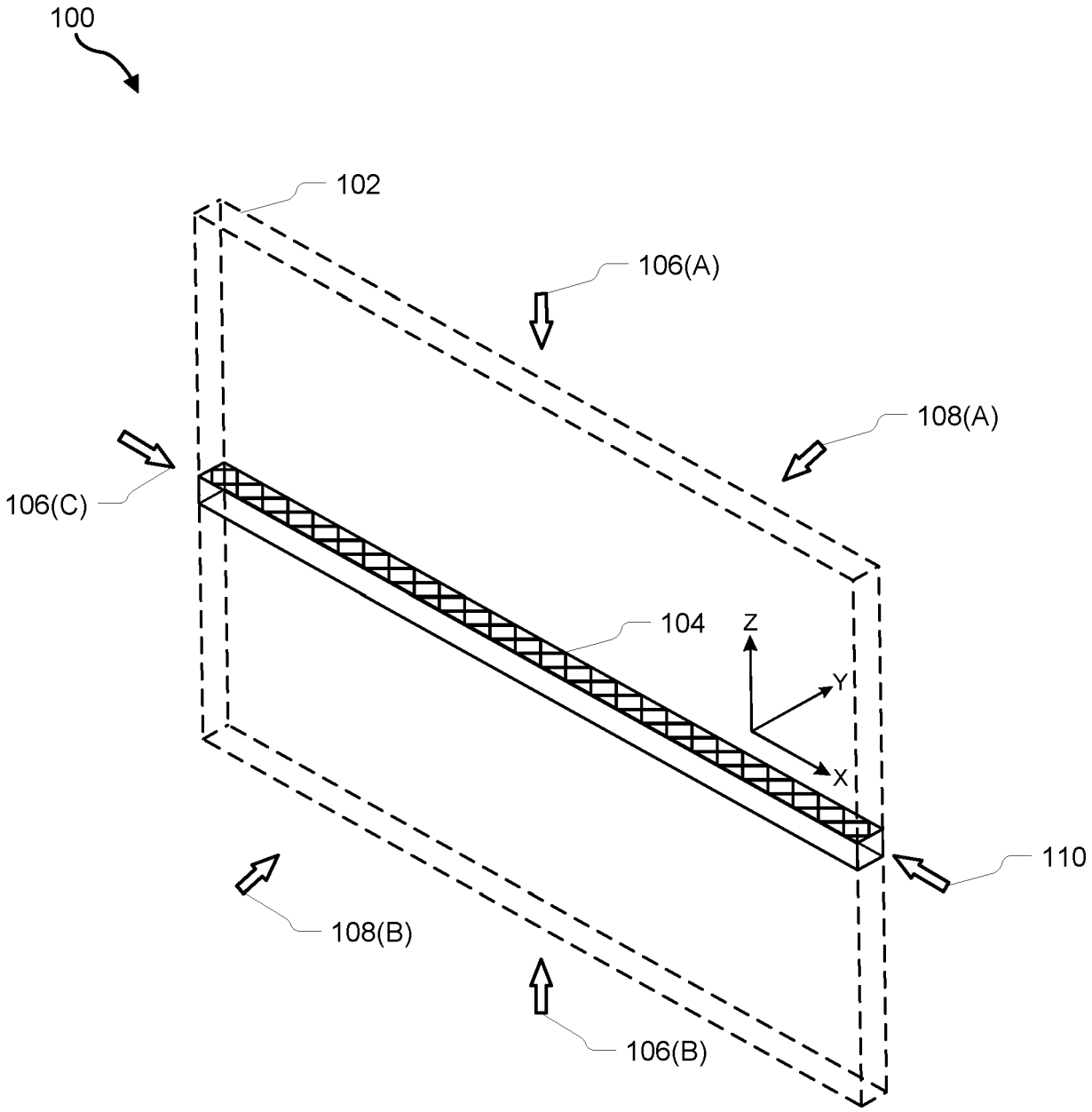


FIG. 1

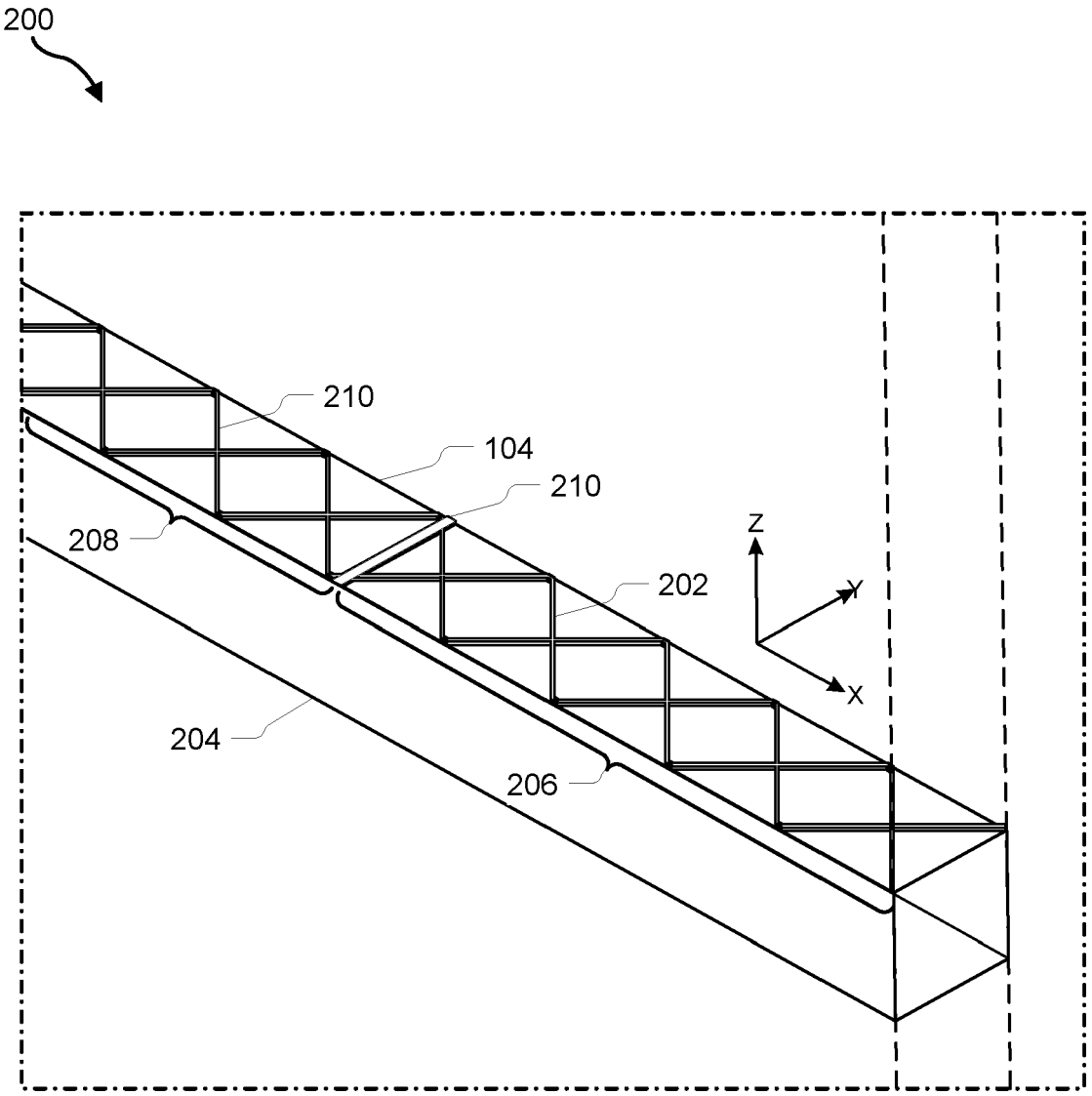


FIG. 2

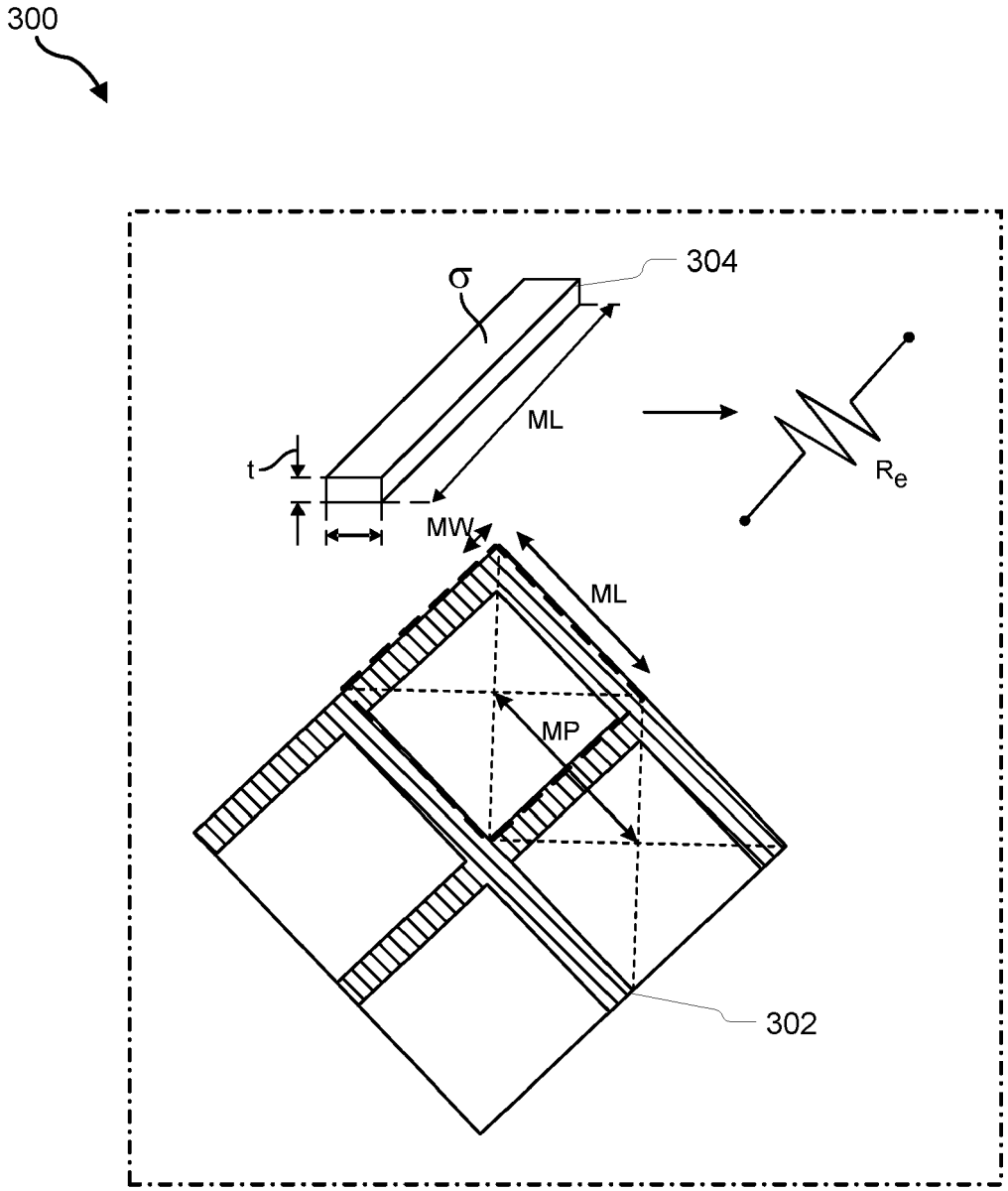
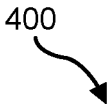


FIG. 3



402

$$Ap = \frac{(MP - MW)^2}{MP^2}$$

$$AC = MP^2$$

$$R = \frac{1}{\sigma}\frac{MP}{tMW}$$

$$MP = ML$$

404

σ	t	MP=ML	MW
5.8e7×20%	1 um	80 um	2 um

Ap	Rs	SW	LW
95.1%	3.45Ω/Sq.	Approx. 1mm	5 um

BM DK	BM DF		
2.25	1/1000		

FIG. 4

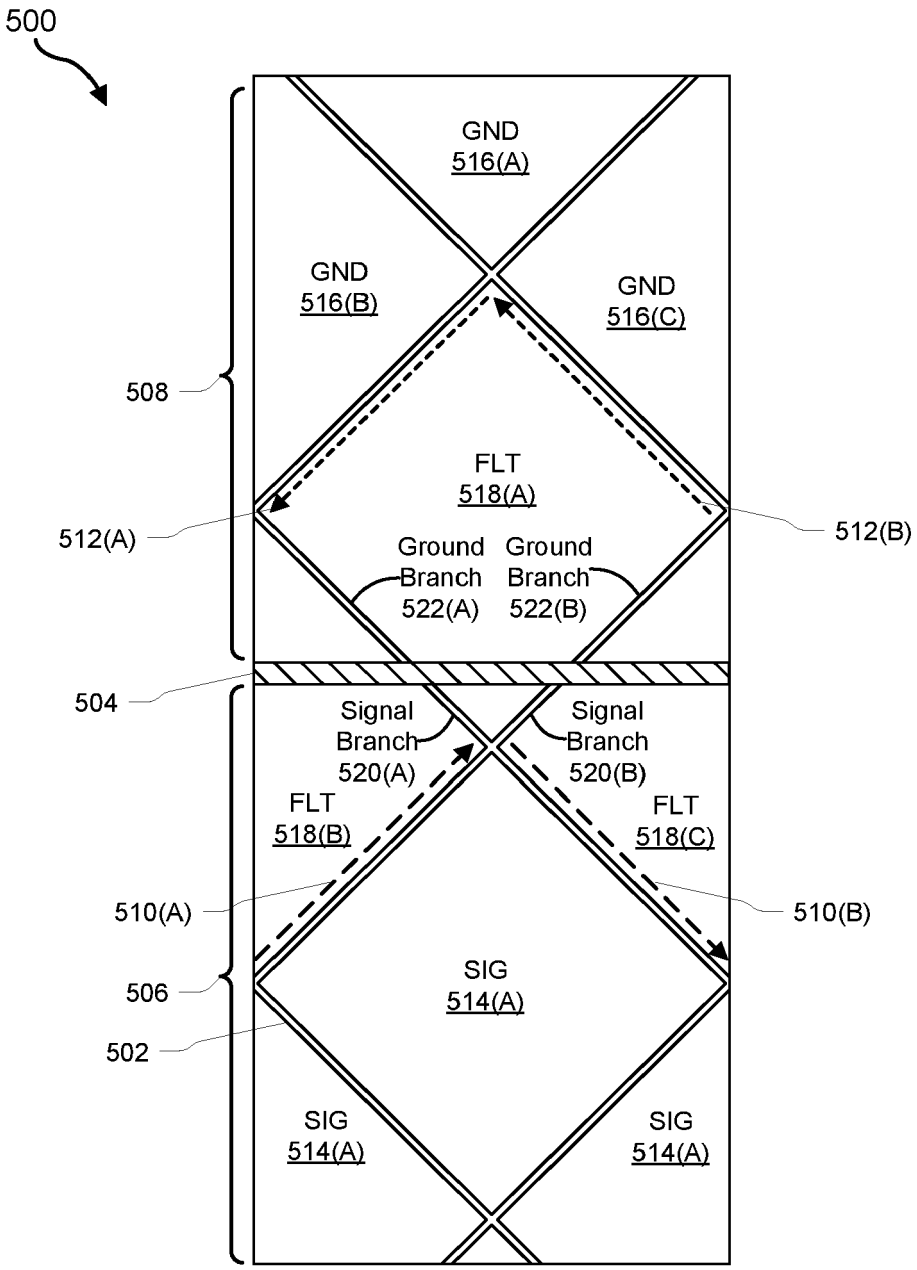

500
GND
516(A)
GND
516(B)
GND
516(C)
508
FLT
518(A)
512(A)
512(B)
Ground
Branch
522(A)
Ground
Branch
522(B)
504
Signal
Branch
520(A)
Signal
Branch
520(B)
FLT
518(B)
FLT
518(C)
510(A)
510(B)
506
SIG
514(A)
502
SIG
514(A)
SIG
514(A)

FIG. 5

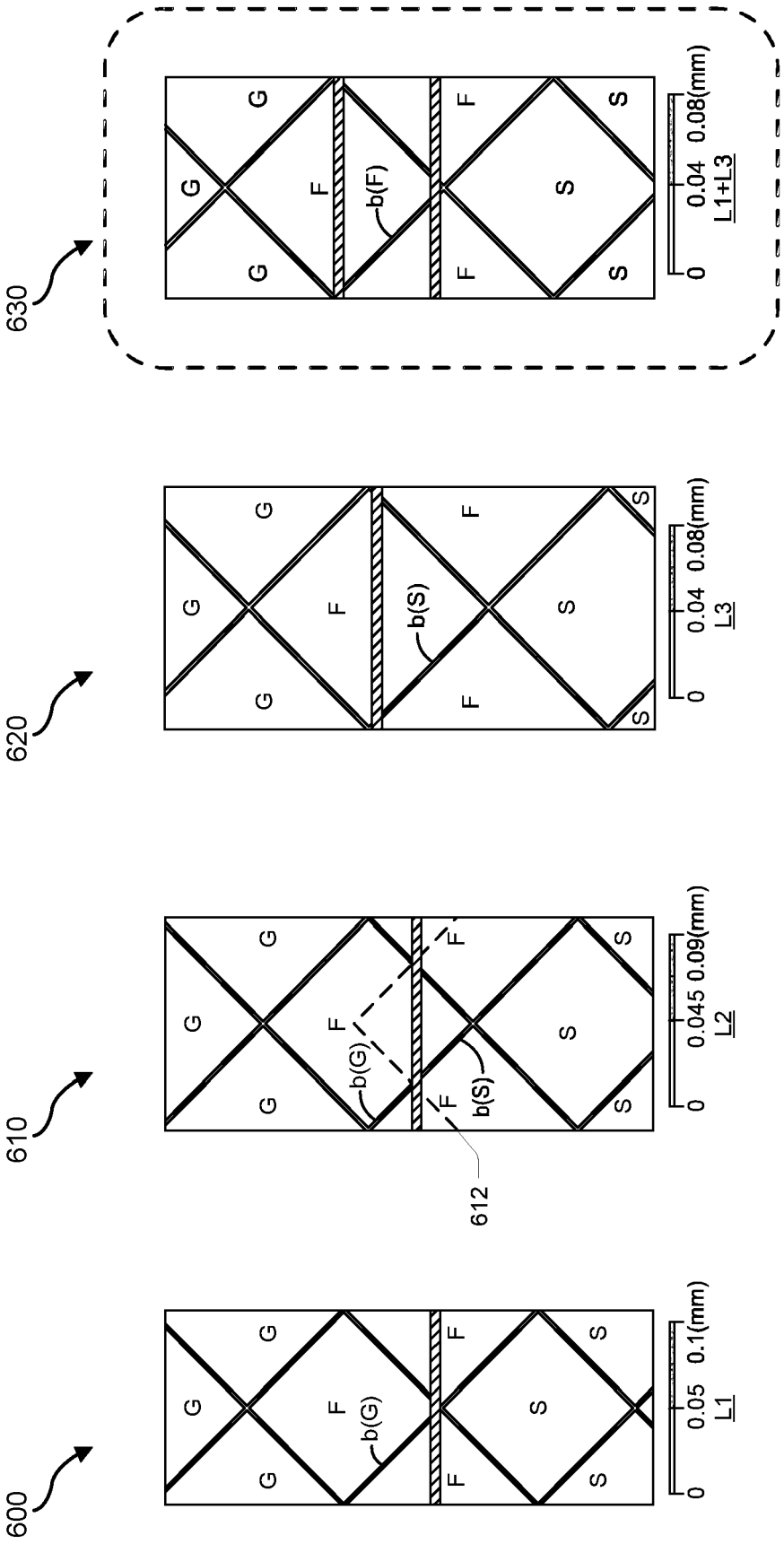

600
610
620
630
G
F
S
b(G)
b(S)
b(F)
612
0
0.05
0.1(mm)
L1
0.045
0.09(mm)
L2
0.04
0.08(mm)
L3
L1+L3

FIG. 6

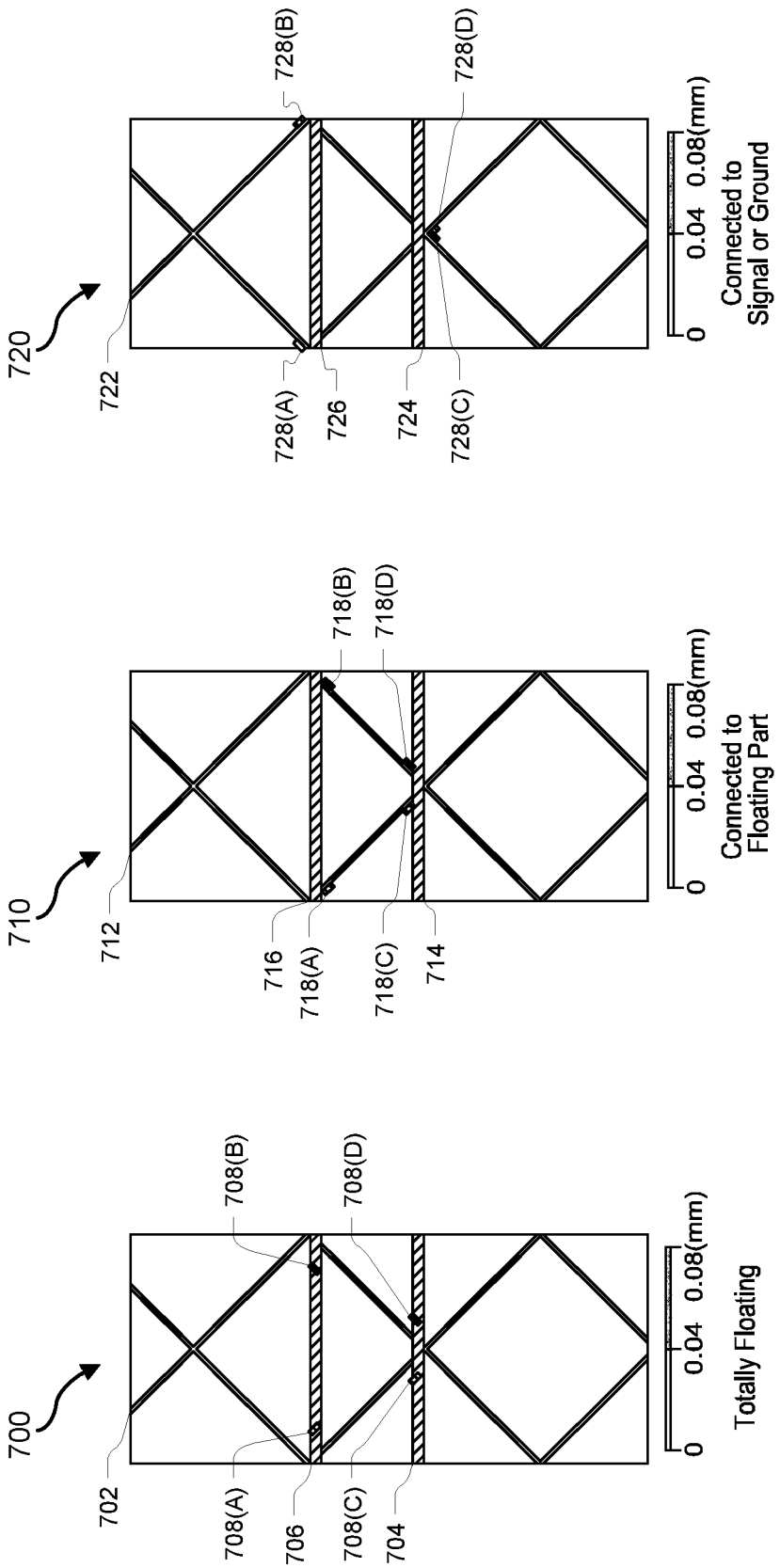

700
702
708(A)
706
708(C)
704
708(B)
708(D)
0
0.04
0.08(mm)
Totally Floating
710
712
716
718(A)
718(C)
714
718(B)
718(D)
0
0.04
0.08(mm)
Connected to
Floating Part
720
722
728(A)
726
724
728(C)
728(B)
728(D)
0
0.04
0.08(mm)
Connected to
Signal or Ground

FIG. 7

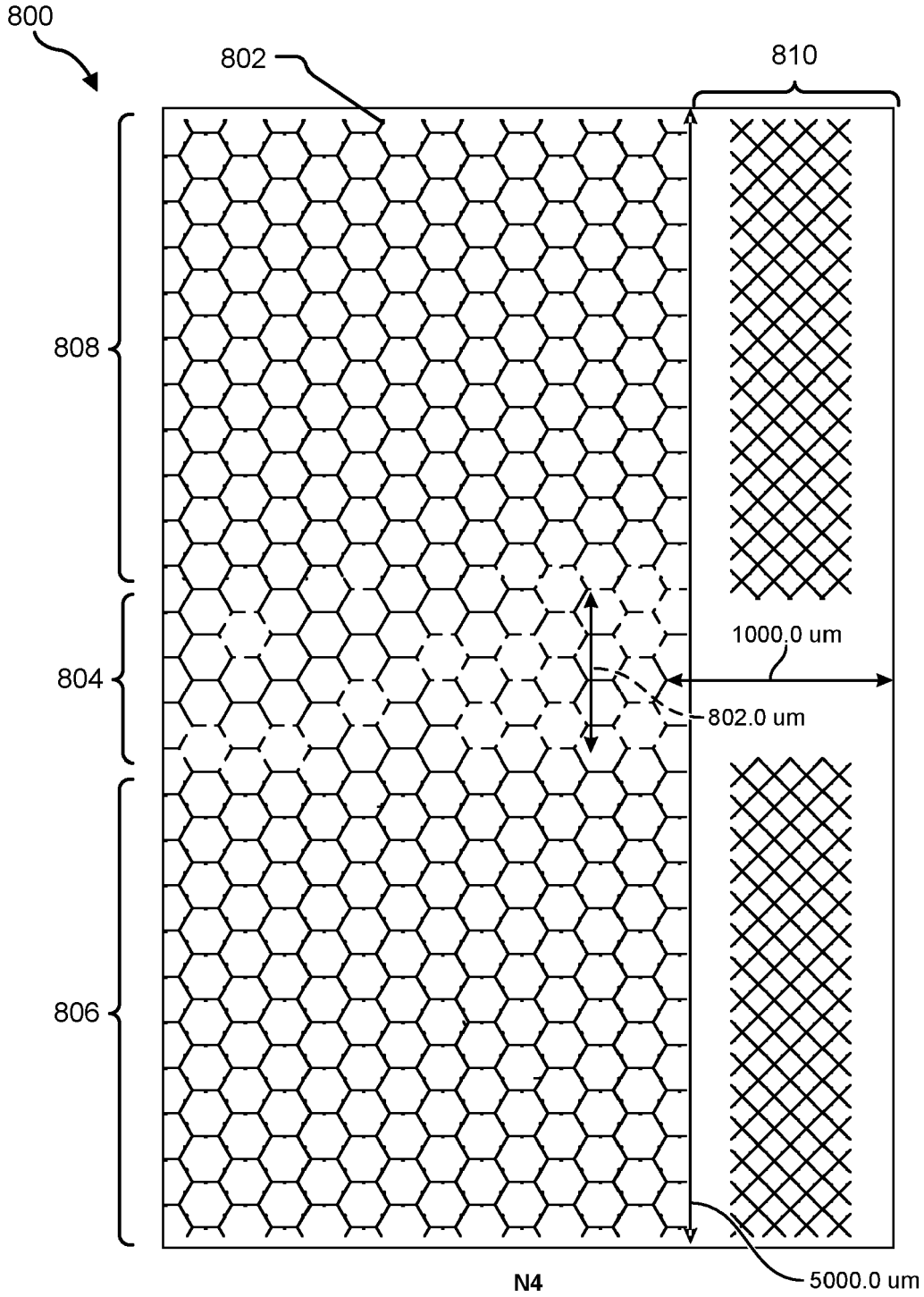


FIG. 8

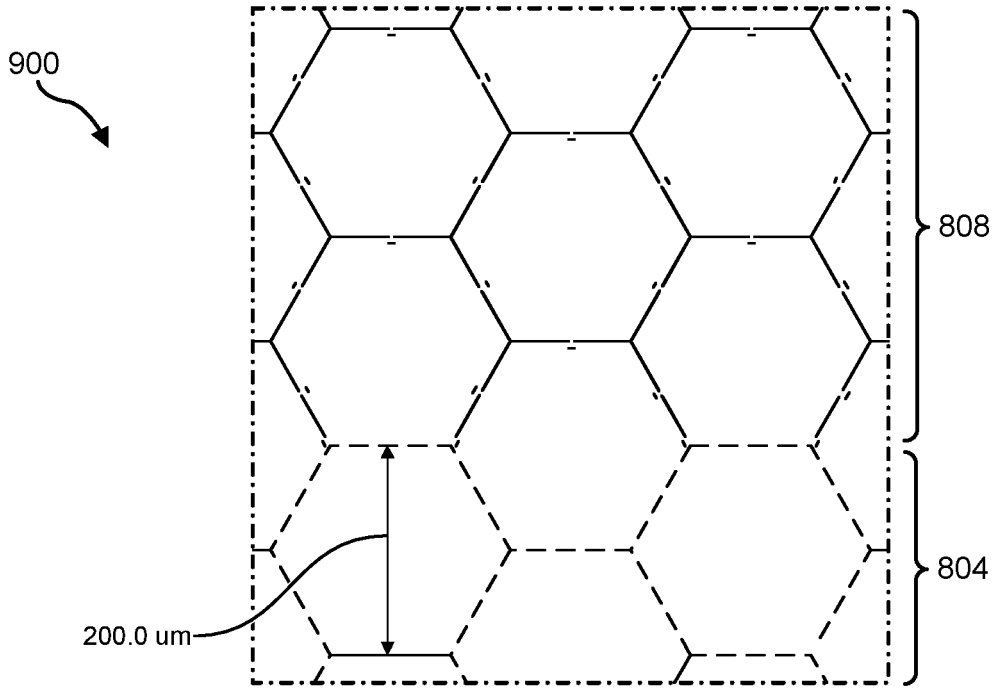
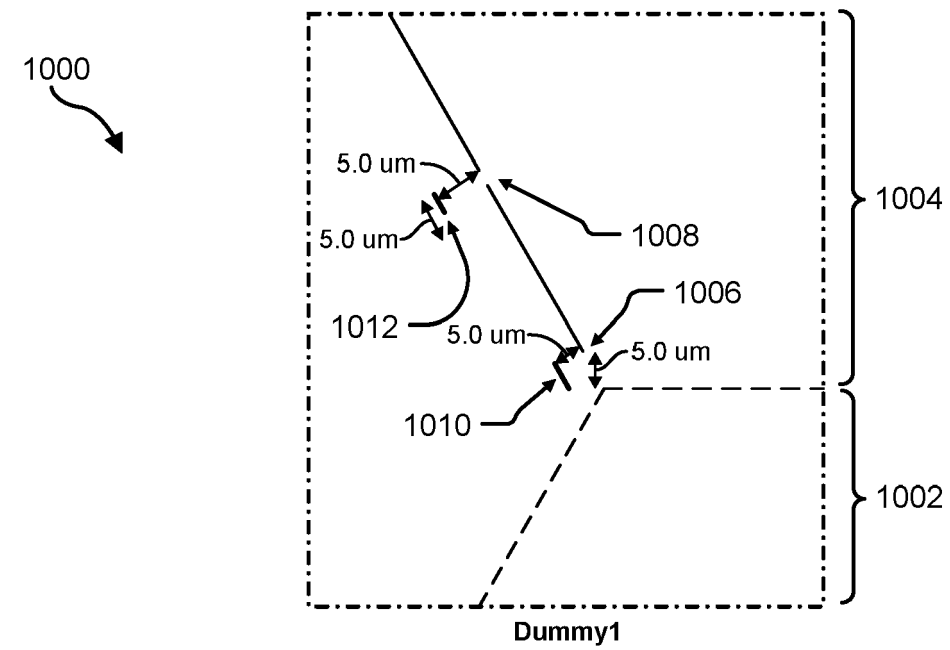


FIG. 9


1000
5.0 um
5.0 um
1012
1008
1006
5.0 um
5.0 um
1010
1004
1002
Dummy1

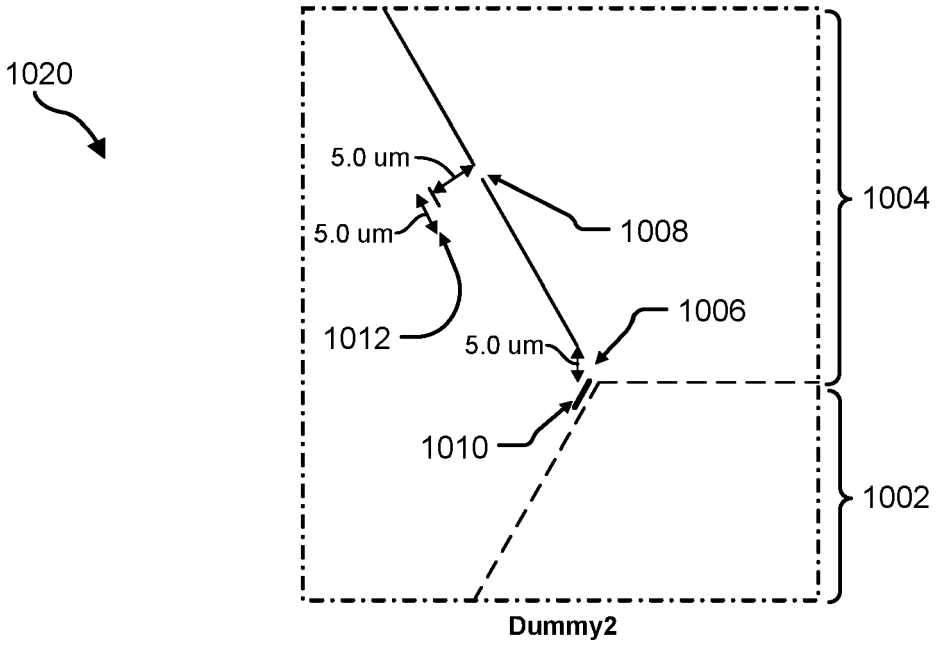

1020
5.0 um
5.0 um
1012
1008
1006
5.0 um
1010
1004
1002
Dummy2

FIG. 10

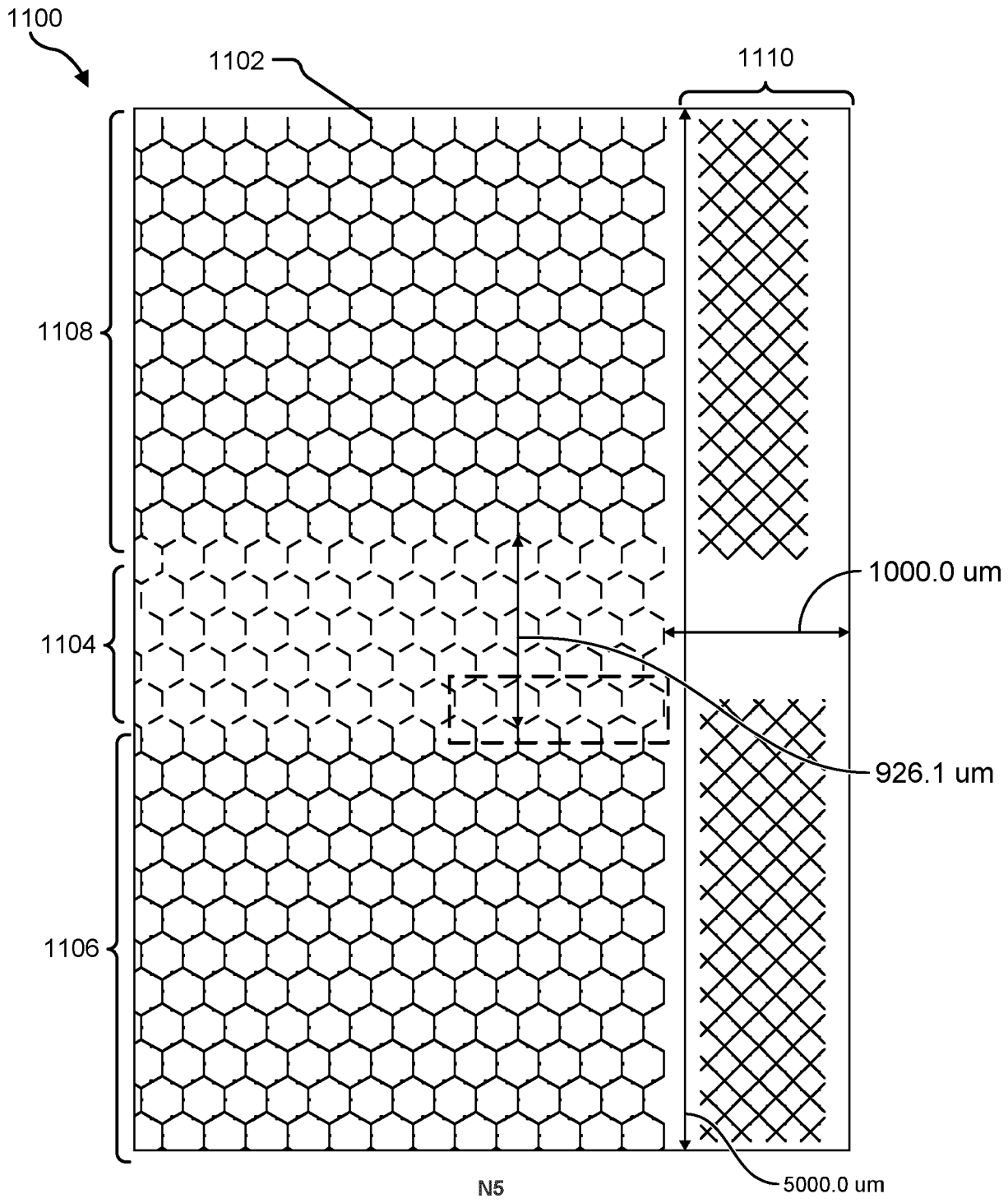


FIG. 11

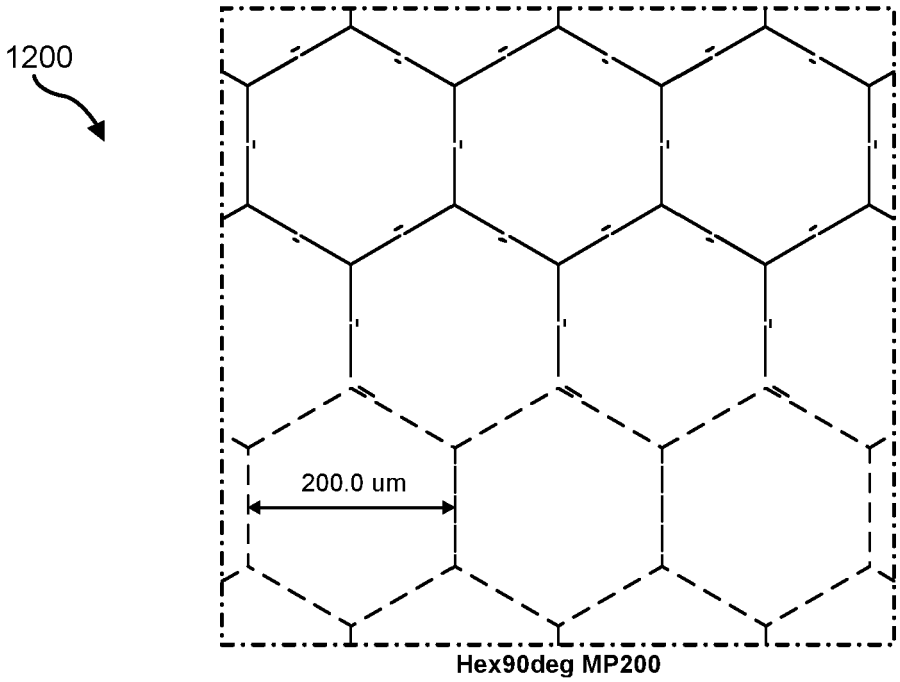
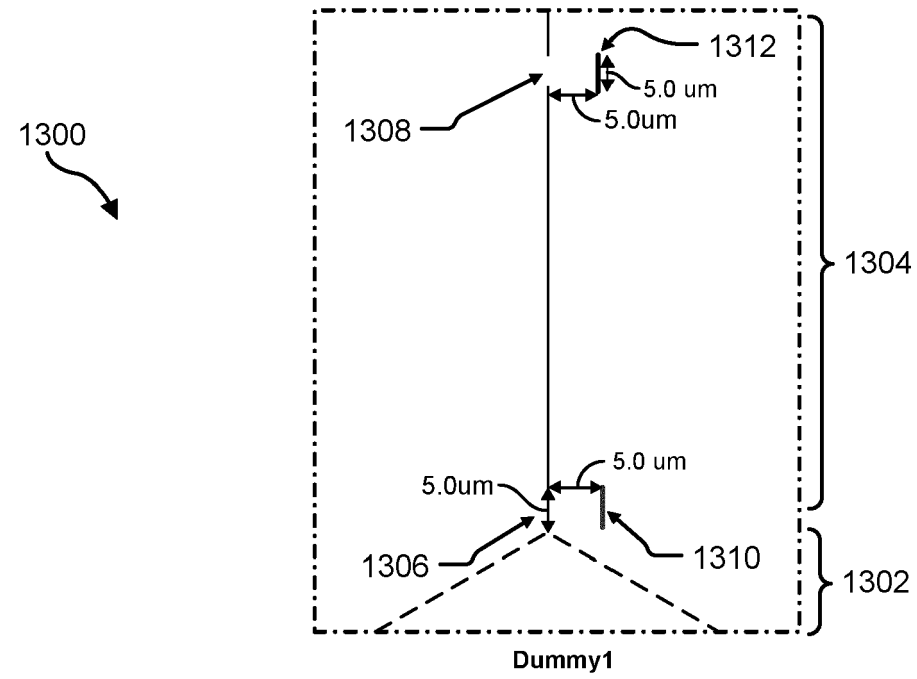


FIG. 12


1300
1312
5.0 um
5.0um
1308
1304
5.0 um
5.0um
1310
1306
1302
Dummy1

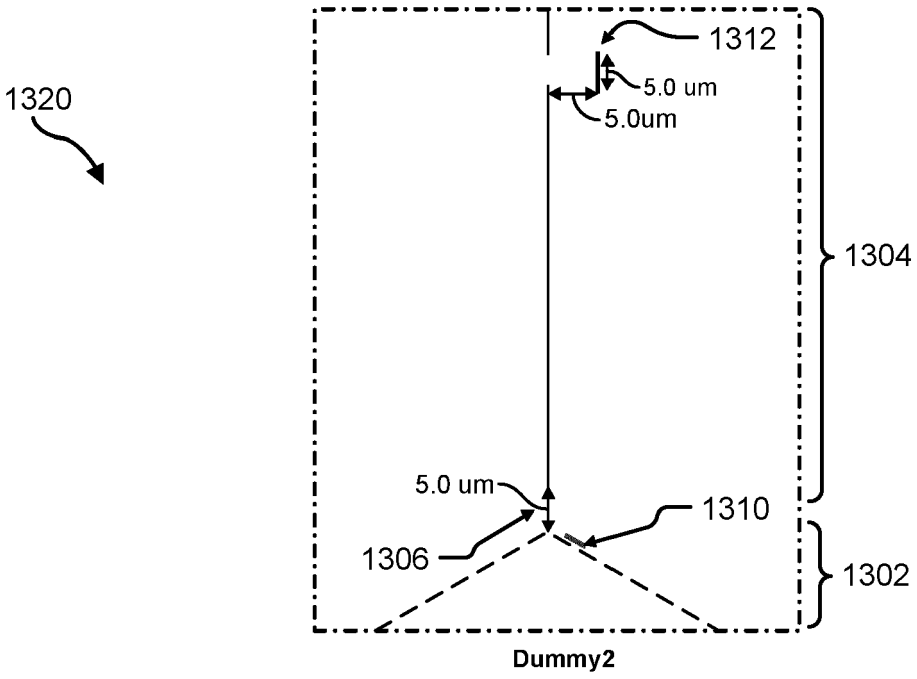

1320
1312
5.0 um
5.0um
1304
5.0 um
1310
1306
1302
Dummy2

FIG. 13

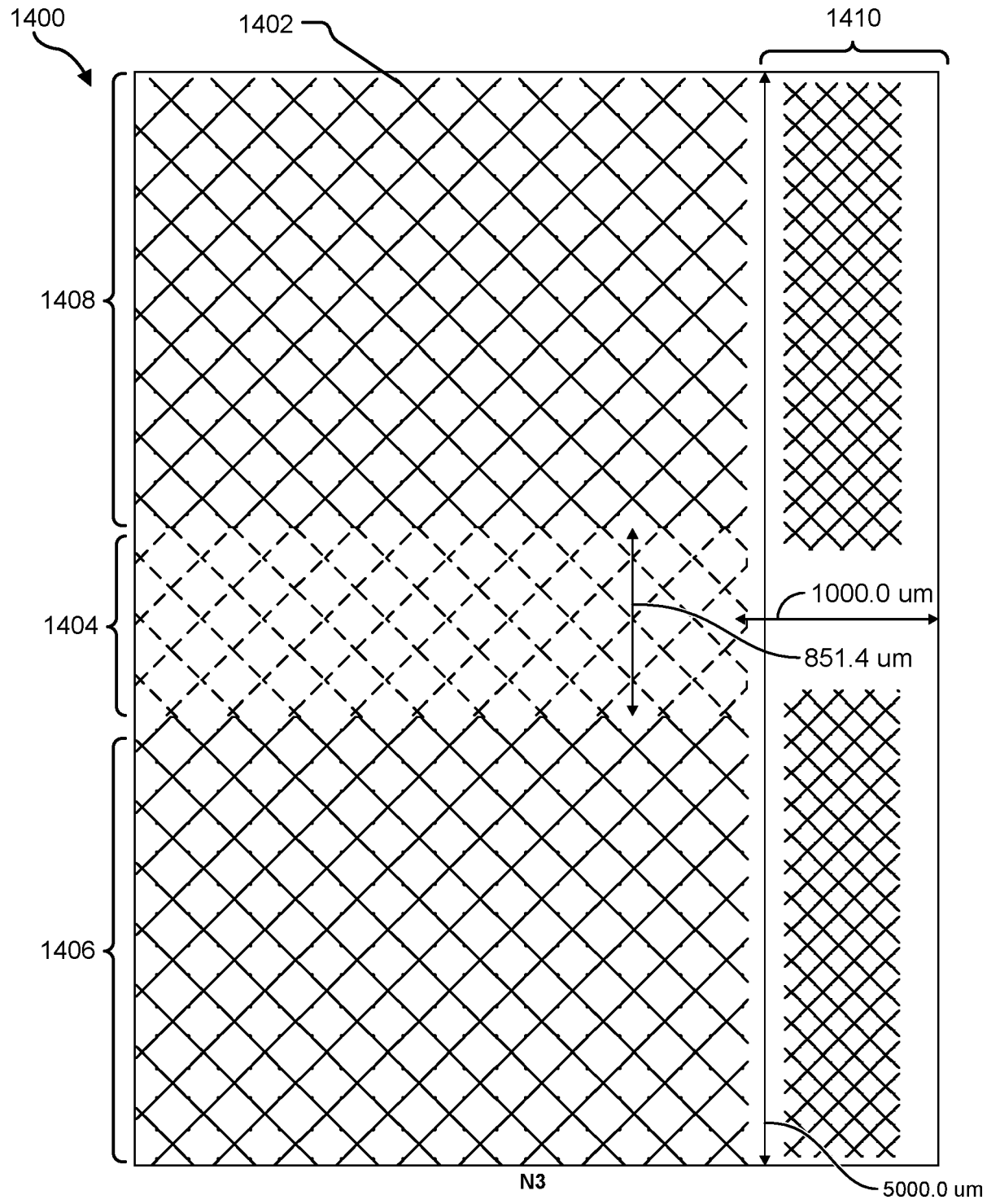


FIG. 14

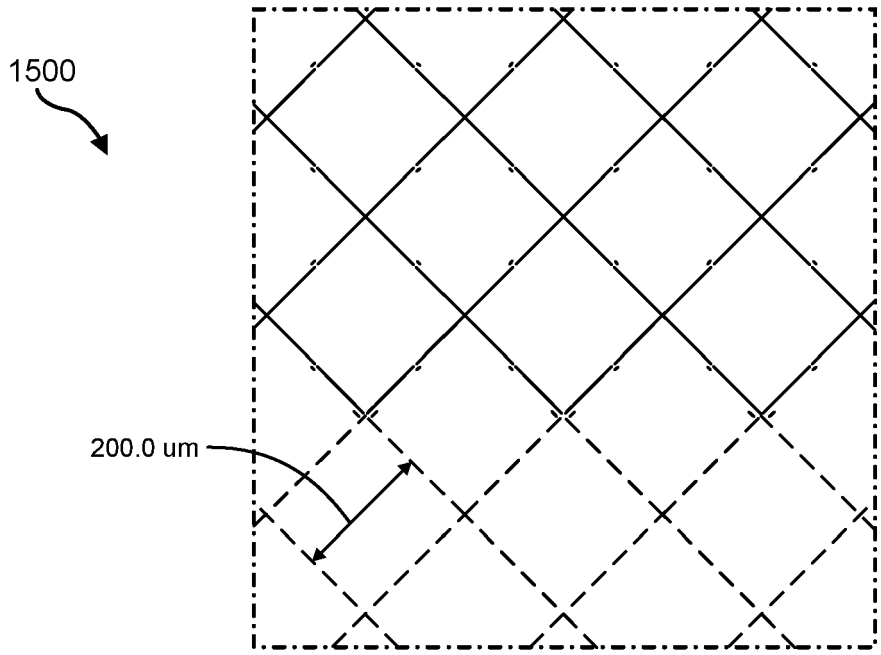
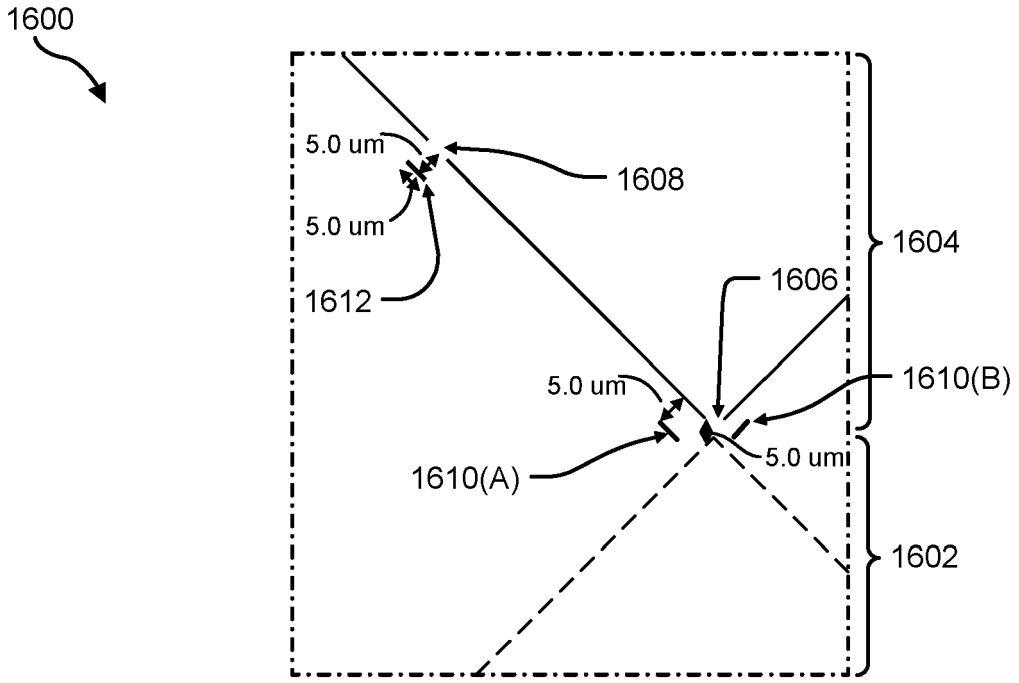


FIG. 15


1600
5.0 um
5.0 um
1612
1608
1606
1604
1610(B)
5.0 um
5.0 um
1610(A)
1602
Dummy1

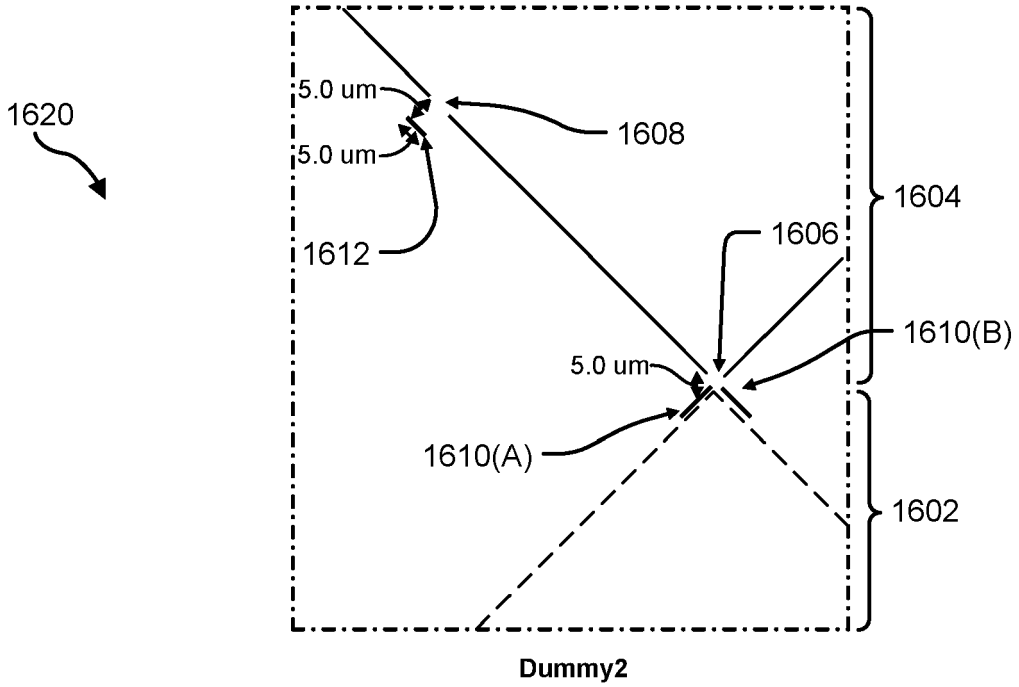

1620
5.0 um
5.0 um
1612
1608
1606
1604
1610(B)
5.0 um
1610(A)
1602
Dummy2

FIG. 16

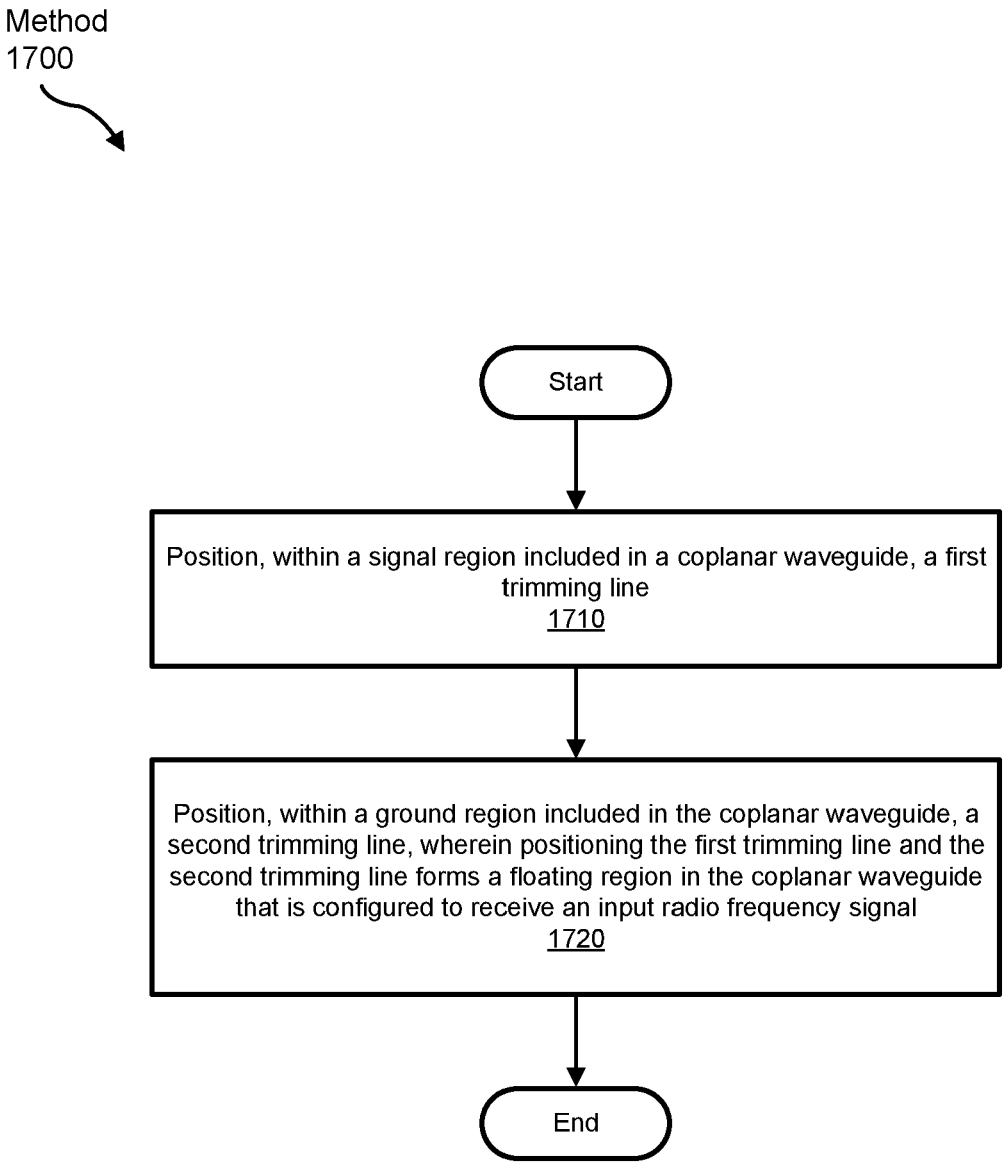

Method
1700
Start
Position, within a signal region included in a coplanar waveguide, a first trimming line
1710
Position, within a ground region included in the coplanar waveguide, a second trimming line, wherein positioning the first trimming line and the second trimming line forms a floating region in the coplanar waveguide that is configured to receive an input radio frequency signal
1720
End

FIG. 17

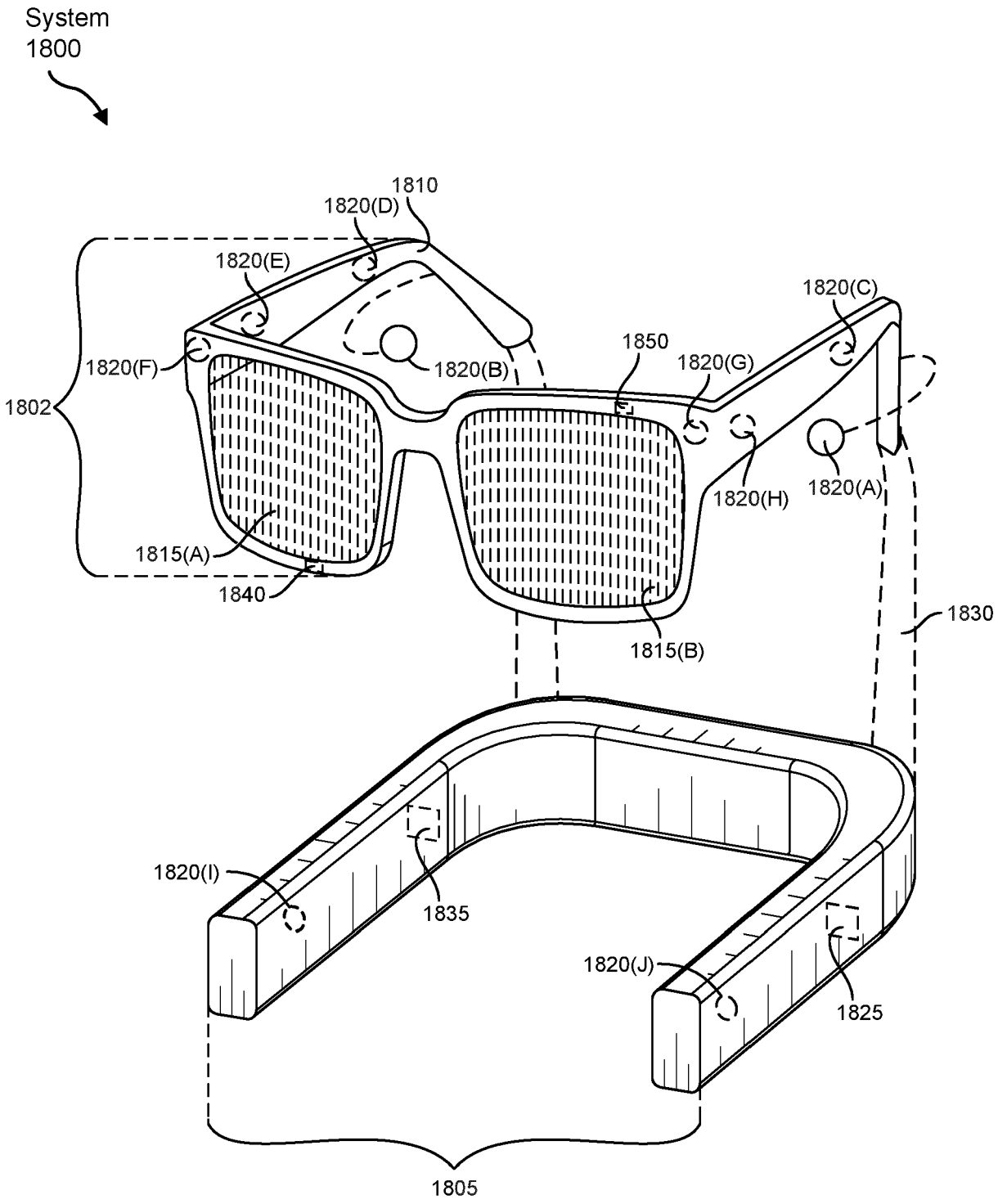

System
1800
1810
1820(D)
1820(E)
1820(C)
1820(F)
1820(B)
1850
1820(G)
1802
1820(H)
1820(A)
1815(A)
1840
1830
1815(B)
1820(I)
1835
1820(J)
1825
1805

FIG. 18

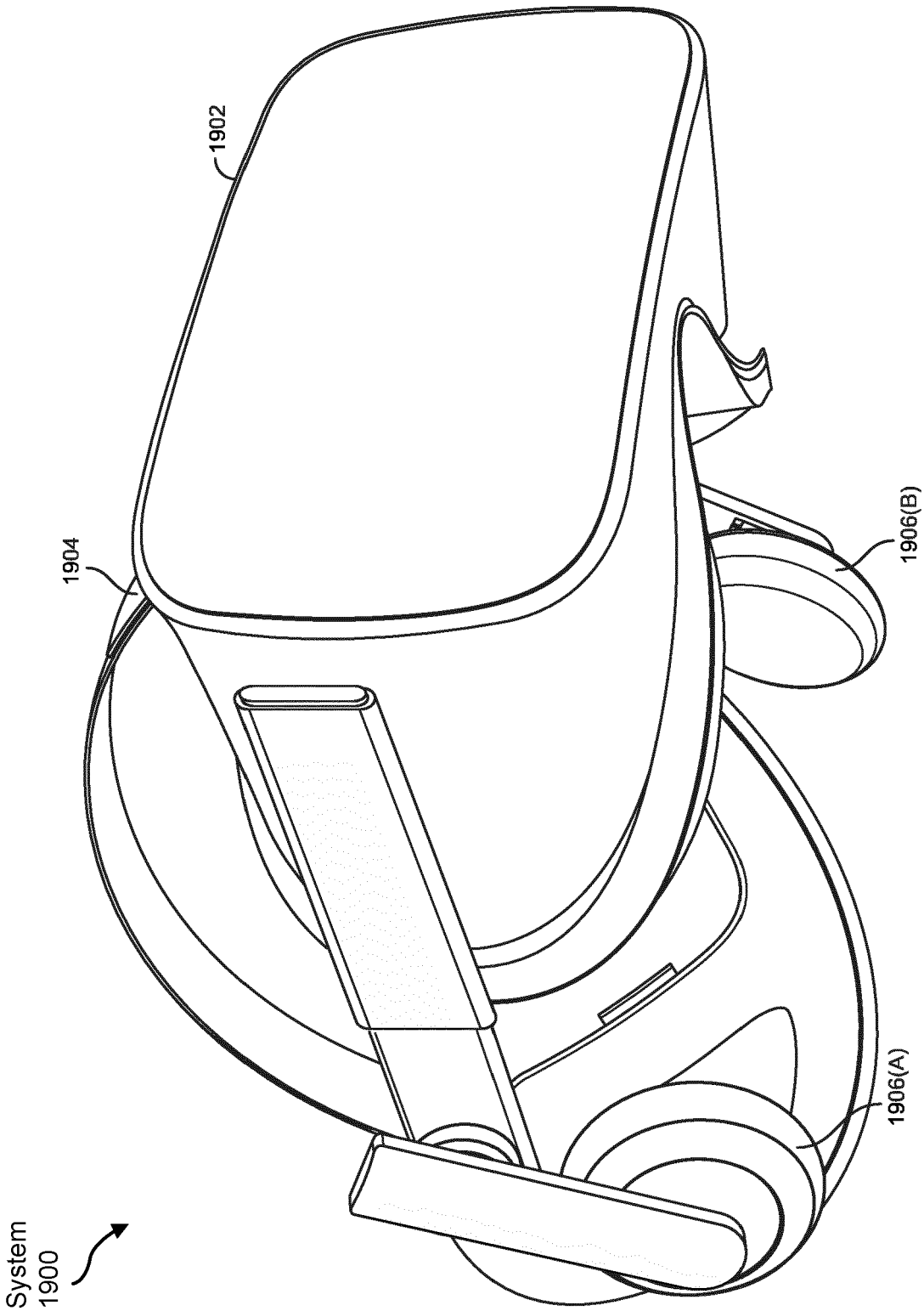


FIG. 19

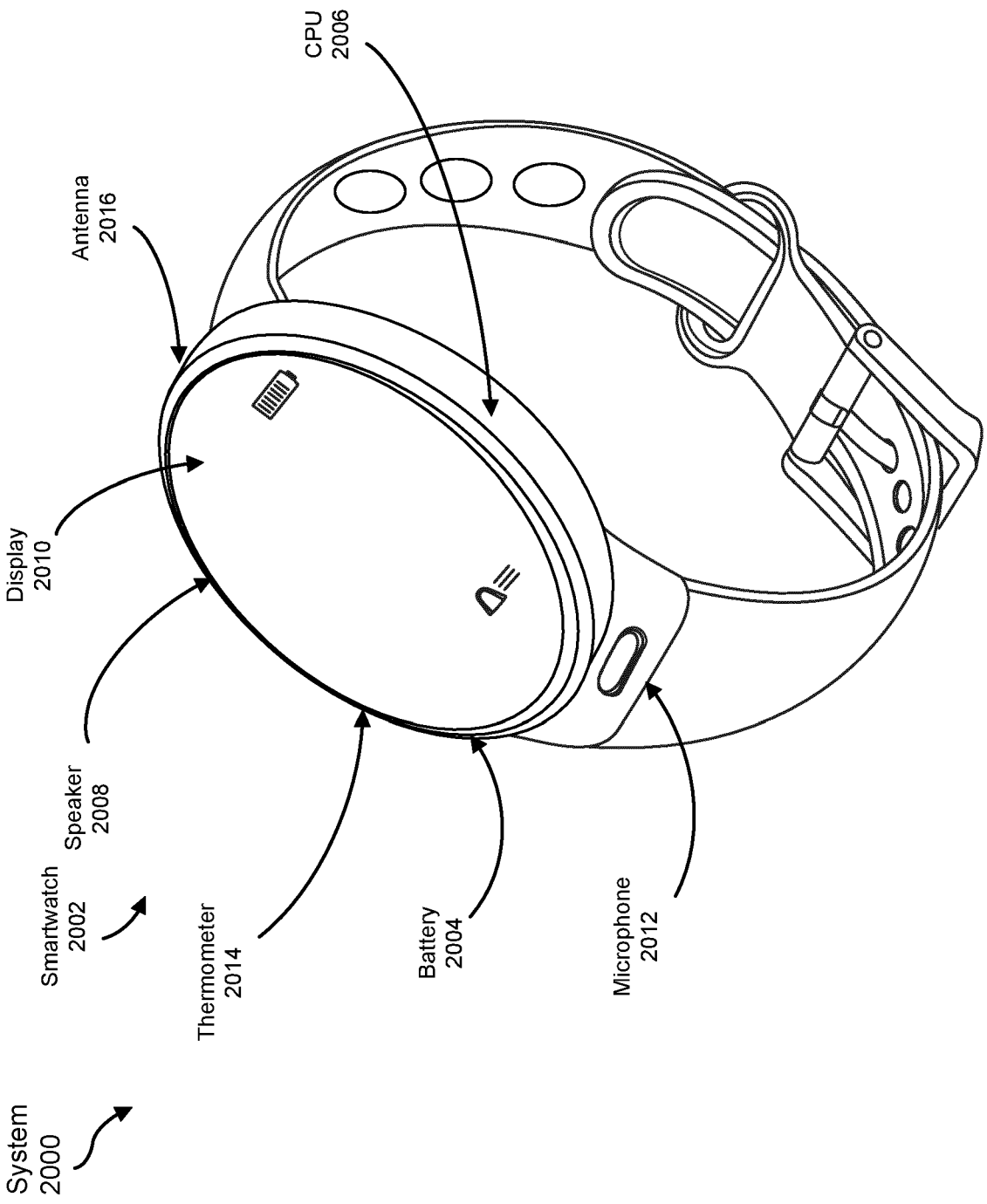

System
2000
Smartwatch
2002
Display
2010
Antenna
2016
CPU
2006
Speaker
2008
Thermometer
2014
Battery
2004
Microphone
2012

FIG. 20

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EUROPEAN SEARCH REPORT

Application Number
EP 23 19 1160

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 2021/033805 A1 (LG ELECTRONICS INC [KR]) 25 February 2021 (2021-02-25) * paragraph [0065] * * paragraph [0162] - paragraph [0174] * * figures 5a, 5b * * paragraph [0181] * * paragraph [0185] - paragraph [0187]; figures 8, 9 * * figures 10a, 10b *	1-4, 8-13,15 5-7,14	INV. H01P3/00 H01P11/00 H01Q1/27 H01Q1/36
X	WO 2022/075587 A1 (LG ELECTRONICS INC [KR]; KOREA ADVANCED INST SCI & TECH [KR]) 14 April 2022 (2022-04-14) * paragraph [0012] * * paragraph [0137] - paragraph [0147] * * figure 5 * & US 2023/261357 A1 (JUNG KANGJAE [KR] ET AL) 17 August 2023 (2023-08-17) * paragraph [0012] * * paragraph [0138] - paragraph [0148] * * figure 5 *	1,2,8,11	
Y	WO 2021/201323 A1 (LG ELECTRONICS INC [KR]) 7 October 2021 (2021-10-07) * paragraph [0176] - paragraph [0178] * * figure 6a *	5-7,14	TECHNICAL FIELDS SEARCHED (IPC) H01P H01Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	11 January 2024	Culhaoglu, Ali

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11-01-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2021033805 A1	25-02-2021	NONE	
WO 2022075587 A1	14-04-2022	KR 20220123133 A	05-09-2022
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WO 2021201323 A1	07-10-2021	NONE	

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