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(54) **LOW EARTH ORBIT MECHANICAL DEPLOYABLE STRUCTURE**

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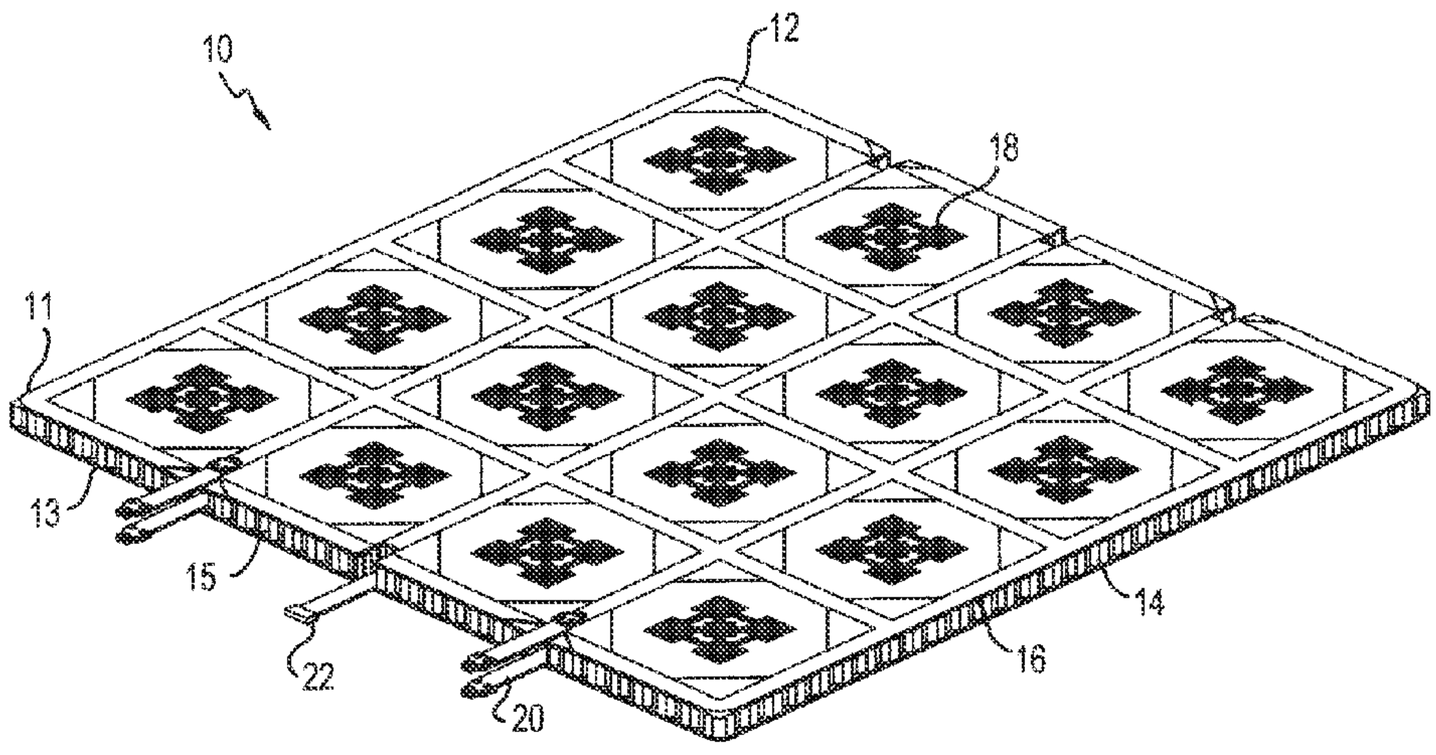
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(57) **ABSTRACT**

An antenna array has a plurality of square or rectangular antenna assemblies. Each assembly includes a first antenna assembly surface with a solar cell and a second antenna assembly with one or more antenna elements. The antenna assemblies are interconnected without gaps therebetween to form a first contiguous array surface comprised of the first antenna assembly surfaces and a second contiguous array
(Continued)



surface comprised of the second antenna assembly surfaces. The antenna assemblies are connected together by mechanically stored-energy connectors, such as spring tape, that self-deploy the array in space without the use of electric energy.

17 Claims, 4 Drawing Sheets

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See application file for complete search history.

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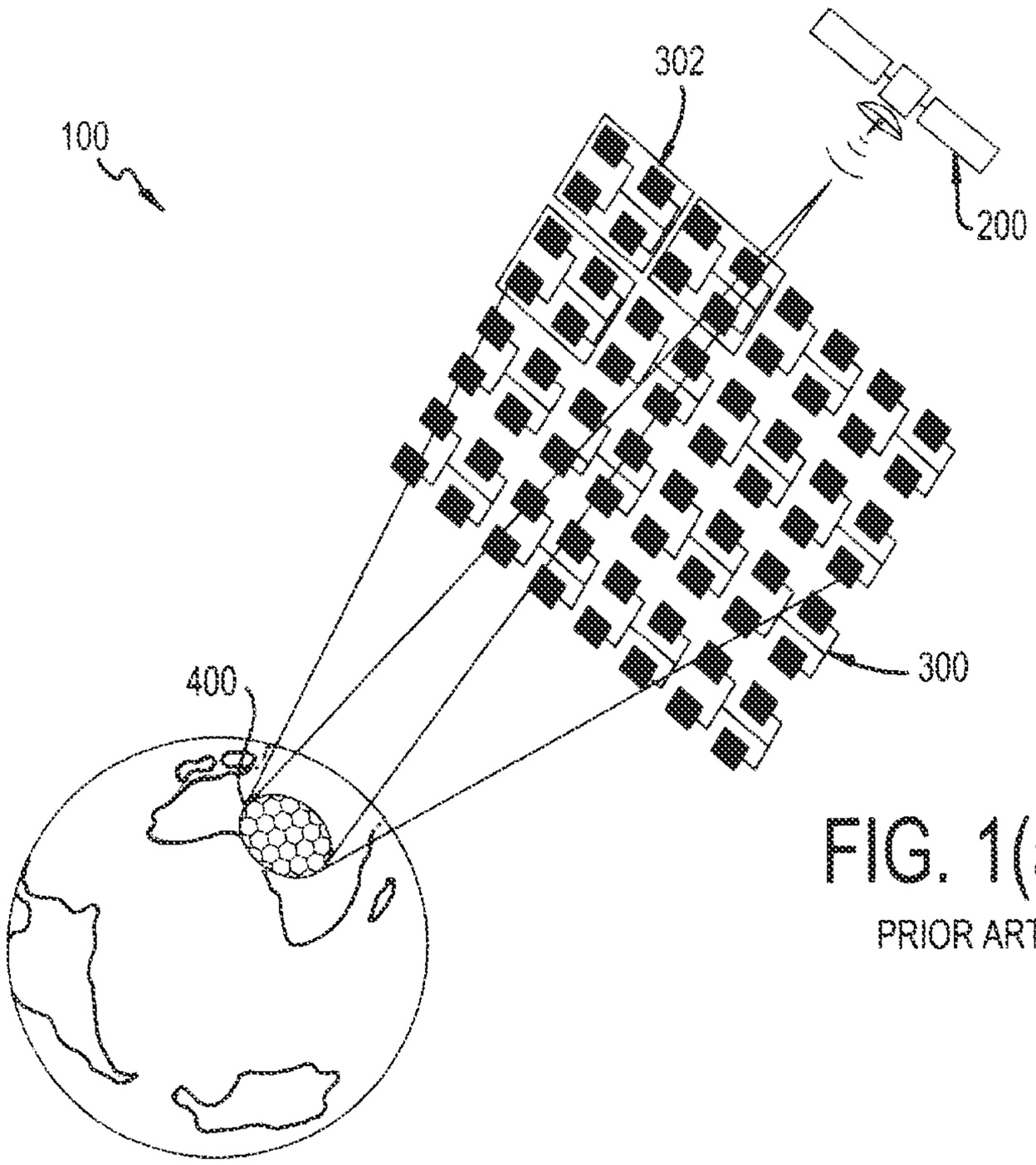


FIG. 1(a)
PRIOR ART

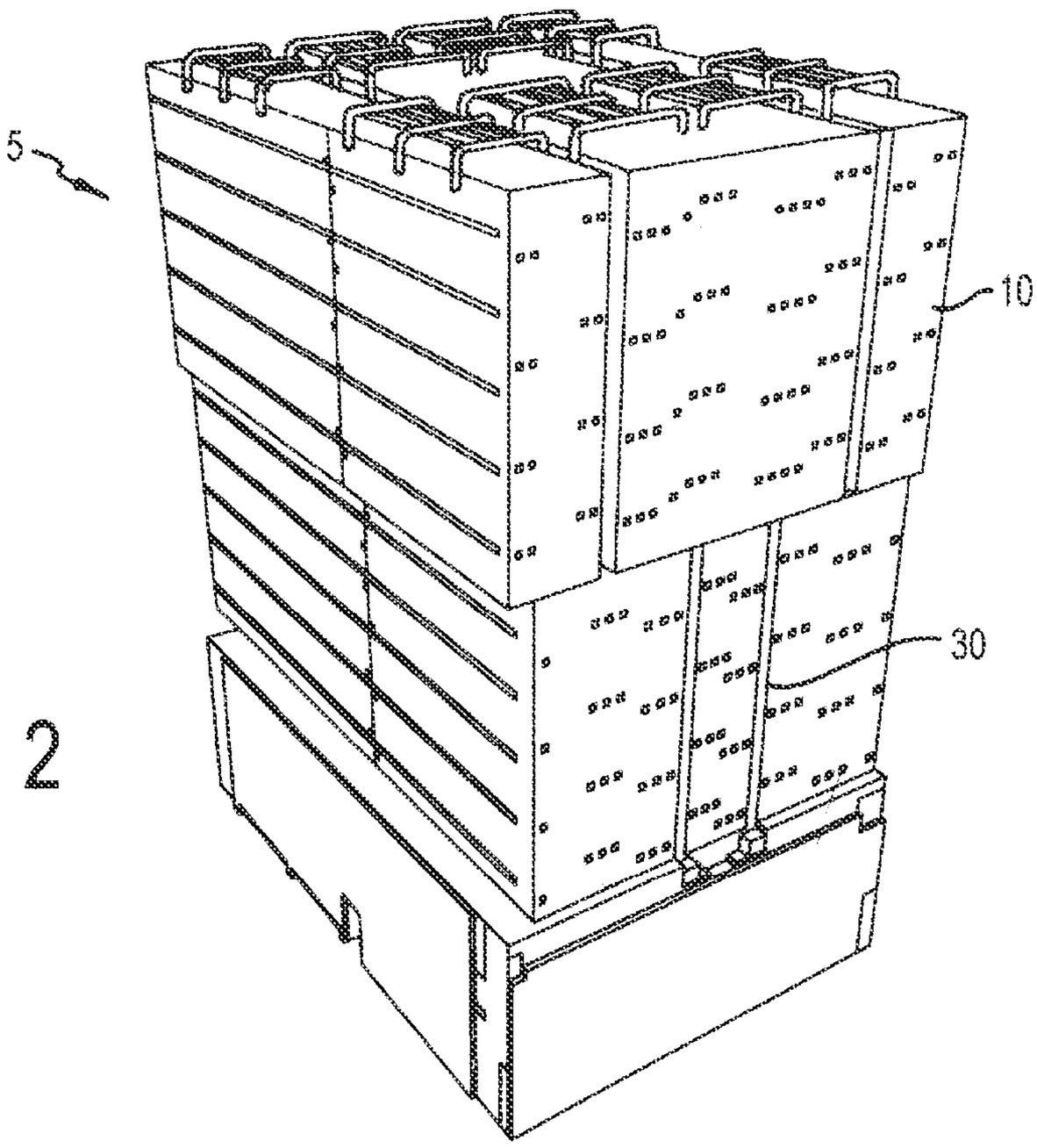


FIG. 2

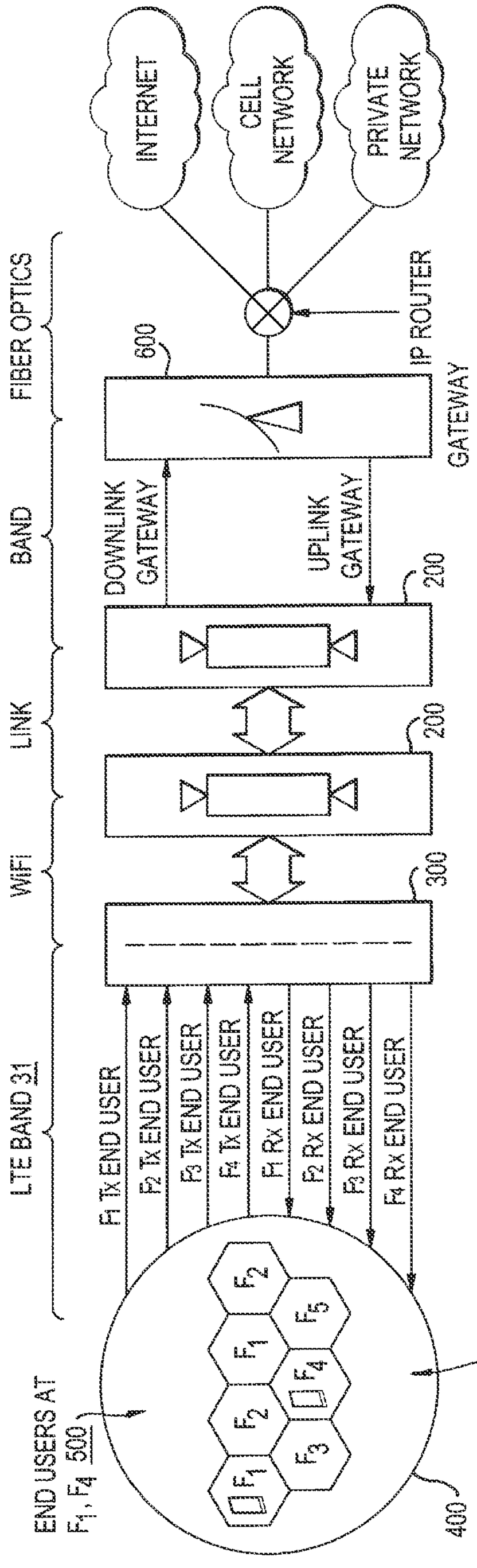


FIG. 1(b)
PRIOR ART

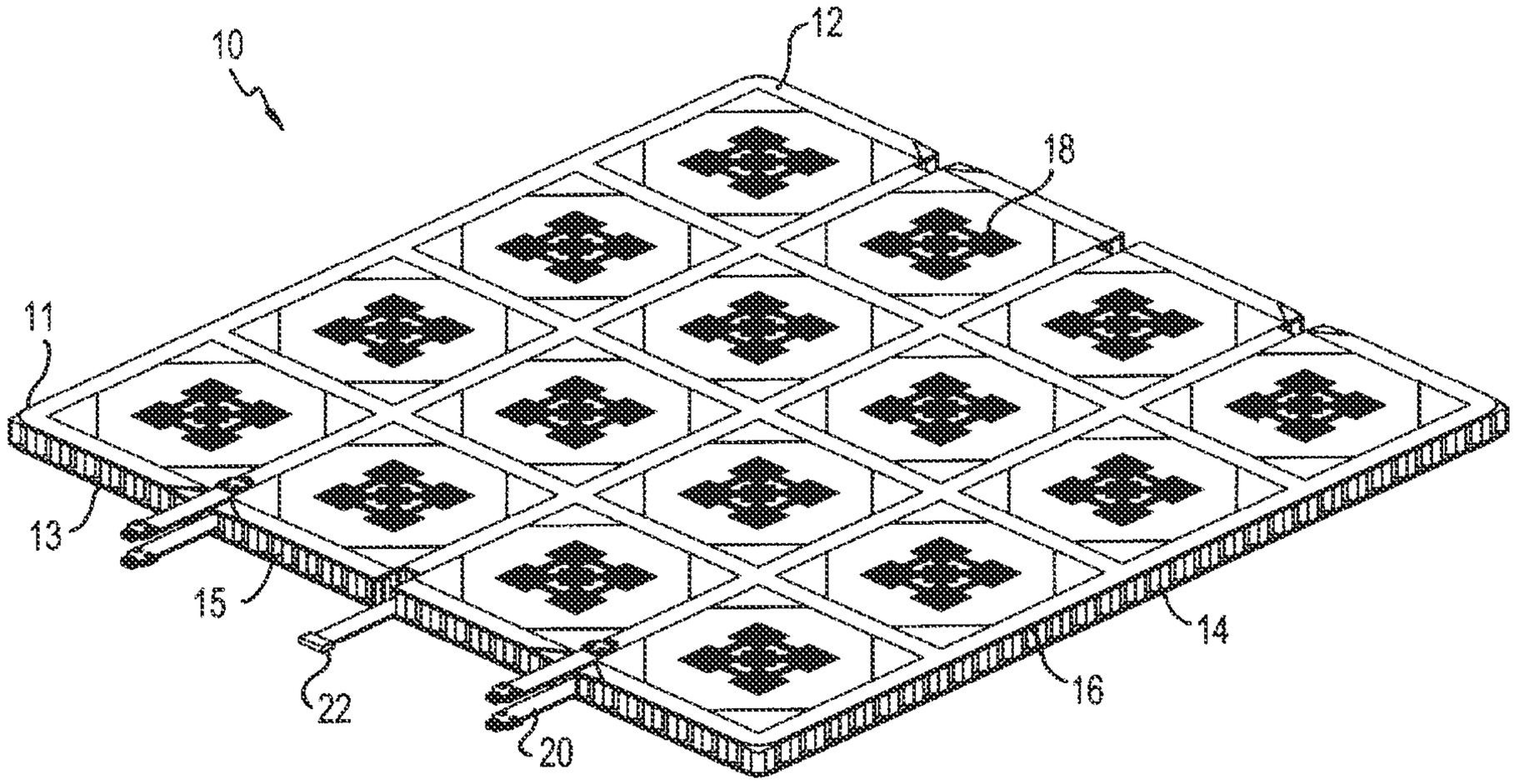


FIG. 3(a)

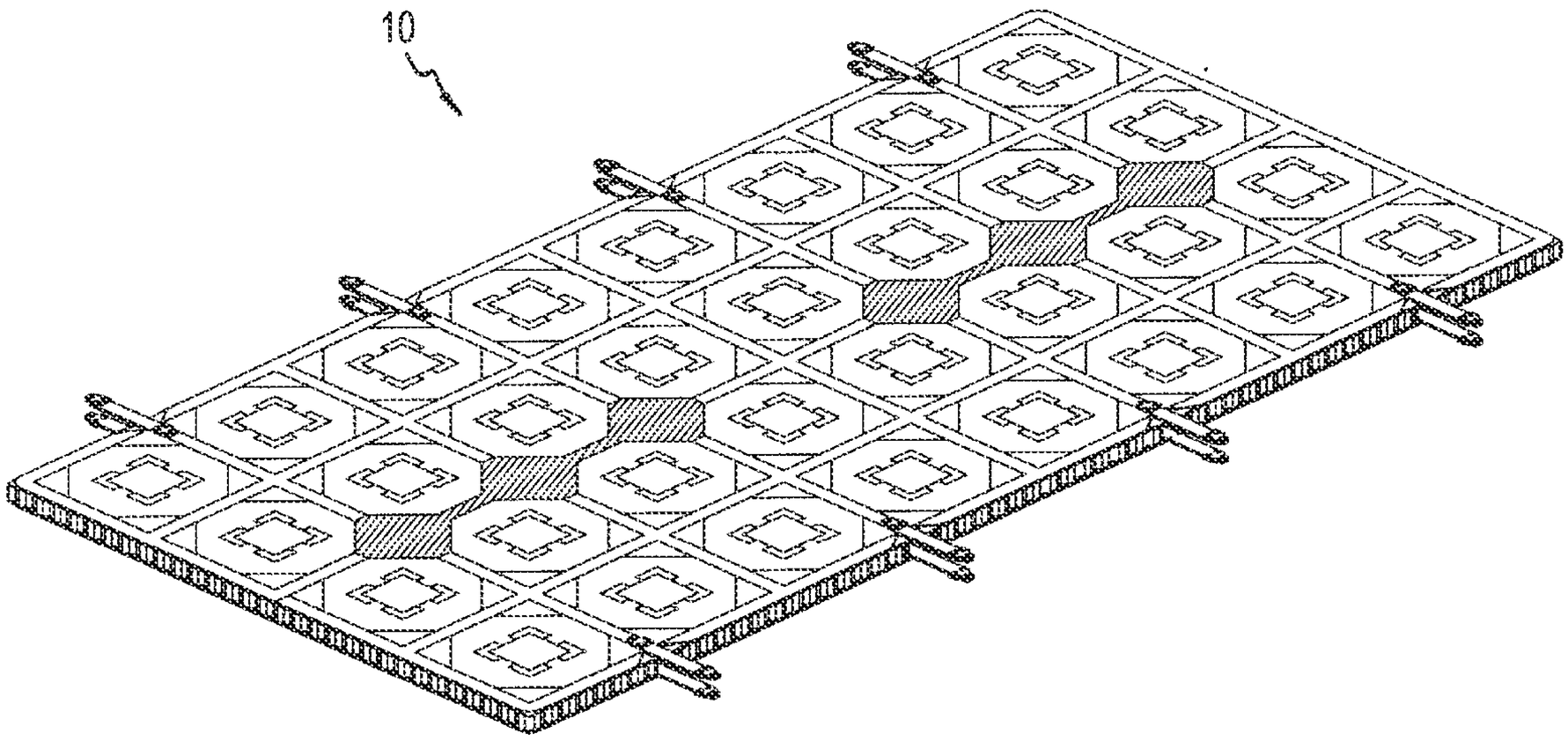


FIG. 3(b)

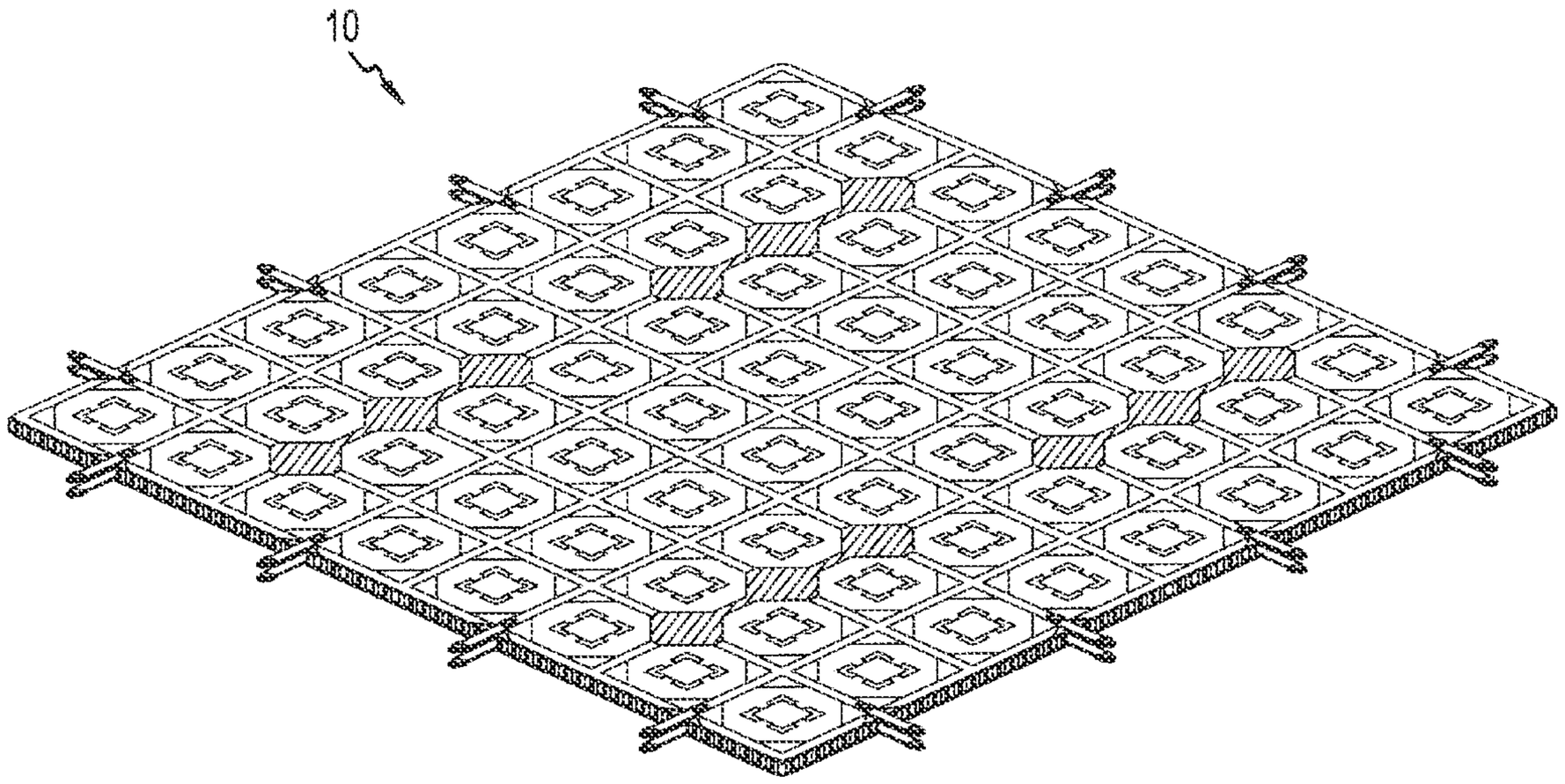


FIG. 3(c)

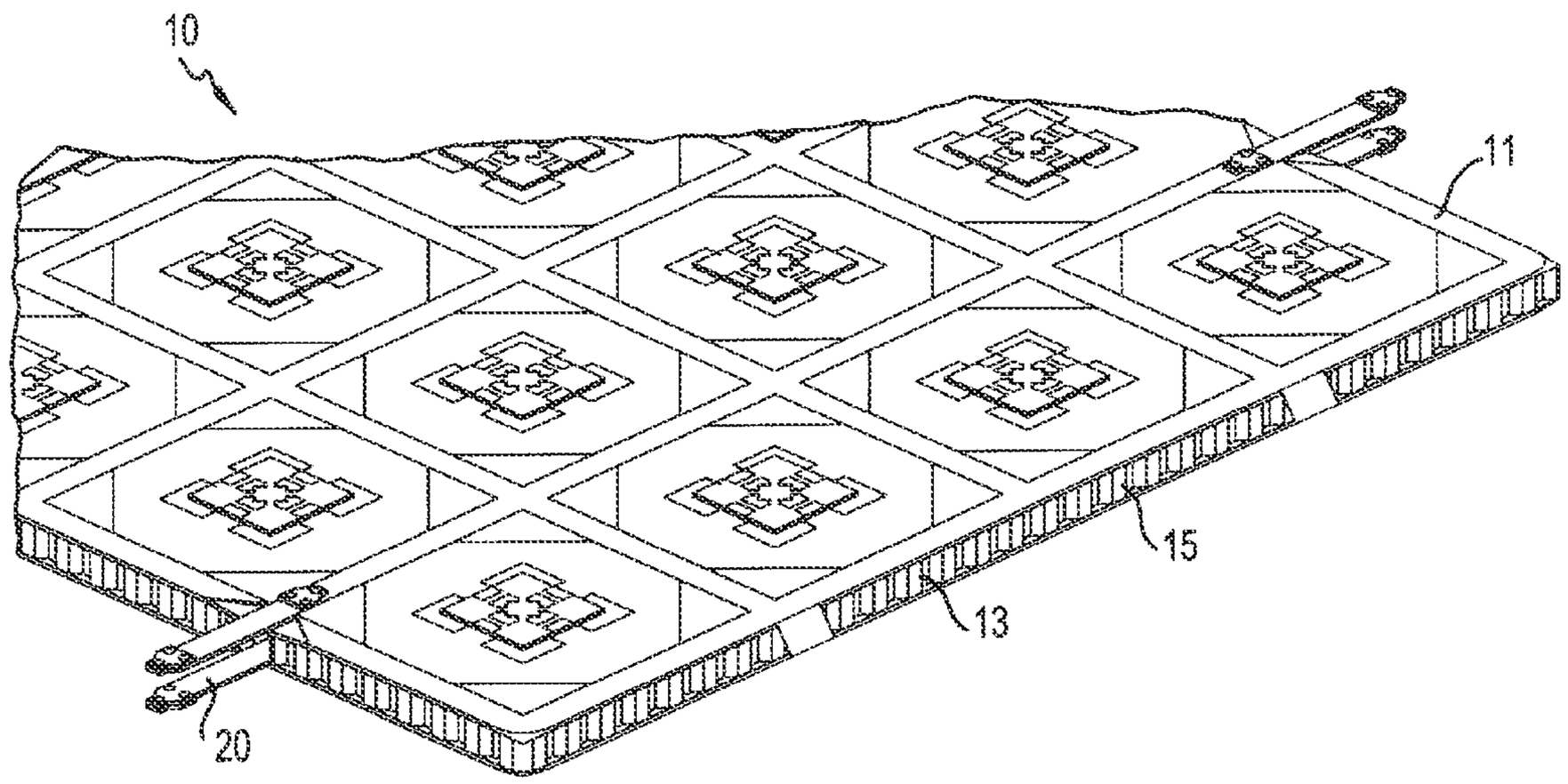


FIG. 3(d)

LOW EARTH ORBIT MECHANICAL DEPLOYABLE STRUCTURE

RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 16/875,646, filed 15 May 2020, which claims the benefit of priority of U.S. Application No. 62/848,317, filed on May 15, 2019, Spanish application Ser. No. 202030123, filed on Feb. 13, 2020, and U.S. Application No. 62/977,864 filed on Feb. 18, 2020. This application also claims priority to Spanish application Ser. No. 202030124, filed on Feb. 13, 2020, Spanish application Ser. No. 202030125, filed Feb. 13, 2020, U.S. Application No. 62/977,860, filed Feb. 18, 2020, and U.S. Application No. 62/978,081, filed Feb. 18, 2020. The content of those applications is relied upon and incorporated herein by reference in their entireties. The present application further incorporates by reference the content of U.S. application Ser. No. 16/875,703, titled Solar, Electric, RF Radiator for Self-Contained Structure for Space Application Array, filed May 15, 2020, and U.S. application Ser. No. 16/875,738, titled Thermal Management System for Structures in Space, filed May 15, 2020.

BACKGROUND

U.S. Pat. No. 9,973,266 and U.S. Publ. No. 2019/0238216 show a system for assembling a large number of small satellite antenna assemblies in space to form a large array. The entire content of the '266 patent is incorporated herein by reference. As disclosed in the '266 Patent, FIGS. **1**(*a*), **1**(*b*) show a satellite communication system **100** having an array **300** of small satellites **302** and a central or control satellite **200**. The small satellites **302** communicate with end users **500** within a footprint **400** on Earth, and also communicate with the control satellite **200**, which in turn communicates with a gateway **600** at a base station. The small satellites **302** can each include, for example, a processing device (e.g., a processor or controller) and one or more antenna elements. And the control satellite **200** can include a processing device and one or more antenna or antenna elements.

SUMMARY

An antenna array has a plurality of square or rectangular antenna assemblies. Each assembly includes a first antenna assembly surface with a solar cell and a second antenna assembly with one or more antenna elements. The antenna assemblies are interconnected without gaps therebetween to form a first contiguous array surface comprised of the first antenna assembly surfaces and a second contiguous array surface comprised of the second antenna assembly surfaces.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**(*a*), **1**(*b*) show a conventional structural array;

FIG. **2** is a perspective view of a structural array in a stowed configuration;

FIG. **3**(*a*) is a perspective view of a 1×1 structural element of the structural array of FIGS. **2**(*a*), **2**(*b*);

FIG. **3**(*b*) is a perspective view of a 2×1 structural element;

FIG. **3**(*c*) is a perspective view of a 2×2 structural element; and

FIG. **3**(*d*) is a detailed view of the spring tape connections.

DETAILED DESCRIPTION

In describing the illustrative, non-limiting embodiments of the disclosure illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, the disclosure is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents that operate in similar manner to accomplish a similar purpose. Several embodiments of the disclosure are described for illustrative purposes, it being understood that the disclosure may be embodied in other forms not specifically shown in the drawings.

Turning to FIG. **2**, the present disclosure is a Low Earth Orbit (LEO) Mechanical Deployable Structure (LMDS) **5**. The LMDS **5** is a self-deployable structure for space applications formed by a plurality of discrete antenna assemblies **10**, referred to here as remote satellite modules or just panels or tiles **10**, all of them mechanically connected by a connection or interconnection assembly. The LMDS **5** is a satellite system having one or more remote satellite modules or assemblies, in the form of tiles **10**, that together form a single large phase array in space. Each satellite module assembly has a plurality of satellite tiles **10** that are mechanically connected together by one or more hinges. A plurality of satellite module assemblies can also be connected in space to form the single large phase array having a single orbital inclination and/or single aperture.

In one example embodiment shown in FIG. **3**(*a*), the tiles **10** are individually separate and distinct, and are square and/or rectangular in shape. The tiles **10** are thin and have an outer layer **11**, inner layer **13**, and middle layer **15**. The outer layer **11** can be formed by a first thin plate with a square or rectangular first planar side **12** (here shown as top plate **11** with a top or top surface **12**) with a first side surface. The inner layer **13** can be formed by a second thin plate **13** having a second planar side **14** (here shown as a bottom plate **13** with a bottom or bottom surface **14**) opposite the first side **12** and having a second side surface. The middle layer can be formed by a middle structure, such as a honeycomb support structure **15**, that is positioned at the interior of the tile **10** between the first plate **11** and the second plate **13**. The inner, outer and middle layers have four lateral sides or side edges **16**. The tiles **10** have a rectangular cross-section that forms the shape of the lateral sides **16** that define the tile thickness which is substantially less than the length and/or width of the tile **10**. The first and second plates **11**, **13** and the support structure **15** are lightweight. The support structure **15** provides structural support to the first and second plates **11**, **13**. However, in other embodiments, a support structure **15** need not be provided.

The deployable structure **5** can be launched in a stowed configuration (FIG. **2**) and deployed to a large deployed configuration (FIG. **1**(*a*)) once in orbit (e.g., under no gravity conditions). In the stowed configuration, the tiles **10** are in a compact form that can be transported to space. The tiles **10** can be arranged in any suitable manner, such as for example folded onto each other so that the tiles **10** are in stacked arrangement with the top surface **12** of one tile facing and parallel to the top or bottom surface **12**, **14** of another tile **10**, though one or more of the tiles **10** can also optionally be positioned orthogonal to other tiles **10**. In the deployed configuration (e.g., FIG. **1**(*a*)), the tiles **10** are unfolded and substantially planar with one another to form

a structural array. Thus, the antenna **18** is received in a recess of the top plate **11** so that the top of the antenna **18** is flush with the top surface **12** of the top plate **11** to form a planar top surface **12**. And the solar cells can be positioned in a recess of the bottom plate **13** so that the top surface of the solar cells are flush with the bottom surface **14** to form a planar bottom surface **14**. Thus, the top and bottom surfaces **12**, **14** can come together in the stowed configuration without gaps or spacing therebetween. In accordance with one embodiment of the present disclosure, the tiles form a contiguous uniform uninterrupted surface.

The LMDS **5** can be utilized for a number of applications, including for example an antenna, reflector, or data center. FIGS. **3**(*a*)-**3**(*d*) show one embodiment of the LMDS **5** utilized for an antenna, and the plurality of tiles **10** are antenna assemblies. Each antenna assembly **10** represents a small satellite (also referred to here as a micron) and has one or more antenna elements **18** and a processing device (e.g., processor or controller). The antenna assemblies **10** are connected together by an interconnection assembly having one or more mechanical connectors **20**, electrical connectors **22** that enable power and/or data transfer between the antenna assemblies **10**, and one or more latches that retain the structure **5** in the stowed configuration (FIG. **2**). The electrical connector **22** electronically connects the electronic components (e.g., processing device, sensors, actuators, power) of adjacent tiles **10**. Thus, the array of tiles **10** is modular, and the size and shape of the array can be adjusted by adding or removing tiles **10**.

The structure **5** deploys in a passive way, for example, the antenna assemblies **10** are connected by stored-energy connectors **20**. The stored-energy connectors **20** have a stored-energy position and a released-energy position. In the folded stowed configuration of the array of antenna assemblies **10** (FIG. **2**(*a*)), the stored-energy connectors **20** are in the stored-energy position, where they retain mechanical energy and are biased outward to the released-energy position. In the unfolded deployed configuration of the array of antenna assemblies **10** (FIG. **2**), the stored-energy connectors **20** are in the released-energy position. For example, in one embodiment the connectors **20** can mechanically store energy, such as for example an elongated straight one-piece integral spring that is biased outward (i.e., to a linear position). In the stored-energy position, the spring connectors **20** can folded (e.g., curved to fold in half), and in the released-energy position the spring connectors **20** can be unfolded and substantially straight (i.e., linear) or planar. However, the stored-energy connectors **20** need not be a spring, but can be any suitable connector that stores energy, either mechanical or electrical.

The structure **5** is kept in the stowed configuration by one or more mechanical and/or electrical locking mechanisms **30** having a locked state and an unlocked state, such as a latch. The locks can be, for example, a latching system that is positioned on the outer surface of the LMDS **5** when in the stowed position (FIG. **2**). Or the locks can be, for example, a mechanism that prevents rotation of the tiles **10**. In the locked state, the locks prevent the array of tiles **10** from inadvertently moving from the stowed configuration to the deployed configuration until the locks are placed in the unlocked state. Once the deployment is ready to initiate, the latching is triggered to unlock the folded antenna arrays. For example, the latches can be manually actuated or actuated by a processing device at the antenna assembly **10**. Once the latches are unlocked, the stored-energy connectors begin to move the array of antenna assemblies **10** to the deployed configuration in a controlled manner. The energy in the stored-energy connectors **20** begins to release and the stored-energy connectors move toward the released-energy position. As the stored-energy connectors move to the released-energy position, the antenna assemblies **10** unfold from the stowed configuration into the deployed configuration.

The stored-energy connectors **20** are folded into the stored-energy position when the LMDS **5** is on Earth. The LMDS **5** can then be transported into space in the compact stowed configuration. Once in space, the latch(es) are unlocked (e.g., manually or electrically such as by a remotely operated solenoid) and the stored-energy connectors **20** move the antenna assemblies **10** into the deployed configuration utilizing the mechanical power that is stored in the stored-energy connector **20**. Thus, in one embodiment where the connectors **20** are mechanical, the antenna array does not require any electric power to move from the stowed configuration to the deployed configuration. In addition, the connectors **20** are positioned to not interfere with operation of the antenna assemblies **10**. For example, the connectors **20** are positioned at the side edges **16** of the antenna assemblies **10** so they do not interfere with electrical operations at either the top **12** or bottom **14** of the antenna assembly **10**. And, the connectors **20** allow the assemblies **10** to come together in the deployed configuration so that the sides **16** come into contact with one another to form a single contiguous uniform and planar surface without gaps between adjacent antenna assemblies **10**.

Connectors **20**

As shown in FIGS. **3**(*a*)-(*d*), in one example embodiment, the stored-energy connectors **20** are a tape spring, though other suitable connectors can be utilized. The tape springs can be thin, linear and elongated. They can either be flat (i.e., a linear cross-section) or arcuate (i.e., a curved cross-section). In addition, the interconnection assembly can include other attachment mechanisms, such as latches, joints, hinges or connectors that connect to the tiles **10**. The tape springs **20** are spring loaded hinges that once deployed, give the structure a required mechanical stiffness. As best shown in FIG. **3**(*a*), one or more tape springs **20** are provided at one or more of the side edges **16** of the antenna assembly **10**. In FIG. **3**(*d*), the tape springs **20** are metal structures that can be curved to create a spring-like bias when folded in the stored-energy position, and a locking force when in the deployed released-energy position. The locking force maintains the antenna assemblies **10** in the deployed configuration and prevent them from returning to the deployed configuration. Thus, the tiles are small separate discrete devices that are physically connected to one another by one or more connectors **20** to form a large array in space.

The connector **20** has sufficient length to connect neighboring tiles **10** when they are folded upon one another in the stowed configuration and substantially parallel to one another, and also in the deployed configuration when they are unfolded and substantially planar with one another. The tape spring connectors **20** deliver energy to deploy the panels and keeps the panels **10** in position once deployed. The connectors **20** can include outwardly biased springs that are biased to spring outward when in the stowed configuration. When the panels **10** are folded upon one another, the connectors **20** are in a bent or folded configuration and are biased outward to be in a straightened or linear position. In the stowed configuration, the springs apply an outward force that facilitates movement of the panels **10** from the stowed configuration to the deployed configuration.

As further illustrated in FIGS. **3**(*a*)-(*d*), a connector **20** (i.e., the tape spring in the current example embodiment) can

be attached (e.g., by fastener(s), adhesive or the like) to both the top surface **12** and the bottom surface **14** of the tile **10**. And tape springs **20** on the top surface **12** align with the tape springs **20** on the bottom surface **14**. However, the tape springs **20** can be provided at any suitable position at the tile **10**, such as between the top and bottom surfaces **12**, **14**. And, tape springs **20** need not be provided on both the top and bottom surfaces **12**, **14**, or the tape springs on the top surface **12** need not be aligned with the tape springs on the bottom surface **14**.

It is further noted that in the example above, the stored-energy connectors **20** are a spring tape that stores mechanical energy. However, any suitable stored-energy connector can be utilized that mechanically stores energy. In addition, any suitable connector can be utilized that electronically stores energy. In addition, the stored-energy connectors **20** can move the tiles **10** from the stowed configuration to the deployed configuration in any suitable amount of time, from hours to days.

Thus, each tile **10** has at least one connector **20** that mechanically connects the tile **10** to an adjacent tile **10**, but at the same time allows the tile **10** to move (e.g., bend, fold, rotate or pivot) with respect to one or more of the other tiles **10**, and move between the stowed position and the deployed position.

For example, the connectors **20** allow the top or bottom surface **12**, **14** of a first tile **10** to touch the top or bottom surface of an n^{th} tile **10**. And, the first tile **10** can be either vertically or horizontally aligned with the n^{th} tile **10**, and the first and n^{th} tiles **10** need not be immediately adjacent or an adjacent tile connected by the connector. That is, the first tile can be positioned several tiles away from the n^{th} tile, such that there are intervening tiles between the first and n^{th} tiles. For example, the n^{th} tile can be the second tile, which is immediately adjacent the first tile in the same row or column. Or the n^{th} tile can be the fifth tile, which has three intervening tiles between the first and fifth tiles in the same row or column. Or the n^{th} tile can be the fifth tile, which can be in a different row and column as the first tile. In one embodiment, each tile has two connectors and is mechanically connected to two adjacent tiles.

In a further embodiment of the disclosure, the connector **20** can be a hinge that directly couples a first tile **10** to an immediately adjacent second tile **10**. The hinge can be coupled to the inside or outside surfaces of the tiles, or to the middle layer of the tile. The hinge can provide a mechanical and/or electrical connection, though in one embodiment the hinge at least has a mechanical connection and can be controlled electronically to move between the operating configuration and the storage configuration. Any suitable control mechanism can be utilized to control the rotation of the modules, either mechanical and/or electrical. For example, the control mechanism can be a coil that receives an electric current to cause an electromagnetic force, and are positioned on the tiles to control rotation of the tiles **10** with respect to one another.

The electromagnetic forces formed by the coil can cause the tiles **10** to move, and/or can cause the hinges to move. Other suitable control mechanisms can be provided, such as magnets, a biased mechanical spring and/or solenoids. If needed, electrical wires or fibers can pass through the hinges between tiles to carry data such as control signals to control movement of the phase array in space and/or to control movement of the tiles **10** between the operating and storage configurations. In one embodiment, the wire can carry a current that passes through the coils to create a magnetic field that opens the hinge to move the tiles **10** from a storage configuration to an operating configuration. The coils can also be utilized to tilt the phase array to track the sun and/or the pointing of the aperture or to otherwise move the phase array **300**. In another embodiment, the connector **20** can include both a tape spring and a hinge at one or more of the side edges of the tiles **10**.

LMDS Configuration

The tiles **10** forming the structure **5** can be assembled in different configurations, i.e. 1×1 Tile, 2×1 Tile, 2×2 Tile, etc. as shown in FIGS. **3**(*a*), **3**(*b*), **3**(*c*), respectively. Each of the tiles **10** have a communications face/side, here shown as the top **12**, and a solar power face/side, here shown as the bottom **14**. The communications side **12** have the antenna elements **18** that conduct radio frequency (RF) communications with user devices on Earth. By the propagation of the tiles **10**, this generates the array/structure **5** with one RF side and one solar panel side. The RF side forms a top surface **12** that faces Earth, and the second side forms a bottom surface **14** that faces away from Earth.

In addition, a solar cell can be positioned on the surface (here, the bottom surface **14**) that faces away from the Earth. The solar cell receives solar energy from the Sun, especially when the LMDS **5** is between the Earth and the Sun. Thus, one side of the satellite module can have the solar cell and the opposite side can point the antenna in the desired direction. The solar energy can be utilized to power the electronic components of the tile or for array thrust. For example, the tiles can be made from photovoltaic material or other material that converts solar energy to electrical energy to operate as a solar panel, and also operate as an antenna structure (or other structure of the satellite or satellite module) to transmit and receive signals in accordance with the present disclosure. The electrical energy is used to power the satellite or satellite modules or stored for later use. Thus, the same structure can be used for solar energy and for operation as a satellite antenna.

In the deployed position, the tiles are closely arranged and can contact one or more of its neighboring tile. Accordingly, the RF side collectively form the large phase array. The tiles **10** can optionally also house other electronic components, such as a receiver, transmitter or processing device(s). Those electronic components are positioned at the interior (between the top surface and the bottom surface) of the tile so that they do not interfere with the operation of the antenna elements **18** or the formation of the phase array.

To further avoid any interference between the connectors **20** and the RF side **12**, the connectors **20** are arranged such that when the structure deploys, the connectors **20** do not obstruct the top surface of the RF side **12**. In FIG. **3**(*a*), the tile **10** is a 4×4 array of sixteen antenna elements **18** with two connectors **20** formed at each of two side edges of the tile **10**. However, other suitable sizes and dimensions can be utilized. For example, the tile **10** can be formed as a 4×8 array of 32 antenna elements **18**, FIG. **3**(*b*), or an 8×8 array of 64 antenna elements **12**, FIG. **3**(*c*), and the connectors **20** can be located at the outer side edges of the tile **10**.

The LMDS **5** is modular and can be designed in many different layout combinations (tile sizes, number of tiles, overall shape, overall size, etc.) but the shape of the tiles is square and rectangular, and all tiles **10** are mechanically interconnected (for each independent deployable area). In one embodiment, the structure will deploy all at once. However, in other embodiments, the structure can deploy in two halves or four quarters. Although the LMDS is especially configured for LEO orbit, it is applicable to any other possible orbit, or on ground.

FIG. **1**(*a*) show the structure **5** having a square shape, though in other applications the structure **5** has a circular shape. In addition, the various sizes, layout and shapes of the individual tiles **10** differ, as well as the numbers of columns and rows of tiles **10** in the array. The overall shape and structure can be changed by adding or removing tiles **10**, or by changing the number of rows, columns, size or shape of the tiles.

Latches

In one embodiment of the disclosure, the locking mechanism **30** can be one or more latches. The latches can be micro sized and light weight and are attached to one or more of the tiles **10**. The latches hold down one or more of the tiles **10** and prevent the array **5** from inadvertently moving from the stowed configuration to the deployed configuration. The latches can be any suitable device. In one embodiment, the latches are made of a Shape Memory Alloy (SMA). A small current is passed through the latch, which causes the latch to unlock the array of tiles **10** so that the tiles **10** can move from the folded stowed configuration to the unfolded deployed configuration. Unlocking can be controlled manually by manually moving the latch, pressing a button to remotely activate the latch, or automatically by a processor at one or more of the tiles **10**. The latches respond quickly (within milliseconds) and reliably, despite the harsh conditions in space, where temperatures can be −65 to +70 degrees Celsius.

Transportation

In one embodiment of the operating configuration, all of the tiles **10** are arranged in a single plane, i.e., all of the tiles are side by side with the top surfaces in a single plane. And in the storage configuration, all of the connected tiles are aligned and arranged facing one another in a line (single column).

Accordingly, the system has a very large number of satellite tiles that are connected by connectors **20**. The tiles **10** can be placed in a storage or transport configuration. The small tiles **10** are separate discrete devices and are physically connected to one another by one or more connectors **20**. The tiles can be folded into the transport configuration for storage and transportation and then deployed in space into the large satellite array of the operating configuration.

For example, in the storage configuration, the multiple tiles are folded along the connectors **20** and placed together in a single shipping container such as a box, for transport on a rocket or other transport device or space craft. Once the shipping container(s) reaches a release position in space at a desired orbit, the shipping container can be opened and the tiles can be released into space. The tiles can then automatically maneuver to enter into the operating configuration array in space where it forms a very large and dense array of the satellite tiles.

This greatly reduces the space required by the tiles during transport, but enables the tiles to form a very large array when in the operating configuration. The tiles can take up a space of a few square meters depending on the number of tiles, which converts to many square meters when deployed in space. Thus, the satellite array can be formed with minimal human intervention (such as to release the tiles from the shipping container and space craft, and optionally to unlatch the locking mechanism to initiate self-deployment of the connectors), and can even be formed without any physical human intervention (such as to build a frame or other structure for the array). In addition, multiple tiles can be connected together in space to form a single phase array that is hundreds or thousands of square meters in size.

CONCLUSION

The tiles **10**, connectors **20** and locking mechanisms **30** are utilized for the LMDS **5** and deployed in space. However, the tiles **10**, connectors **20** and locking mechanisms can be utilized in other structures or applications. And, the LMDS **5** can utilize any suitable tiles, connectors and locking mechanisms, and is not restricted to those shown and described with respect to the illustrative examples. And other suitable positioning of the tiles, connectors and locking mechanism can be provided within the structure as part the LMDS.

It is further noted that the shape and size of the tiles **10** enable them to be placed immediately adjacent to each other in the deployed configuration. That is, all of the sides of the tiles **10** come into direct contact with the respective side of the neighboring adjacent tiles. The connectors enable the tiles to be substantially contiguous with one another to form a single contiguous structure **5** without any gaps between the adjacent tiles **10**. The connectors **20** enable (and do not obstruct) adjacent tiles **10** to directly contact one another in the deployed position.

When the LMDS **5** is configured as an antenna array, it (e.g., the antenna elements **18**) communicates with processing devices on Earth, such as for example a user device (e.g., cell phone, tablet, computer) and/or a ground station. The present disclosure also includes the method of utilizing the LMDS **5** to communicate with processing devices on Earth (i.e., transmit and/or receive signals to and/or from). The present disclosure also includes the method of processing devices on Earth communicating with the LMDS **5** (i.e., transmit and/or receive signals to and/or from). In addition, while the LMDS **5** is used in Low Earth Orbit (LEO) in the examples disclosed, it can be utilized in other orbits or for other applications. In addition, while the disclosure has been described as for an array of antenna assemblies, the disclosure can be utilized for other applications, such as for example data centers, reflectors, and other structures, both implemented in space or terrestrially.

In one embodiment, the disclosure provides a phase array having a large dense array formed by a plurality of flat discrete satellite modules each having an antenna; a plurality of coils at one or more of the plurality of flat discrete satellite modules, each of said plurality of coils generating an electromagnetic force; said plurality of flat discrete satellite modules interconnected by hinges, wherein the plurality of flat discrete satellite modules have a compact transport configuration for transport to space, and an operating configuration whereby the electromagnetic forces form said plurality of flat discrete satellite modules into a the large dense array in space. In addition, said plurality of flat discrete satellite modules in the operating configuration form a large planar mechanically-interconnected structure. In addition, each of said plurality of flat discrete satellite modules have a solar cell on top and a transmitter on bottom. In addition, the electromagnetic forces pivot said plurality of flat discrete satellite modules about said hinges. In addition, said coil creates a magnetic field that moves the phase array to track the sun or objects on the ground.

In another embodiment, the disclosure provides a phase array having a first module; a second module; a connector connected to the first module and the second module to move the first and second modules between an operating configuration and a storage configuration; and a control

mechanism coupled to said connector to move the first and second modules between the operating configuration and the storage configuration. In addition, the first and second modules include an antenna. In addition, said control mechanism comprises a coil and said control mechanism passes a current through said coil to create a magnetic field that moves said first and/or second satellite module to pivot about said connector. In addition, said control mechanism comprises a coil and said control mechanism passes a current through said coil to create a magnetic field that moves the phase array to track the sun or objects on the ground. In addition, said control mechanism comprises a coil and said control mechanism passes a current through said coil to create a magnetic field that moves the phase array to point an aperture formed by the phase array. In addition, said connector comprises a mechanical connector. In addition, an electrical wire or cable passing through said connector. In addition, said first and second modules are flat with a top, bottom and sides, and in the operating configuration are arranged side-by-sides in rows and columns and in the storage configuration are arranged with the tops and/or bottoms facing each other. In addition, said first and second modules are flat with a top, bottom and sides, and having a solar collector on the top and an antenna on the bottom.

In another embodiment, a phase array has a first satellite module; a second satellite module; a mechanical connector comprising a hinge rotatably connected to the first satellite module and the second satellite module to rotate said first satellite module with respect to said second satellite module to move said first and second satellite modules between an operating configuration and a storage configuration; and a control mechanism comprising a coil coupled to said connector to create an electromagnetic field in response to a current passing through said coil, to move the first and second satellite modules about said hinge between the operating configuration and the storage configuration.

It is further noted that the present disclosure can be utilized separately, and can also be utilized in combination with the systems and methods disclosed in U.S. application Ser. No. 16/875,703, titled Solar, Electric, RF Radiator for Self-Contained Structure for Space Application Array, filed May 15, 2020, and U.S. application Ser. No. 16/875,738, titled Thermal Management System for Structures in Space, filed May 15, 2020. Thus, for example, the self-deployable tiles **10** can have structure as shown and described in the Solar, Electric, RF radiator application, and/or can utilize the thermal management as shown and described in the Thermal Management application.

It is further noted that the description and claims use several geometric, relational, directional, positioning terms, such as planar, square, rectangular, linear, flush, elongated, circular, parallel, perpendicular, orthogonal, transverse, flat, side, top, and bottom. Those terms are merely for convenience to facilitate the description based on the embodiments shown in the figures, and are not intended to limit the present disclosure. Thus, it should be recognized that the disclosure and disclosure can be described in other ways without those geometric, relational, directional or positioning terms. In addition, the geometric or relational terms may not be exact. For instance, surfaces may not be exactly flat, planar or parallel but still be considered to be substantially flat, planar or parallel because of, for example, roughness of surfaces, tolerances allowed in manufacturing, forces applied in practice during use, etc. And, other suitable geometries and relationships can be provided without departing from the spirit and scope of the disclosure.

The foregoing description and drawings should be considered as illustrative only of the principles of the disclosure, which may be configured in a variety of ways and is not intended to be limited by the embodiment herein described. Numerous applications of the disclosure will readily occur to those skilled in the art. Therefore, it is not desired to limit the disclosure to the specific examples disclosed or the exact construction and operation shown and described. Rather, all suitable modifications and equivalents may be resorted to, falling within the scope of the disclosure.

The invention claimed is:

1. An antenna array comprising:

a plurality of antenna assemblies each having one or more antennas; and

a plurality of stored-energy connectors connecting adjacent antenna assemblies of the plurality of antenna assemblies, the plurality of stored-energy connectors configured to store energy in a stored-energy position and configured to release energy in a released-energy position to move the plurality of antenna assemblies to a deployed configuration of the plurality of antenna assemblies, wherein the plurality of stored-energy connectors comprises a first stored-energy connector connected to a first layer of the adjacent antenna assemblies and a second stored-energy connector connected to a second layer of the adjacent antenna assemblies, the first layer different than the second layer.

2. The antenna array of claim **1**, wherein the plurality of antenna assemblies form a planar array in the deployed configuration.

3. The antenna array of claim **1**, further comprising:

a control mechanism to cause the plurality of stored-energy connectors to move the plurality of antenna assemblies from a stowed configuration of the plurality of antenna assemblies to the deployed configuration of the plurality of antenna assemblies.

4. The antenna array of claim **3**, wherein the plurality of antenna assemblies are configured to be parallel in the stowed configuration and configured to be planar when in the deployed configuration.

5. The antenna array of claim **1**, wherein the first layer of each of the plurality of antenna assemblies comprises an antenna of the one or more antennas and the second layer of each of the plurality of antenna assemblies comprises a solar cell.

6. The antenna array of claim **1**, further comprising a control mechanism comprising one or more of a solenoid, a coil, or a magnet.

7. The antenna array of claim **1**, wherein the stored-energy connectors comprise tape springs.

8. The antenna array of claim **1**,

wherein the first layer of the adjacent antenna assemblies comprises one or more antennas, and

wherein the second layer of the adjacent antenna assemblies comprises one or more solar cells.

9. The antenna array of claim **1**, wherein the first stored-energy connector and the second stored-energy connector are positioned at side edges of the adjacent antenna assemblies.

10. An antenna array comprising:

a plurality of antenna assemblies each having one or more antennas; and

a plurality of stored-energy connectors connecting adjacent antenna assemblies of the plurality of antenna assemblies, the plurality of stored-energy connectors configured to store energy in a stored-energy position and configured to release energy in a released-energy

position to move the plurality of antenna assemblies to a deployed configuration of the plurality of antenna assemblies, wherein each stored-energy connector of the plurality of stored-energy connectors are positioned at side edges of the adjacent antenna assemblies to enable side edges of the adjacent antenna assemblies to contact when in the deployed configuration to form a planar surface without gaps between the adjacent antenna assemblies.

11. The antenna array of claim **10**, wherein the plurality of antenna assemblies are configured with a stowed configuration in which the plurality of antenna assemblies are arranged in a folded configuration.

12. The antenna array of claim **10**, wherein the deployed configuration comprises a configuration in which the plurality of antenna assemblies are arranged in a planar configuration.

13. The antenna array of claim **10**, further comprising:

a control mechanism to cause the plurality of stored-energy connectors to move the plurality of antenna assemblies from a stowed configuration of the plurality of antenna assemblies to the deployed configuration of the plurality of antenna assemblies.

14. The antenna array of claim **13**, wherein the control mechanism comprises one or more of a spring, a solenoid, a coil, or a magnet.

15. The antenna array of claim **10**, wherein the stored-energy connectors are configured to be folded in the stored-energy position.

16. The antenna array of claim **10**, wherein the stored-energy connectors are configured to be substantially straight in the released-energy position.

17. The antenna array of claim **10**, wherein the stored energy connectors are configured to store mechanical energy or electrical energy.

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