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(54) **BANDWIDTH EXTENDED BALANCED TIGHTLY COUPLED DIPOLE ARRAY ADDITIVELY MANUFACTURED MODULAR APERTURE**

(71) Applicant: **BAE SYSTEMS Information and Electronic Systems Integration Inc.**, Nashua, NH (US)

(72) Inventors: **Alexander D. Johnson**, Waltham, MA (US); **James F. Fung**, Manchester, NH (US); **Randall R. Lapierre**, Hooksett, NH (US)

(73) Assignee: **BAE Systems Information and Electronic Systems Integration Inc.**, Nashua, NH (US)

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H01Q 21/12 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 5/48*** (2015.01); ***H01Q 21/12*** (2013.01)

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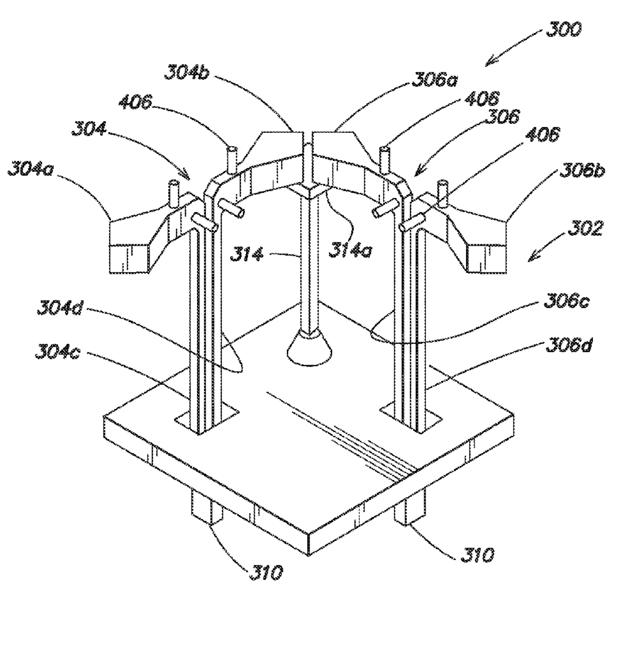
Primary Examiner — Graham P Smith
(74) *Attorney, Agent, or Firm* — Gary McFaline

(57) **ABSTRACT**

An antenna assembly includes a balanced antenna feed configured to receive a differential signal and a ground plane. The assembly further includes a first conductive dipole arm in planar alignment with a surface of the ground plane and a second conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the first conductive dipole arm. The assembly further includes a first feedline in electrical communication with the first conductive dipole arm and the balanced antenna feed and a second feedline in electrical communication with the second conductive dipole arm and the balanced antenna feed. The assembly further includes a conductive wall ("H-wall") in electrical communication with the ground plane and having an end adjacent to, and physically separate from, the second conductive dipole arm. The H-wall has an axial length orthogonal to the ground plane.

20 Claims, 12 Drawing Sheets



(58) **Field of Classification Search**
CPC .. H01Q 3/30; H01Q 9/16; H01Q 1/48; H01Q 5/25; H01Q 25/001; H01Q 19/06; H01Q 1/40; H01Q 1/523; H01Q 15/0013; H01Q 21/0075; H03H 7/425; H01P 5/028
See application file for complete search history.

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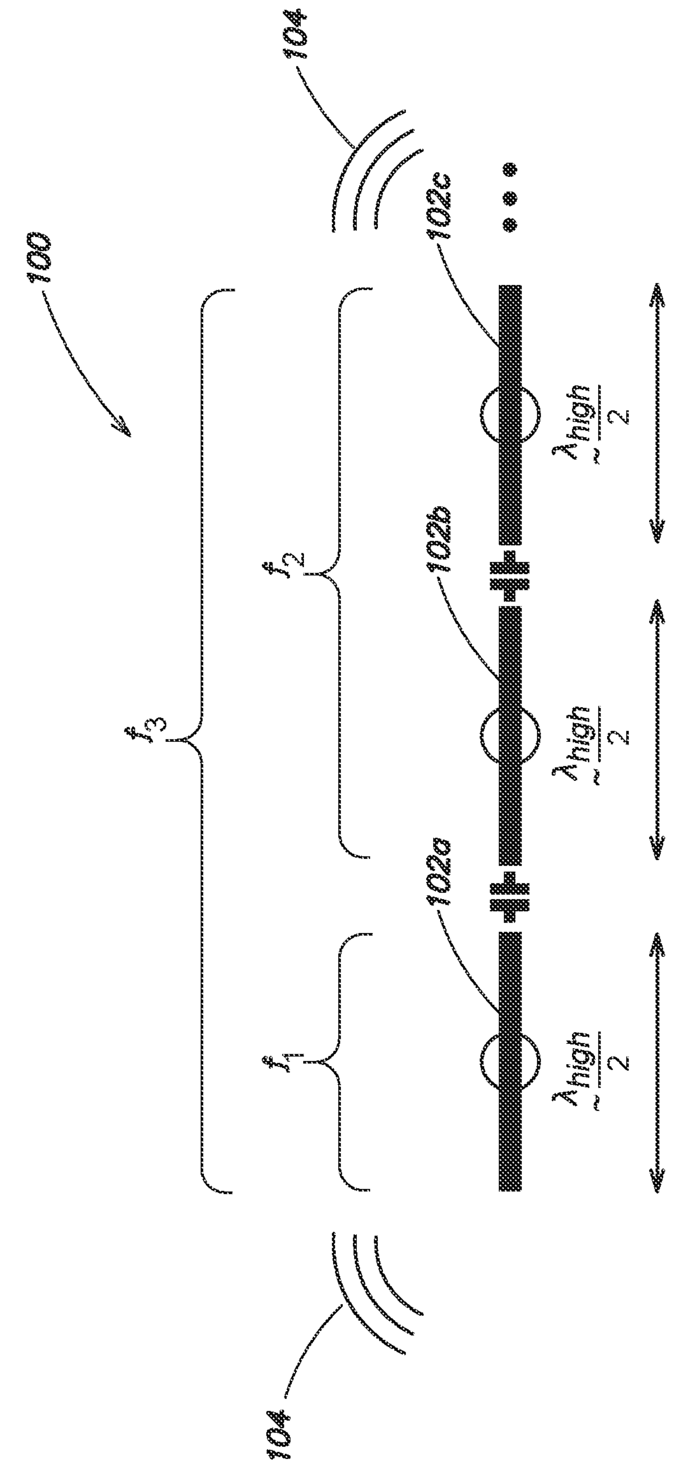
100
104
104
102a
102b
102c
f_1
f_2
f_3
$\sim\frac{\lambda_{high}}{2}$
$\sim\frac{\lambda_{high}}{2}$
$\sim\frac{\lambda_{high}}{2}$

FIG. 1

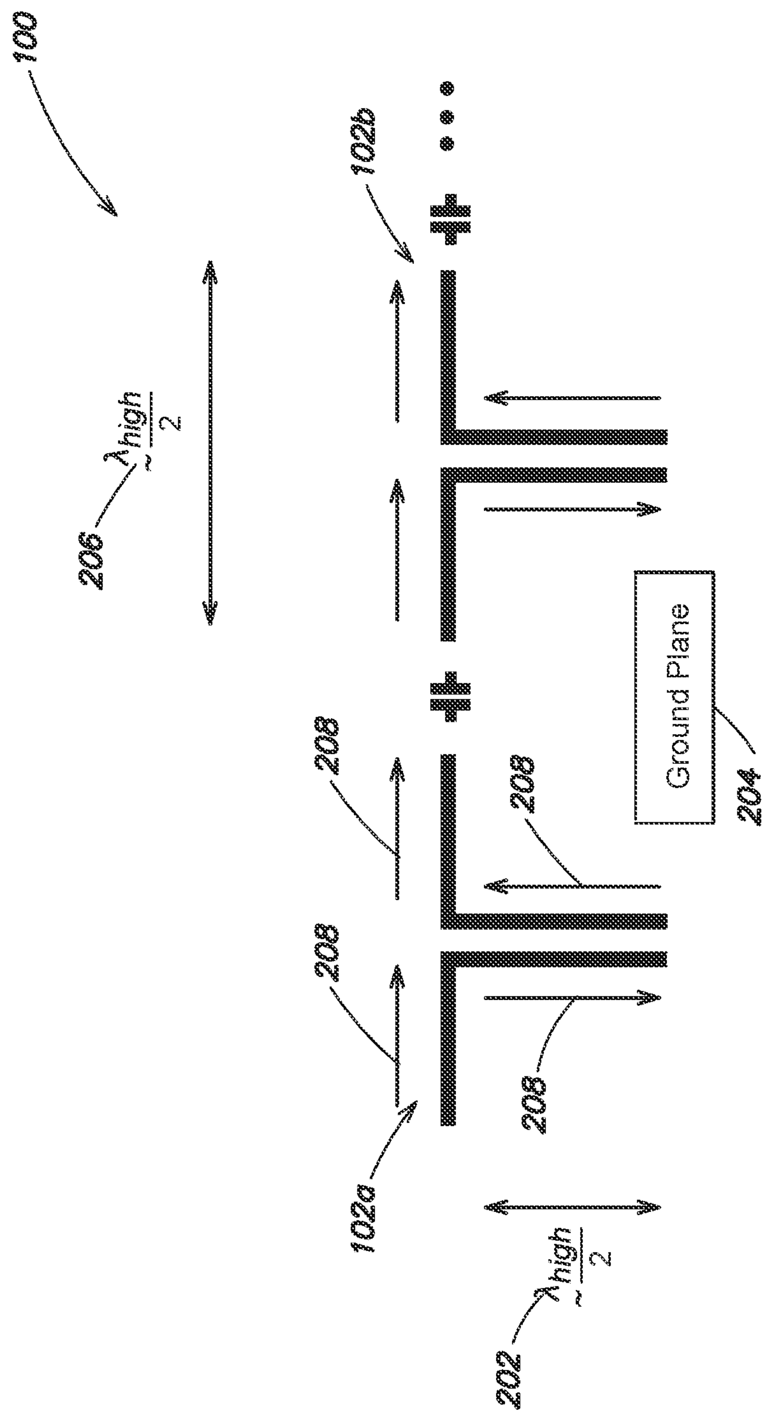
100
206
$\sim\frac{\lambda_{high}}{2}$
102b
208
208
208
208
Ground Plane
204
102a
202
$\sim\frac{\lambda_{high}}{2}$

FIG. 2

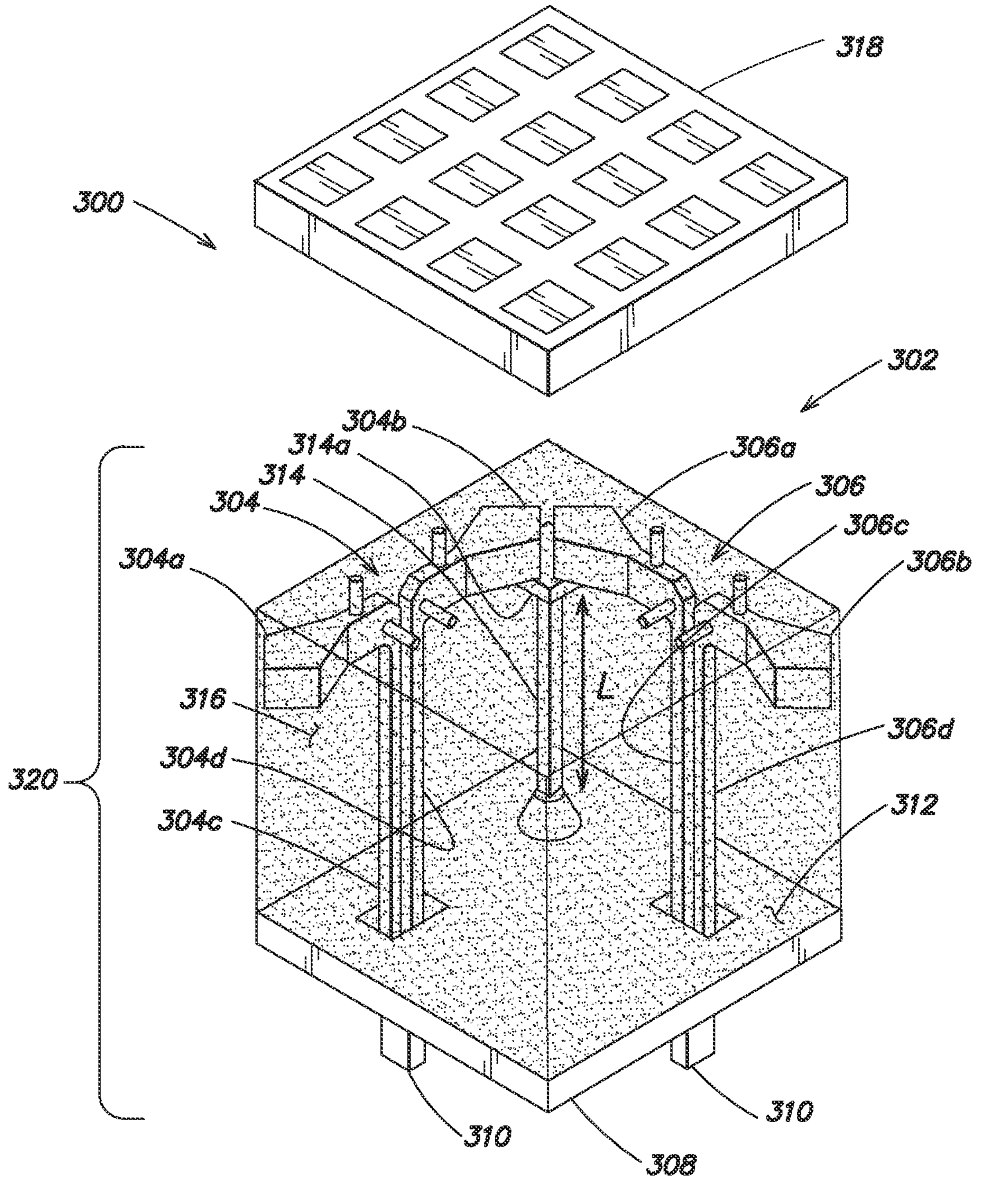
318
300
302
304b
314a
306a
314
306
304
306c
304a
306b
L
316
306d
320
304d
312
304c
310
310
308

FIG. 3A

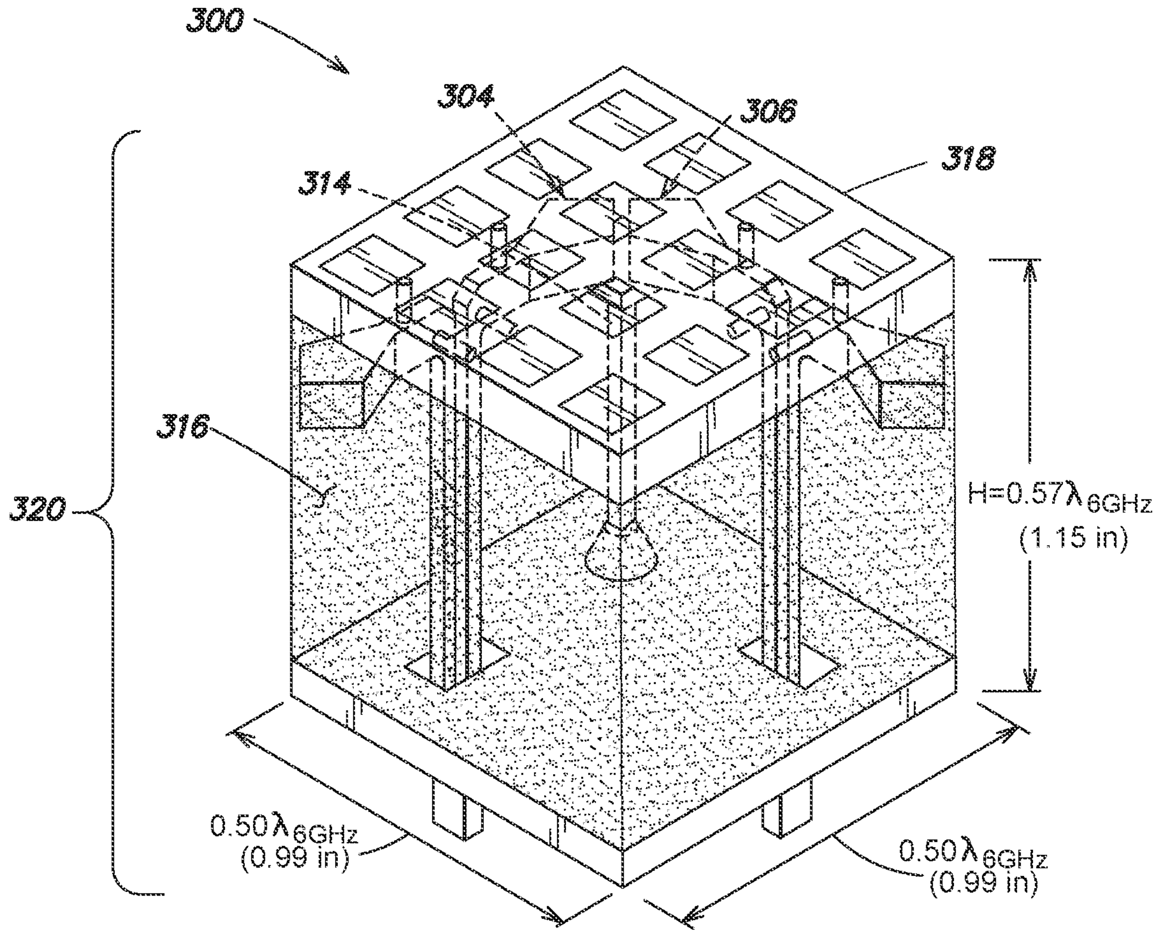
300
304
306
318
314
316
320
H=0.57λ6GHz
(1.15 in)
0.50λ6GHz
(0.99 in)
0.50λ6GHz
(0.99 in)

FIG. 3B

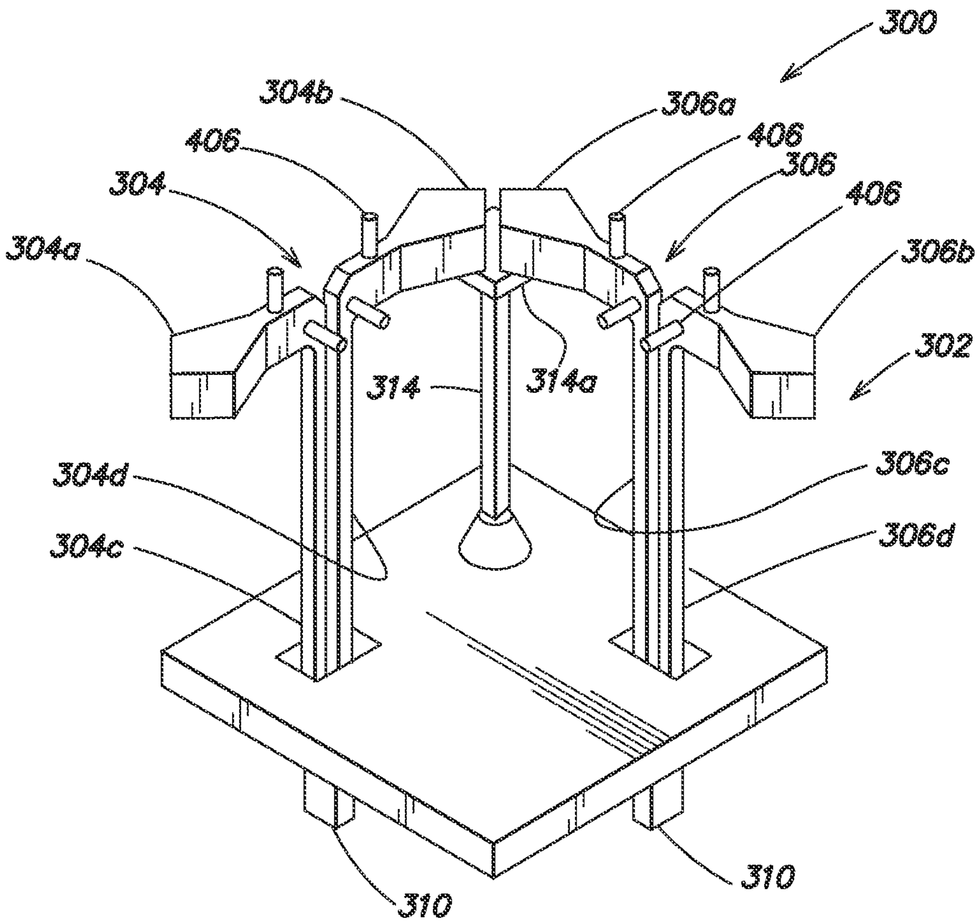
300
304b
306a
406
406
306
304
406
304a
306b
302
314
314a
304d
306c
304c
306d
310
310

FIG. 4A

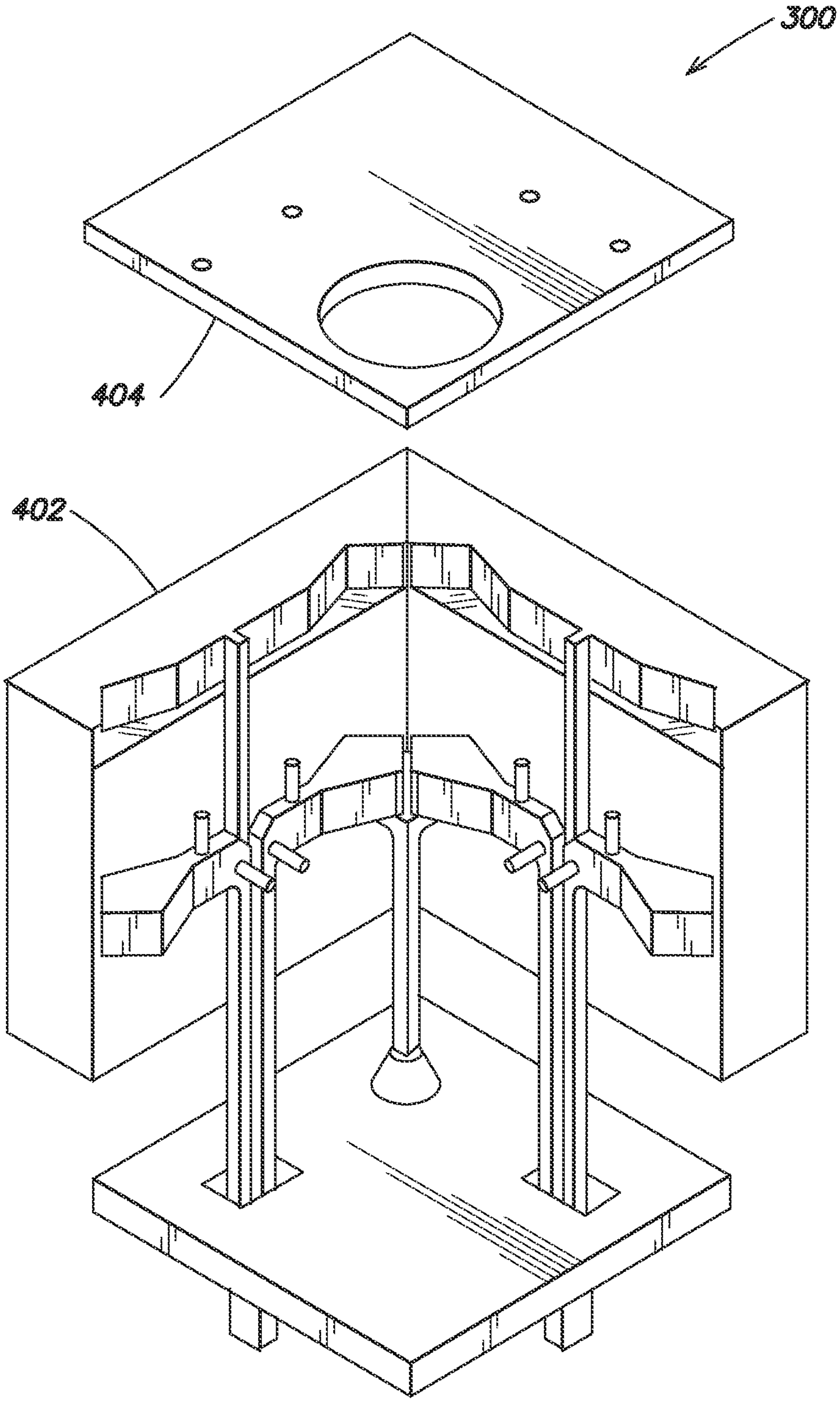

FIG. 4B

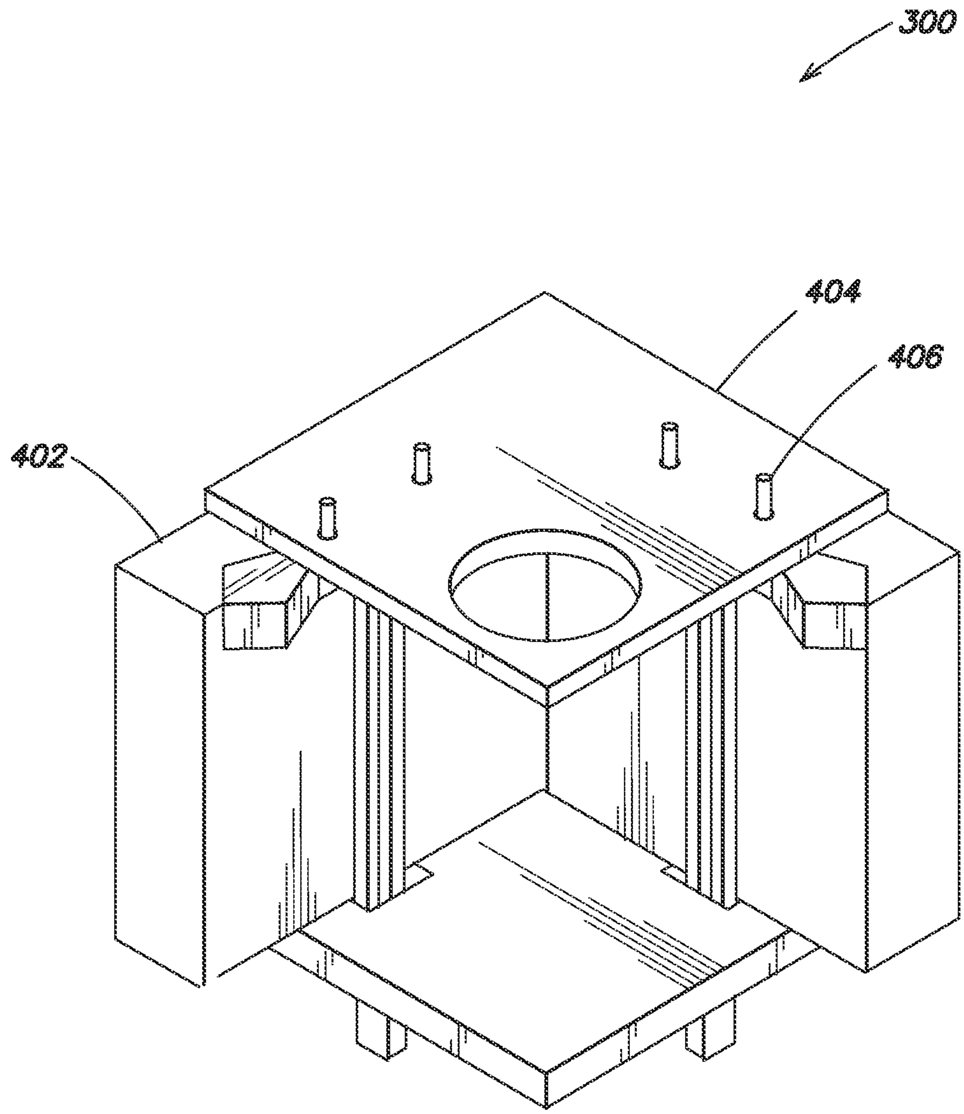

FIG. 4C

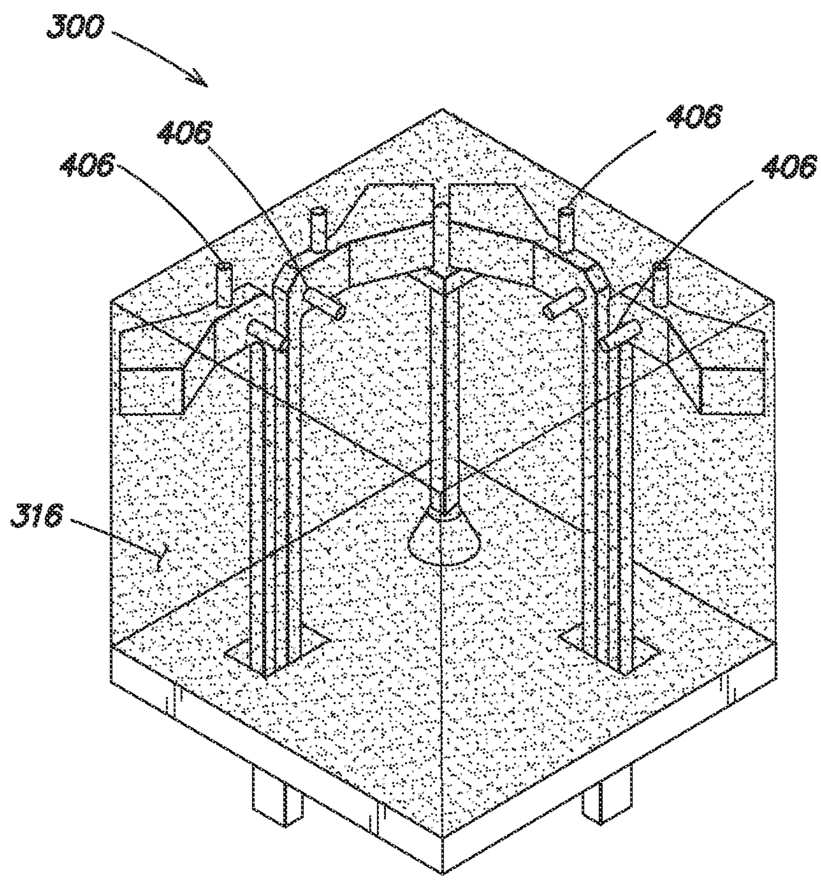

FIG. 4D

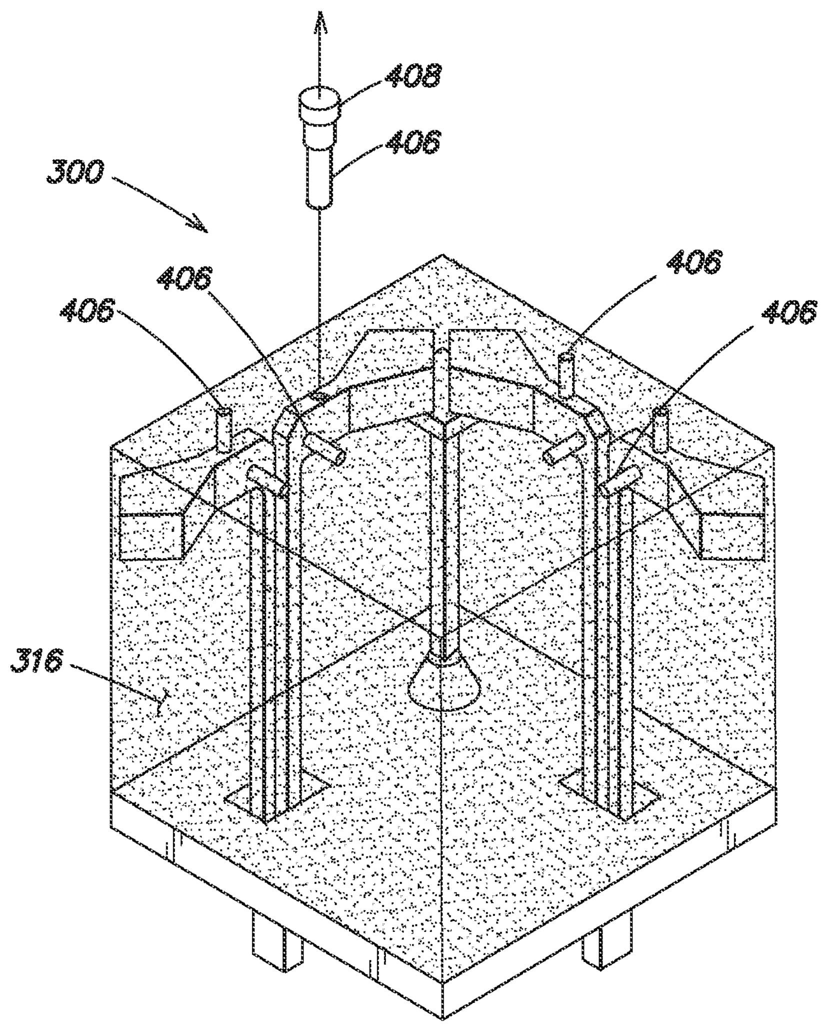

FIG. 4E

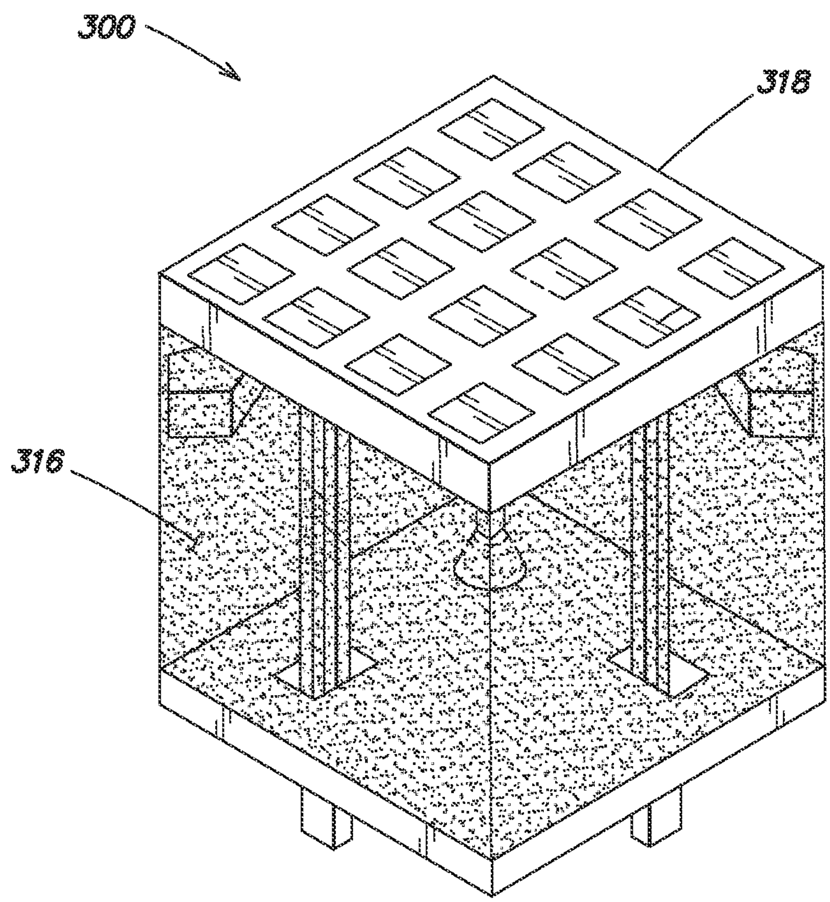

FIG. 4F

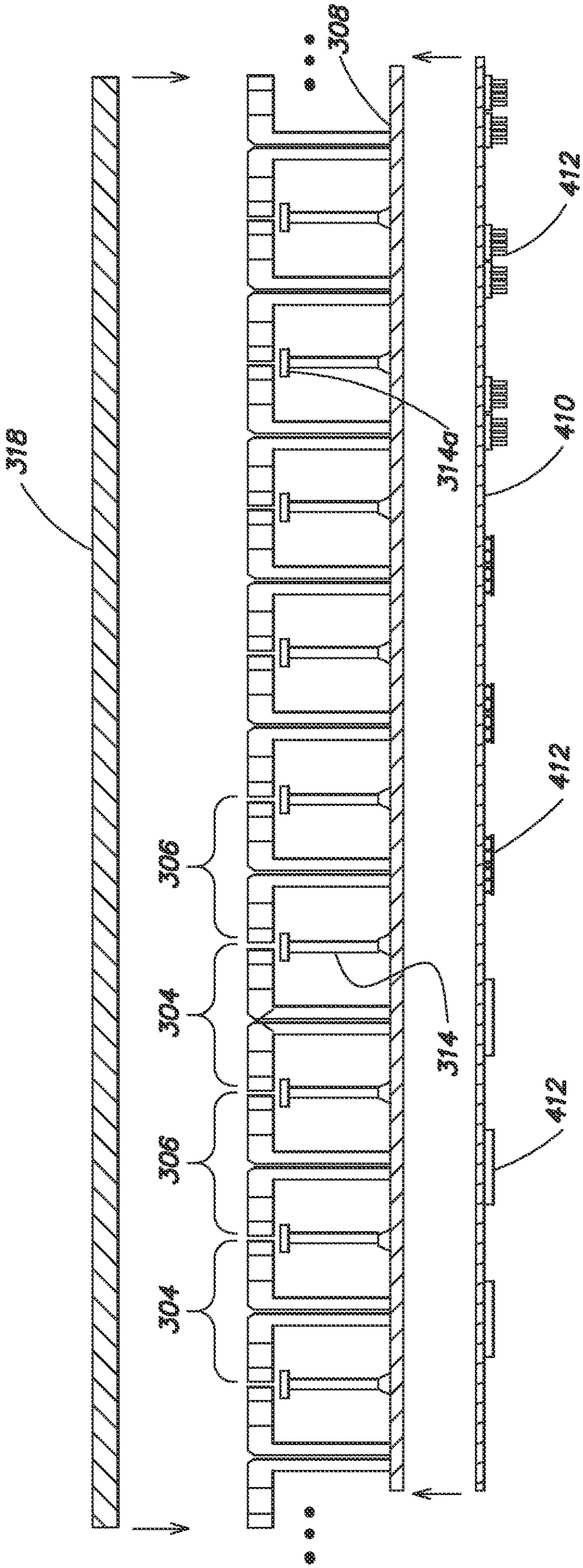

FIG. 4G

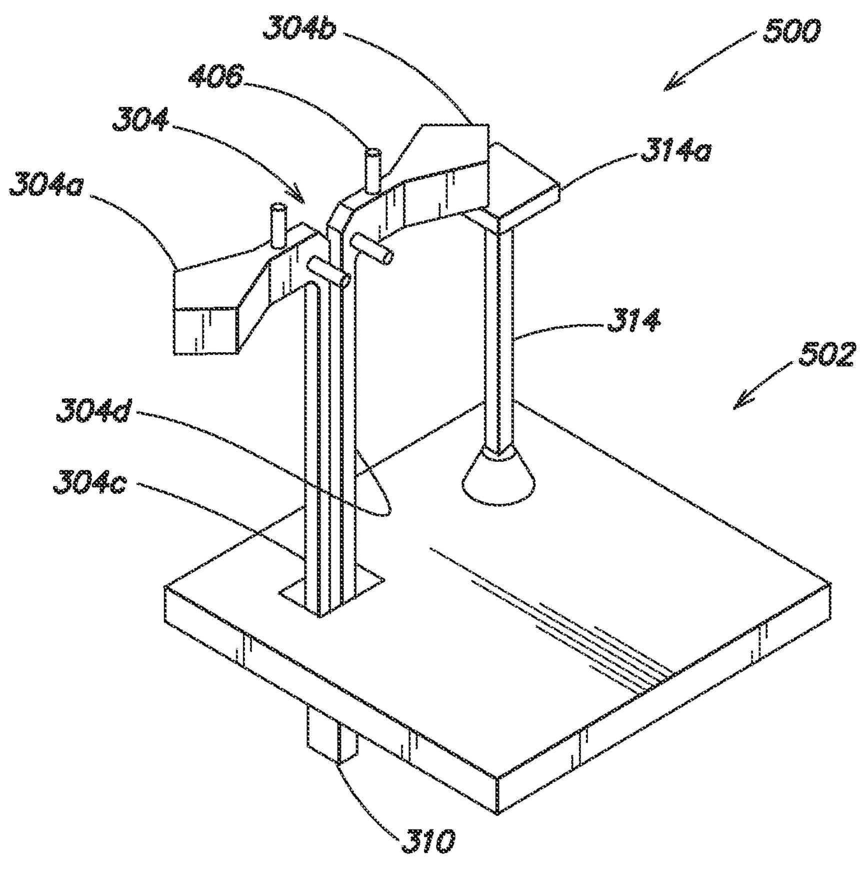

FIG. 5

BANDWIDTH EXTENDED BALANCED TIGHTLY COUPLED DIPOLE ARRAY ADDITIVELY MANUFACTURED MODULAR APERTURE

FIELD OF DISCLOSURE

The present disclosure relates to antennas, and more particularly, to bandwidth extended additively manufactured modular aperture antennas and antenna arrays.

BACKGROUND

An antenna transduces electromagnetic (EM) waves to radio frequency (RF) electrical signals. An aperture is typically considered as the portion of a surface of an antenna through which a majority of the EM waves are transmitted or received. Antennas can be arranged in arrays to provide wideband and ultra-wideband (UWB) operations, such as in conjunction with radar and tracking systems, high data rate communication links, and multi-waveform, multi-function front end systems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a tightly coupled dipole array ("TCDA"), in accordance with an embodiment of the present disclosure.

FIG. **2** is another schematic diagram of the TCDA of FIG. **1**, in accordance with an example of the present disclosure.

FIGS. **3**A-B are top isometric perspective views of a modular antenna, according to an example of the present disclosure.

FIGS. **4**A-F are top isometric perspective views of various structures during several stages of fabrication of the modular antenna of FIG. **3**A, in accordance with an example of the present disclosure.

FIG. **4**G is a cross-sectional plan view of the modular antenna of FIG. **3**A, in accordance with an example of the present disclosure.

FIG. **5** is a top isometric perspective view of a modular antenna, according to another example of the present disclosure.

Although the following detailed description will proceed with reference being made to illustrative examples, many alternatives, modifications, and variations thereof will be apparent in light of this disclosure.

DETAILED DESCRIPTION

In accordance with an example of the present disclosure, an antenna assembly includes a balanced antenna feed configured to receive a differential signal and a ground plane. The assembly further includes a first conductive dipole arm in planar alignment with a surface of the ground plane and a second conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the first conductive element. The assembly further includes a first feedline in electrical communication with the first conductive dipole arm and the balanced antenna feed and a second feedline in electrical communication with the second conductive dipole arm and the balanced antenna feed. The assembly further includes a conductive wall ("H-wall") in electrical communication with the ground plane and having an end adjacent to, and physically separate from, the second conductive dipole arm. The H-wall has an axial length orthogonal to the ground plane.

In some examples, the assembly includes an integral element additively manufactured into a single continuous piece of material. For example, the integral element includes the ground plane, the first conductive dipole arm, the second conductive dipole arm, the first feedline, the second feedline, and the H-wall. The integral element includes an electrically conductive material, or a non-conductive material plated with an electrically conductive material. In some examples, the assembly further includes a non-conductive structural support, such as a dielectric foam or resin, surrounding integral element. The non-conductive structural support provides mechanical stability for the integral element and can also include sacrificial features that can be removed during fabrication of the assembly. For example, the assembly can be manufactured using any suitable additive or subtractive manufacturing process, including, but not limited to, 3-D printing, casting, computer numerical control (CNC), or the like. In some examples, the assembly can be manufactured as a single continuous unit or structure. In some other examples, individual components of the assembly can be manufactured separately and assembled. According to another example, the assembly can include any suitable material encased in, coated with, or otherwise covered with a conductive material, such as a conductive metal or the like to provide a conductive metal surface. For example, the assembly can include a plastic core with a conductive surface coating thereon.

OVERVIEW

As noted above, aperture antennas can be arrayed to provide wideband and ultra-wideband operation. The bandwidth ratio is expressed as a function of the upper frequency band of the antenna divided by the lower frequency band of the antenna. Ultra-wideband operation is typically considered to include antenna arrays having a bandwidth ratio of 10:1 or greater. An example of such an antenna array includes a tightly coupled dipole array (TCDA), the aperture of which includes a cluster of closely spaced dipole elements extending from a ground plane. For instance, a digital phased array (DPA) aperture is a type of TCDA that provides UWB operation and a large field of view (FOV).

Example TCDA

FIG. **1** is a schematic diagram of a TCDA **100**, in accordance with an embodiment of the present disclosure. The TCDA **100** includes multiple half wave dipole antennas **102**_a_, **102**_b_, **102**_c_, etc. Each dipole antenna **102**_a_, **102**_b_, **102**_c_, can radiate or receive a signal **104** at a frequency of approximately

$$\frac{\lambda_1}{2}, \frac{\lambda_2}{2}, \text{ and } \frac{\lambda_3}{2},$$

respectively. An individual dipole antenna, such as dipole antenna **102**_a_, radiates or receives a signal at a frequency f_1. The dipole antennas **102**_a_, **102**_b_, **102**_c_ can be located or arrayed adjacent to each other to radiate or receive signals at frequencies f_2, f_3, etc., such as shown in FIG. **1**. Such an arrangement approximates a flat current distribution across all of the dipole antennas **102**_a_, **102**_b_, **102**_c_.

FIG. **2** is another schematic diagram of the TCDA **100** of FIG. **1**, in accordance with an example of the present disclosure. The upper cutoff frequency of the TCDA **100** is established by the height **202** of the dipole elements above a ground plane **204** and a pitch (width) **206** of each of the antennas **102**_a_, **102**_b_. The lower cutoff frequency can be extended by coupling each of the antennas **102**a, **102**b and through the use of dielectric loading in the substrate.

TCDAs have demonstrated large impedance bandwidths and scanning performance in a low profile of ($\lambda_{High}/2$). TCDAs provide certain benefits in certain applications; however, there is typically a trade-off in bandwidth and design complexity. Thus, highly skilled designers are required to tune these TCDA's many interdependent design features for applications-specific requirements. With many TCDAs being highly application-specific, they are not easily scalable and/or compatible across varying platforms and/or varying applications. The typical construction of current TCDAs tends to increase the cost to manufacture as they utilize multiple materials and multiple manufacturing processes.

Tightly coupled dipoles are vulnerable to common-mode currents when fed improperly. When balanced-fed, common-modes occur while scanning in the E-plane, due to mutual coupling between adjacent elements. These common-mode currents have the detrimental effect of feed-line resonance (unintended radiation) and cause significant reductions to scanned beam efficiency. Some TCDA employ internal or external balun feeds to avoid this issue, though this may introduce broadside common mode currents if not designed properly. As RF circuits are consolidated, front-end components utilize differential designs, which are more resilient to noise and interference. Hence, a balun can be used to accommodate the single ended (e.g., coax) connection out from the array electronics to the aperture. Where on-pitch electronics are employed directly behind the aperture, it is advantageous to employ a differential fed array to remove the balun.

A challenge in the design of an on-pitch differential radio is the reduction of the common mode currents that can exist at the aperture and in between the ports that feed the aperture. Common mode currents at the aperture can significantly reduce the impedance bandwidth. Previous balanced feed antennas have used shielding isolation, intentional losses, reactive open-stubbed differential pairs, or reactive shorting posts to mitigate common mode currents that cause common mode resonances. Further, many of these solutions limit the achievable bandwidth ratios for TCDA.

Thus, there is a need for a balanced TCDA antenna that is easily scalable and has ultra-wide bandwidth of at least 10:1 without incurring increased losses. Examples of the present disclosure provide a TCDA that does not use a balun and/or a single-ended feed and permits differential (two balanced or complementary) signals to be fed into the antenna.

Example Modular Antenna Array

FIGS. **3**A-B are top isometric perspective views of a modular antenna **300**, according to an example of the present disclosure. The antenna **300** includes a 1×1 unit cell **302**. The antenna **300** can, in some examples, include multiple unit cells arrayed together, such as 3×3, 6×6, etc., where each unit cell is similar to the 1×1 unit cell **302** shown in FIGS. **3**A-B. In any event, the antenna **300** includes one or more 1×1 unit cells **302**.

Referring to FIG. **3**A, the unit cell **302** includes a first antenna element **304**, a second antenna element **306**, a ground plane **308**, and at least one balanced antenna feed **310**. It will be understood that in some examples, it is not necessary to include both the first and second antenna elements **304**, **306**. For example, FIG. **5** shows a modular antenna **500** with a unit cell **502** including a single antenna element **304** (with corresponding elements as described herein) for single linear polarization, in accordance with an example of the present disclosure. In some other examples, such as shown and described with respect to FIG. **3**A, the unit cell **302** includes both the first and second antenna elements **304**, **306** (e.g., two orthogonal arrays) for dual polarization. A surface of the first antenna element **304** and/or the second antenna element **306** includes at least a portion of an aperture of the modular antenna **300**. The at least one balanced antenna feed **310** is configured to receive a differential (balanced) signal. Each antenna element **304**, **306** includes a first conductive dipole arm **304**a, **306**a and a second conductive dipole arm **304**b, **306**b. The first conductive dipole arm **304**a, **306**a and the second conductive dipole arm **304**b, **306**b are each in planar alignment with a surface **312** of the ground plane **308**. In some examples, the first conductive dipole arm **304**a, **306**a is a mirror image of the second conductive dipole arm **304**b, **306**b about a longitudinal axis extending perpendicular to the surface **312** of the ground plane **308**, such that the first conductive dipole arm **304**a, **306**a is adjacent to the second conductive dipole arm **304**b, **306**b. Each antenna element **304**, **306** further includes a first feedline **304**c, **306**c in electrical communication with the first conductive dipole arm **304**a, **306**a and the balanced antenna feed **310**, and a second feedline **304**d, **306**d in electrical communication with the second conductive dipole arm **304**b, **306**b and the balanced antenna feed **310**.

The unit cell **302** further includes a conductive wall ("H-wall") **314** in electrical communication with the ground plane **308**. The H-wall **314** has an end **314**a adjacent to, and physically separate from, the second conductive dipole arm **304**b of the first antenna element **304** and the first conductive dipole arm **306**a of the second antenna element **306**. An axial length l of the H-wall **314** is orthogonal to the ground plane **308**. In other words, the H-wall **314** extends orthogonally from the ground plane **308** toward the second conductive dipole arm **304**b of the first antenna element **304** and the first conductive dipole arm **306**a of the second antenna element **306**. The H-wall **314** does not physically contact the first or second antenna elements **304**, **306**. Rather, the H-wall **314** disrupts the common mode resonances (e.g., the coupled signal between adjacent unit cells **102**) that would otherwise cause feed line radiation/coupling and reduce antenna efficiency. As a result, the H-wall **314** enables efficient radiation from the first and second conductive dipole arms **304**a, **304**b, **306**a, **306**b without added losses such that a bandwidth ratio of the antenna aperture can reach 10:1 (e.g., between approximately 2-20 GHz) for balanced operation while using a differential feed and without a balun or other components for mitigating the common mode resonances.

In some examples, the unit cell **302** further includes at least one non-conductive structural support element **316** between the ground plane **308** and the first feedline **304**c, **306**c, the second feedline **304**d, **306**d, or both feedlines **304**c, **306**c, **304**d, **306**d of the first and second antenna elements **304**, **306**, respectively. In some examples, the non-conductive structural support **316** includes a dielectric foam or resin surrounding the antenna elements **304** and **306**. The non-conductive structural support **316** provides mechanical stability for the first antenna element **304** and/or the second antenna element **306** and can also include sacrificial features that can be removed during fabrication of the unit cell **302**, such as during an additive manufacturing process where components of the unit cell **302** (e.g., the ground plane **308**, the feedlines **304**c, **304**d, **306**c, **306**d, and the dipole arms **304**a, **304**b, **306**a, **306**b) are fabricated by the successive addition of material (e.g., via a three-dimensional printing or other deposition process).

In some examples, the first conductive dipole arms **304***a*, **306***a* are linearly polarized with respect to a first plane of polarization (e.g., V-pol), and the second conductive dipole arms **304***b*, **306***b* are linearly polarized with respect to a second plane of polarization (e.g., H-pol), where the first plane of polarization is orthogonal to the second plane of polarization.

In operation, a signal, such as an analog RF signal, can propagate between the first conductive dipole arms **304***a*, **306***a* and the balanced antenna feed **310** via the first feedline **304***c*, **306***c*. The signal can further propagate between the second conductive dipole arms **304***b*, **306***b* and the balanced antenna feed **310** via the second feedline **304***d*, **306***d*. The balanced antenna feed **310** can include a positive terminal and a negative terminal coupled to the first feedline **304***c*, **306***c* and the second feedline **304***d*, **306***d*, respectively, or vice versa. In some examples, a signal at the positive terminal is 180 degrees out-of-phase with a signal at the negative terminal (i.e., balanced or complementary signals).

In some examples, the unit cell **302**, or an array of unit cells **302**, is covered by a superstrate **318** or another overlay material. The superstrate **318** can include dielectric or other impedance matching materials to provide physical protection and temperature resilience for the modular antenna **300**, and/or to increase power transfer and reduce signal reflection into and out of the modular antenna **300**.

Referring to FIG. 3B, the dimensions of the unit cell **302**, in accordance with an example for a 6 GHz application, can be approximately 0.99 inches wide by 0.99 inches deep by 1.15 inches high, or approximately 0.50λ (wavelength of signal) by 0.50λ by 0.57λ.

Modular Antenna Array Fabrication

FIGS. 4A-F are top isometric perspective views of various structures during several stages of fabrication of the modular antenna **300** of FIG. 3A, in accordance with an example of the present disclosure. In general, the modular antenna **300**, including one or more unit cells **302** or portions thereof, is printed or otherwise fabricated using additive manufacturing techniques. It will be understood that any number of the unit cells **302** can be fabricated in the disclosed manner, for example, as component arrays (i.e., a single unit cell **302**), blocks of sub-arrays (i.e., multiple adjacent unit cells **302**), or complete arrays of the unit cells **302**.

The modular antenna **300** and certain other structural or sacrificial components are fabricated by additively depositing or printing material to form the various structures of the antenna, such that the product is formed from a single piece of continuous material, also referred to as an integral element **320**. The integral element **320** includes, for example, the first antenna element **304**, the second antenna element **306**, and the H-wall **314**. In some examples, the material is at least partially electrically conductive (e.g., it is all metal or at least partially metal). In some other examples, the material is at least partially non-conductive and at least partially plated with another conductive material (e.g., a metal plating).

In some examples, the at least one non-conductive structural support element includes a low dielectric foam or resin added to voids around the additively fabricated material of the antenna components. The at least one non-conductive structural support element **316** provides shock and vibration mitigation or other mechanical support of the antenna components, such as the first conductive dipole arm **304***a*, **306***a*, the second conductive dipole arm **304***b*, **306***b*, the first feedline **304***c*, **306***c*, and/or the second feedline **304***d*, **306***d*. In some examples, a perimeter caul plate **402** and a perforated top plate **404** can be placed around at least a portion of the modular antenna **300** to contain the at least one non-conductive structural support element **316** during fabrication and prior to baking or setting the foam or resin into a semi-solid state.

In some examples, such as shown in FIGS. 4A-D, one or more mechanical alignment structures **406** are fabricated in conjunction with one or more antenna components, including, for example, the first conductive dipole arm **304***a*, **306***a*, the second conductive dipole arm **304***b*, **306***b*, the first feedline **304***c*, **306***c*, and the second feedline **304***d*, **306***d*. The alignment structures **406** align the top plate **404** with the first conductive dipole arm **304***a*, **306***a*, the second conductive dipole arm **304***b*, **306***b*, prior to baking or otherwise setting the foam or resin. Once set, at least a portion of the foam or resin provides structural support for the first conductive dipole arm **304***a*, **306***a*, the second conductive dipole arm **304***b*, **306***b*. Other portions of the at least one non-conductive structural support element **316** and any mechanical alignment structures **406** not needed for structural support can then be machined or otherwise removed, such as shown at **408** in FIG. 4E. In some examples, a superstrate, such as the superstrate **318**, or other overlay material can be attached to the modular antenna **300**, such as shown in FIG. 4F.

FIG. 4G is a cross-sectional plan view of the modular antenna **300**, in accordance with an example of the present disclosure. In some examples, a circuit board **410** can be attached at or to the ground plane **308**, such as shown in FIG. 4G. The circuit board **410** can be configured to provide signal paths between the various components of the modular antenna array, such as the first feedline **304***c*, **306***c*, the second feedline **304***d*, **306***d*, and/or the H-wall **314** of each component antenna **300**. The circuit board can include terminations or other connectors **412**.

Further Examples

The following examples pertain to further examples, from which numerous permutations and configurations will be apparent.

Example 1 an antenna assembly including a balanced antenna feed configured to receive a differential signal; a ground plane; a first conductive dipole arm in planar alignment with a surface of the ground plane; a second conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the first conductive dipole arm; a first feedline in electrical communication with the first conductive dipole arm and the balanced antenna feed; a second feedline in electrical communication with the second conductive dipole arm and the balanced antenna feed; and a conductive wall ("H-wall") in electrical communication with the ground plane and having an end adjacent to, and physically separate from, the second conductive dipole arm, an axial length of the H-wall being orthogonal to the ground plane.

Example 2 includes the subject matter of Example 1, further including at least one non-conductive structural support element between the ground plane and the first feedline, the second feedline, or both.

Example 3 includes the subject matter of Example 2, wherein the at least one non-conductive structural support includes a dielectric foam or resin.

Example 4 includes the subject matter of any one of Examples 1-3, further including a third conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the second conductive dipole arm; a fourth conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the third conductive dipole arm; a third feedline in electrical communication with the third conductive dipole arm and the balanced antenna feed; and a fourth feedline in electrical communication with the fourth conductive dipole arm and the balanced antenna feed.

Example 5 includes the subject matter of Example 4, wherein the end of the H-wall is further adjacent to, and physically separate from, the third conductive dipole arm.

Example 6 includes the subject matter of Example 4, wherein the third conductive dipole arm is perpendicular to the second conductive dipole arm.

Example 7 includes the subject matter of Example 6, wherein the first conductive dipole arm is parallel to the second conductive dipole arm, and wherein the fourth conductive dipole arm is parallel to the third conductive dipole arm.

Example 8 includes the subject matter of any one of Examples 4-7, wherein the first and second conductive dipole arms are linearly polarized with respect to a first plane of polarization, wherein the third and fourth conductive dipole arms are linearly polarized with respect to a second plane of polarization, and wherein the first plane of polarization is orthogonal to the second plane of polarization.

Example 9 includes the subject matter of any one of Examples 1-8, further including an integral element additively manufactured into a single continuous piece of material, the integral element including the ground plane, the first conductive dipole arm, the second conductive dipole arm, the first feedline, the second feedline, and the H-wall.

Example 10 includes the subject matter of Example 9, wherein the integral element includes an electrically conductive material.

Example 11 includes the subject matter of Example 9, wherein the integral element includes a non-conductive material plated with an electrically conductive material.

Example 12 includes the subject matter of any one of Examples 1-11, further comprising an aperture configured to provide up to a 10:1 bandwidth ratio.

Example 13 provides an antenna assembly method including additively manufacturing an integral element as a single continuous piece of material, the integral element including a balanced antenna feed configured to receive a differential signal; a ground plane; a first conductive dipole arm in planar alignment with a surface of the ground plane; a second conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the first conductive dipole arm; a first feedline in electrical communication with the first conductive dipole arm and the balanced antenna feed; a second feedline in electrical communication with the second conductive dipole arm and the balanced antenna feed; and a conductive wall ("H-wall") in electrical communication with the ground plane and having an end adjacent to, and physically separate from, the second conductive dipole arm, an axial length of the H-wall being orthogonal to the ground plane; and attaching a superstrate to the integral element.

Example 14 includes the subject matter of Example 13, further including attaching at least one non-conductive structural support element between the ground plane and the first feedline, the second feedline, or both.

Example 15 includes the subject matter of Example 14, wherein the at least one non-conductive structural support includes a dielectric foam or resin.

Example 16 includes the subject matter of any one of Examples 13-15, wherein the integral element includes an electrically conductive material.

Example 17 includes the subject matter of any one of Examples 13-15, wherein the integral element includes a non-conductive material plated with an electrically conductive material.

Example 18 includes the subject matter of any one of Examples 13-17, wherein the integral element further includes a third conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the second conductive dipole arm; a fourth conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the third conductive dipole arm; a third feedline in electrical communication with the third conductive dipole arm and the balanced antenna feed; and a fourth feedline in electrical communication with the fourth conductive dipole arm and the balanced antenna feed.

Example 19 includes the subject matter of Example 18, wherein the first and second conductive dipole arms are linearly polarized with respect to a first plane of polarization, wherein the third and fourth conductive dipole arms are linearly polarized with respect to a second plane of polarization, and wherein the first plane of polarization is orthogonal to the second plane of polarization.

Example 20 includes the subject matter of any one of Examples 13-19, further including attaching an aperture configured to provide up to a 10:1 bandwidth ratio.

Numerous specific details have been set forth herein to provide a thorough understanding of the examples. It will be understood, however, that other examples may be practiced without these specific details, or otherwise with a different set of details. It will be further appreciated that the specific structural and functional details disclosed herein are representative of examples and are not necessarily intended to limit the scope of the present disclosure. In addition, although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described herein. Rather, the specific features and acts described herein are disclosed as example forms of implementing the claims. Furthermore, examples described herein may include other elements and components not specifically described, such as electrical connections, signal transmitters and receivers, processors, or other suitable components for operation of the modular antenna.

The terms and expressions which have been employed herein are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described (or portions thereof), and it is recognized that various modifications are possible within the scope of the claims. Accordingly, the claims are intended to cover all such equivalents. Various features, aspects, and examples have been described herein. The features, aspects, and examples are susceptible to combination with one another as well as to variation and modification, as will be appreciated in light of this disclosure. The present disclosure should, therefore, be considered to encompass such combinations, variations, and modifications. It is intended that the scope of the present disclosure be limited not by this detailed description, but rather by the claims appended hereto. Future filed applications claiming priority to this application may claim the disclosed subject matter in a different manner and may generally include any set of one or more elements as variously disclosed or otherwise demonstrated herein.

What is claimed is:

1. An antenna assembly comprising:

a balanced antenna feed configured to receive a differential signal;

a ground plane;

a first conductive dipole arm in planar alignment with a surface of the ground plane;

a second conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the first conductive dipole arm;

a first feedline in electrical communication with the first conductive dipole arm and the balanced antenna feed;

a second feedline in electrical communication with the second conductive dipole arm and the balanced antenna feed; and

a conductive wall in electrical communication with the ground plane and having an end parallel with the ground plane and adjacent to, and physically separate from, the second conductive dipole arm, an axial length of the conductive wall being orthogonal to the ground plane.

2. The antenna assembly of claim 1, further comprising at least one non-conductive structural support element between the ground plane and the first feedline, the second feedline, or both.

3. The antenna assembly of claim 2, wherein the at least one non-conductive structural support includes a dielectric foam or resin.

4. The antenna assembly of claim 1, further comprising:

a third conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the second conductive dipole arm;

a fourth conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the third conductive dipole arm;

a third feedline in electrical communication with the third conductive dipole arm and the balanced antenna feed; and

a fourth feedline in electrical communication with the fourth conductive dipole arm and the balanced antenna feed.

5. The antenna assembly of claim 4, wherein the end of the conductive wall is further adjacent to, and physically separate from, the third conductive dipole arm.

6. The antenna assembly of claim 4, wherein the third conductive dipole arm is perpendicular to the second conductive dipole arm.

7. The antenna assembly of claim 6, wherein the first conductive dipole arm is parallel to the second conductive dipole arm, and wherein the fourth conductive dipole arm is parallel to the third conductive dipole arm.

8. The antenna assembly of claim 4, wherein the first and second conductive dipole arms are linearly polarized with respect to a first plane of polarization, wherein the third and fourth conductive dipole arms are linearly polarized with respect to a second plane of polarization, and wherein the first plane of polarization is orthogonal to the second plane of polarization.

9. The antenna assembly of claim 1, further comprising an integral element additively manufactured into a single continuous piece of material, the integral element including the ground plane, the first conductive dipole arm, the second conductive dipole arm, the first feedline, the second feedline, and the conductive wall.

10. The antenna assembly of claim 9, wherein the integral element includes an electrically conductive material.

11. The antenna assembly of claim 9, wherein the integral element includes a non-conductive material plated with an electrically conductive material.

12. The antenna assembly of claim 1, further comprising an aperture configured to provide up to a 10:1 bandwidth ratio.

13. An antenna assembly method comprising:

additively manufacturing an integral element as a single continuous piece of material, the integral element comprising:

a balanced antenna feed configured to receive a differential signal;

a ground plane;

a first conductive dipole arm in planar alignment with a surface of the ground plane;

a second conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the first conductive dipole arm;

a first feedline in electrical communication with the first conductive dipole arm and the balanced antenna feed;

a second feedline in electrical communication with the second conductive dipole arm and the balanced antenna feed; and

a conductive wall in electrical communication with the ground plane and having an end in parallel with the ground plane and adjacent to, and physically separate from, the second conductive dipole arm, an axial length of the conductive wall being orthogonal to the ground plane; and

attaching a superstrate to the integral element.

14. The antenna assembly method of claim 13, further comprising attaching at least one non-conductive structural support element between the ground plane and the first feedline, the second feedline, or both.

15. The antenna assembly method of claim 14, wherein the at least one non-conductive structural support includes a dielectric foam or resin.

16. The antenna assembly method of claim 13, wherein the integral element includes an electrically conductive material.

17. The antenna assembly method of claim 13, wherein the integral element includes a non-conductive material plated with an electrically conductive material.

18. The antenna assembly method of claim 13, wherein the integral element further comprises:

a third conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the second conductive dipole arm;

a fourth conductive dipole arm in planar alignment with the surface of the ground plane and adjacent to the third conductive dipole arm;

a third feedline in electrical communication with the third conductive dipole arm and the balanced antenna feed; and

a fourth feedline in electrical communication with the fourth conductive dipole arm and the balanced antenna feed.

19. The antenna assembly method of claim 18, wherein the first and second conductive dipole arms are linearly polarized with respect to a first plane of polarization, wherein the third and fourth conductive dipole arms are linearly polarized with respect to a second plane of polarization, and wherein the first plane of polarization is orthogonal to the second plane of polarization.

20. The antenna assembly method of claim **13**, further comprising an aperture configured to provide up to a 10:1 bandwidth ratio.

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