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(71) Applicant: **CommScope Technologies LLC**
Claremont, NC 28610 (US)

(72) Inventor: **MERTA, Samantha**
Plano, 75075 (US)

(74) Representative: **Meissner Bolte Partnerschaft mbB**
Patentanwälte Rechtsanwälte
Postfach 86 06 24
81633 München (DE)

(54) BASE STATION ANTENNAS HAVING AN ACTIVE ANTENNA MODULE(S) AND RELATED MOUNTING SYSTEMS AND METHODS

(57) Base station antennas include an externally accessible active antenna module releasably coupled to a rear of the housing using a mounting frame and active antenna module mounting brackets that may be slanted and/or that may include a spacer and/or cover for debris/critter resistance configurations. The base station antenna housing has a passive antenna assembly that cooperates with the active antenna module.

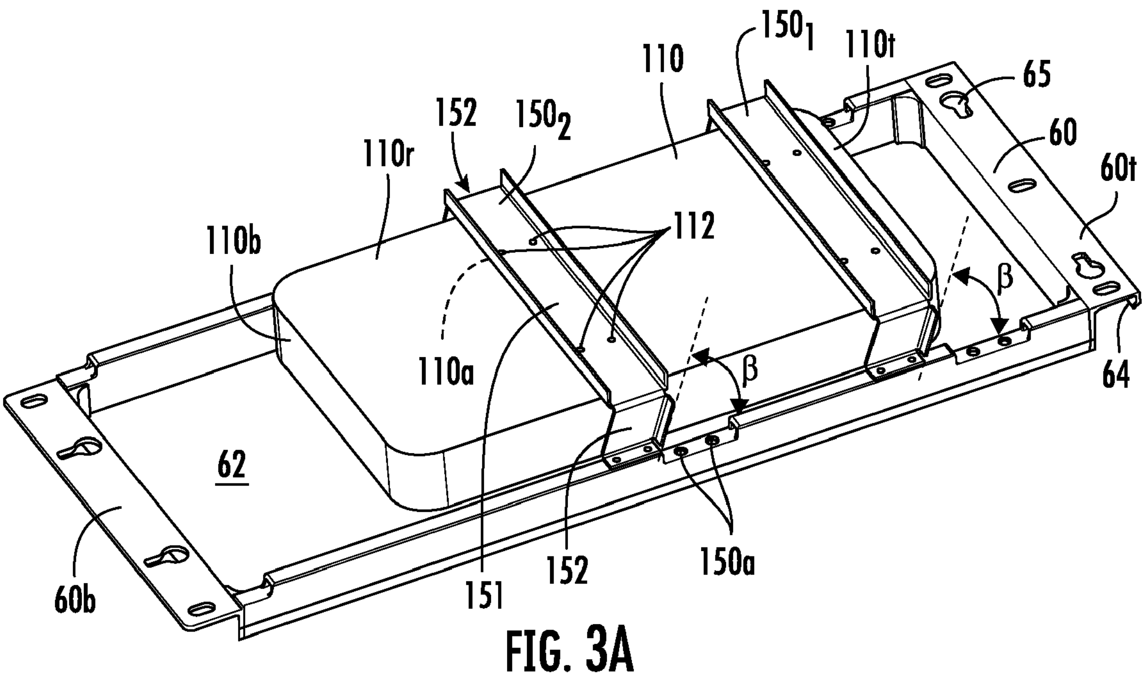

FIG. 3A

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Description

RELATED APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Provisional Application Serial Number 63/486,343, filed February 22, 2023, the contents of which are hereby incorporated by reference as if recited in full herein.

BACKGROUND

[0002] The present invention generally relates to radio communications and, more particularly, to base station antennas for cellular communications systems.

[0003] Cellular communications systems are well known in the art. In a cellular communications system, a geographic area is divided into a series of regions that are referred to as "cells" which are served by respective base stations. The base station may include one or more antennas that are configured to provide two-way radio frequency ("RF") communications with mobile subscribers that are within the cell served by the base station. In many cases, each cell is divided into "sectors." In one common configuration, a hexagonally shaped cell is divided into three 120° sectors in the azimuth plane, and each sector is served by one or more base station antennas that have an azimuth Half Power Beamwidth (HPBW) of approximately 65°. Typically, the base station antennas are mounted on a tower or other raised structure, with the radiation patterns (also referred to herein as "antenna beams") that are generated by the base station antennas directed outwardly. Base station antennas are often implemented as linear or planar phased arrays of radiating elements.

[0004] In order to accommodate the increasing volume of cellular communications, cellular operators have added cellular service in a variety of new frequency bands. In order to increase capacity without further increasing the number of base station antennas, multi-band base station antennas have been introduced which include multiple linear arrays of radiating elements. Additionally, base station antennas are now being deployed that include "beamforming" arrays of radiating elements that include multiple columns of radiating elements. The radios for these beamforming arrays may be integrated into the antenna so that the antenna may perform active beamforming (i.e., the shapes of the antenna beams generated by the antenna may be adaptively changed to improve the performance of the antenna). These beamforming arrays typically operate in higher frequency bands, such as various portions of the 3.3-5.8 GHz frequency band. Antennas having integrated radios that can adjust the amplitude and/or phase of the sub-components of an RF signal that are transmitted through individual radiating elements or small groups thereof are referred to as "active antennas." Active antennas can generate narrowed beamwidth, high gain, antenna beams and can steer the generated antenna beams in different directions by changing the amplitudes and/or phases of the sub-components of RF signals that are transmitted through the antenna.

[0005] **FIGs. 1** and **2** illustrate an example of a prior art "active" base station antenna **10** that includes a pair of beamforming arrays and associated beamforming radios. The base station antenna **10** is typically mounted with the longitudinal axis **L** of the antenna **10** extending along a vertical axis (e.g., the longitudinal axis **L** may be generally perpendicular to a plane defined by the horizon) when the antenna **10** is mounted for normal operation. The front surface of the antenna **10** is mounted opposite the tower or other mounting structure, pointing toward the coverage area for the antenna **10.** The antenna **10** includes a radome **11** and a top end cap **20.** The antenna **10** also includes a bottom end cap **30** which includes a plurality of connectors **40** mounted therein. As shown, the radome **11**, top cap 20 and bottom cap **30** define an external housing **10h** for the antenna **10.** An antenna assembly is contained within the housing **10h.**

[0006] **FIG. 2** illustrates that the antenna **10** can include one or more radios **50** that are mounted to the housing **10h.** As the radios **50** may generate significant amounts of heat, it may be appropriate to vent heat from the active antenna in order to prevent the radios **50** from overheating. Accordingly, each radio **50** can include a (die cast) heat sink **54** that is mounted on the rear surface of the radio **50.** The heat sinks **54** are thermally conductive and include a plurality of fins **54f.** Heat generated in the radios **50** passes to the heat sink **54** and spreads to the fins **54f.** As shown in **FIG. 2**, the fins **54f** are external to the antenna housing **10h.** This allows the heat to pass from the fins **54f** to the external environment. Further details of example conventional antennas can be found in co-pending WO2019/236203 and WO2020/072880, the contents of which are hereby incorporated by reference as if recited in full herein.

SUMMARY

[0007] Embodiments of the present invention are directed to a base station antenna assembly that includes: a housing having a passive antenna assembly and a passive reflector in the housing; a plurality of mounting structure brackets coupled directly or indirectly to a rear of the housing and to a mounting structure; a mounting frame coupled to the plurality of mounting structure brackets; an active antenna module positioned at least partially between opposing long sides of the mounting frame; and at least one active antenna bracket with bracket legs that are slanted and coupled to the mounting frame and to the active antenna module whereby the mounting frame attaches the active antenna module to the housing of the base station antenna.

[0008] Embodiments of the present invention are directed to a base station antenna assembly that includes: a housing having a passive antenna assembly and a passive reflector in the housing; a plurality of mounting structure brackets coupled directly or indirectly to a rear of the housing and to a mounting structure; a mounting frame coupled to the plurality of mounting structure brackets; an active antenna module positioned at least partially between opposing long sides of the mounting frame; at least one active antenna bracket with bracket legs that are coupled to the mounting frame and to the active antenna module whereby the mounting frame attaches the active antenna module to the housing of the base station antenna; and at a cover that is coupled to a top portion of the mounting frame and extends downward behind a rear of the housing, toward a top portion of the active antenna module to thereby provide critter resistant and/or debris resistant protection.

[0009] The active antenna module can include a massive multiple input multiple output (mMIMO) antenna array of radiating elements positioned in front of an active reflector. The passive reflector in the housing can be electrically coupled to the active reflector to thereby provide a common electrical ground.

[0010] The mounting frame can have a top portion with a laterally extending lip. The plurality of mounting structure brackets can include a first mounting structure bracket and a longitudinally spaced apart second mounting structure bracket. The first mounting structure bracket can have a laterally extending ledge that slidably cooperates with the lip.

[0011] The lip can have an upper surface and a lower surface with a forwardly facing laterally extending channel therebetween. The laterally extending ledge of the first mounting bracket can reside in the laterally extending channel of the lip.

[0012] The active antenna module can provide 5G operation and the passive antenna of the base station antenna can provide 4G operation.

[0013] The antenna device can be a radio, a filter, a calibration unit, an S-band antenna or combinations thereof and/or an active antenna module.

[0014] Embodiments of the present invention provide base station antennas with respective passive antenna assemblies within a housing and that are configured to releasably couple to an external device such as, for example, an active antenna module that is at least partially external to the housing of the base station antenna/passive antenna housing.

[0015] Still other embodiments are directed to a base station antenna assembly that includes: a housing of a base station antenna comprising a passive antenna assembly and a passive reflector in the housing; a plurality of mounting structure brackets coupled directly or indirectly to a rear of the housing and to a mounting structure (e.g., pole); a mounting frame coupled to the plurality of mounting structure brackets; an active antenna module positioned at least partially between opposing long sides of the mounting frame; at least one active antenna bracket coupled to the mounting frame and to the active antenna module whereby the mounting frame attaches the active antenna module to the housing of the base station antenna; and a cover that is coupled to a top portion of the mounting frame and that extends downward over an open space between a top portion of the mounting frame and a top of the active antenna module.

[0016] The cover can have a length that is less than a length of the mounting frame and extends downward about a rear of the mounting frame.

[0017] The cover can have a width that extends across a laterally extending open space at a top portion of the mounting frame above the active antenna module and between the right and left long sides of the mounting frame thereby providing a critter and/or debris resistant protection.

[0018] Yet other embodiments are directed to a base station antenna assembly that includes: a housing of a base station antenna comprising a passive antenna assembly and a passive reflector in the housing; a plurality of mounting structure brackets coupled directly or indirectly to a rear of the housing and to a mounting structure; a mounting frame coupled to the plurality of mounting structure brackets; an active antenna module positioned at least partially between opposing long sides of the mounting frame; and an active antenna bracket with right and left side bracket arms that are slanted and project rearward from a laterally extending segment of the active antenna bracket. The right and left side bracket arms couple to the mounting frame, and the laterally extending segment is coupled to a rear surface of the active antenna module whereby the mounting frame attaches the active antenna module to the housing of the base station antenna.

[0019] The mounting frame can have a pair of laterally spaced apart long sides with a rear facing surface. Each rear facing surface can have a plurality of longitudinally spaced apart mounting apertures positioned at different height positions, measured in a Z dimension corresponding to a front to back direction of the base station antenna. Different sets of the mounting apertures at respective corresponding height positions are configured to couple to different size or shape active antenna modules and/or active antenna brackets.

[0020] The active antenna bracket can be configured to be selectively used in one of two use orientations, a first use orientation whereby the bracket arms are slanted downward and a second use orientation whereby the bracket arms are slanted upward.

[0021] In the first use orientation, the bracket arms that are slanted downward can have a first mounting aperture that aligns with a first one of the plurality of mounting apertures of the rear facing surface, and in the second use orientation, the bracket arms are slanted upward and the first mounting aperture aligns with a second one of the plurality mounting apertures on the rear facing surface.

[0022] Still other embodiments are directed to a base station antenna assembly that includes: a housing of a base station antenna comprising a passive antenna assembly and a passive reflector in the housing; a plurality of mounting structure brackets coupled directly or indirectly to a rear of the housing and to a mounting structure; a mounting frame coupled to the plurality of mounting structure brackets; an active antenna module positioned at least partially between opposing long sides of the mounting frame; at least one active antenna bracket coupled to the mounting frame and to the active antenna module whereby the mounting frame attaches the active antenna module to the housing of the base station antenna; and a spacer extending above a top of the active antenna module, behind a rear of a top portion of the housing. The spacer has a width that is greater than a length corresponding to a longitudinally extending direction of the base station antenna assembly.

[0023] The spacer can have a plurality of laterally spaced apart apertures that are configured to allow fasteners to extend therethrough between a front of the mounting frame and the rear of the top portion of the housing.

[0024] The spacer can extend between a top one of the plurality of mounting structures and the top portion of the rear of the housing.

[0025] Additional embodiments are directed to a base station antenna that includes: a housing comprising a passive antenna, wherein the housing has a front radome and a rear radome; an active antenna module behind the rear radome of the housing; and a cover that resides outside of the housing and outside of the active antenna module, between the rear radome of the housing and a front of the active antenna module.

[0026] The cover can have a 2-D or 3-D body.

[0027] The cover can have a frequency selective surface/substrate.

[0028] The cover can be configured to allow radio frequency signal transmitted from the active antenna module to propagate therethrough.

[0029] The cover can be provided, at least in part, by netting or film.

[0030] The mounting frame can be sized and configured to interchangeably serially couple to different configurations of active antenna modules.

[0031] A top portion of the mounting frame can have a laterally extending lip.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032]

FIG. 1 is a perspective view of a prior art base station antenna.

FIG. 2 is a back view of the prior art base station antenna of **FIG. 1.**

FIG. 3A is a rear, side perspective view of a mounting frame coupled to active antenna brackets with slanted bracket arms to attach an active antenna module to a passive antenna/base station antenna housing according to embodiments of the present invention.

FIG. 3B is rear view of the devices shown in **FIG. 3A.**

FIG. 4A is a rear, side perspective view of the devices shown in **FIG. 3A** but with the active antenna brackets with the slanted bracket arms oriented in a second use direction according to embodiments of the present invention.

FIG. 4B is a rear view of the devices shown in **FIG. 4A.**

FIG. 5 is an enlarged side perspective view of the bracket shown in **FIGS. 3A, 3B, 4A,** and **4B.**

FIG. 6 is a side view of an example base station antenna coupled to a mounting structure (pole) with the mounting frame coupled to an active antenna module positioned behind the passive antenna/base station antenna housing according to embodiments of the present invention

FIG. 7 is a greatly enlarged view of a top portion of the devices shown in **FIG. 6** according to embodiments of the present invention.

FIG. 8 is a rear, side perspective view of an example mounting frame according to embodiments of the present invention.

FIG. 9 is an enlarged view of one set of mounting apertures shown on the long sides of the mounting frame in **FIG. 8.**

FIG. 10 is a side view of a rear top portion of a base station antenna with a spacer between the rear of the housing and a top one of the mounting structure brackets shown in **FIG. 6** according to embodiments of the present invention.

FIG. 11 is a side perspective view of the spacer shown in **FIG. 10** according to embodiments of the present invention.

FIG. 12 is a top end, perspective view of the devices shown in **FIG. 10** according to embodiments of the present invention.

FIGS. 13A and **13B** are side views of top rear portions of the base station antenna shown in **FIG. 6** with the spacer in two different positions relative to the rear of the housing and each providing an overlap with an underlying top portion of the active antenna module according to embodiments of the present invention.

FIG. 14 is a rear, side perspective view of another example base station antenna assembly with the active antenna module arranged on the mounting frame so as to have an open space A in a top portion of the mounting frame above the active antenna module according to embodiments of the present invention.

FIG. 15 is a rear view of the active antenna module and mounting frame shown in **FIG. 14** with the open space A, shown without the base station antenna housing/passive antenna according to embodiments of the present invention.

FIGS. 16-18 are rear side perspective views of example mounting frames with covers configured to cover the open space to thereby occlude critters and/or debris according to embodiments of the present invention.

FIG. 19 is a rear view of an example mounting frame with cover over an open space of the mounting frame between a top portion of the mounting frame and a top of the active antenna module according to embodiments of the present invention.

DETAILED DESCRIPTION

[0033] In the description that follows, a base station antenna **100** will be described using terms that assume that the base station antenna **100** is mounted for use on a tower, pole or other mounting structure with the longitudinal axis **L (FIG. 1)** of the antenna **100** (**FIG. 6**) extending along a vertical axis and the front of the base station antenna **100** mounted opposite the tower, pole or other mounting structure pointing toward the target coverage area for the base station antenna **100** and the rear of the base station antenna **100** facing the tower or other mounting structure. It will be appreciated that the base station antenna **100** may not always be mounted so that the longitudinal axis **L** thereof extends along a vertical axis. For example, the base station antenna **100** may be tilted slightly (e.g., less than 10°) with respect to the vertical axis so that the resultant antenna beams formed by the base station antenna **100** each have a small mechanical downtilt.

[0034] Referring to **FIGS. 3A, 3B, 4A** and **4B**, an example mounting frame **60** configured to provide a mounting system for mounting a device behind the base station antenna **100 (FIG. 6).** The device can comprise filters and/or antenna systems, such as S-band antennas, and/or an active antenna module **110.** In some embodiments, the mounting frame **60** is configured to attach the device such as the active antenna module **110** to a base station antenna **100** (**FIG. 6**) without requiring rails provided directly on the base station antenna to mount the frame **60** and/or by modifying the bracket structure providing the mounting interface for the (pole/tower) support structure mounting bracket for mounting the frame **60.** The term "active antenna module" is used interchangeably with "active antenna unit" and "AAU" and refers to a cellular communications unit comprising radio circuitry and associated antenna elements that are capable of electronically adjusting the amplitude and/or phase of the subcomponents of an RF signal that are output to different radiating elements of an array or groups thereof. The active antenna module **110** comprises the radio circuitry and the radiating elements (e.g., a multi-input-multi-output (mMIMO) beamforming antenna array) and may include other components such as filters, a, calibration network, antenna interface signal group (AISG) controller and the like. The active antenna module **110** can be provided as a single integrated unit or provided as a plurality of stackable units, including, for example, first and second sub-units such as a radio sub-unit (box) with the radio circuitry and an antenna sub-unit (box) with a multi-column array of radiating elements and the first and second sub-units stackably attach together in a front to back direction of the base station antenna **100**, with the antenna unit closer to the front **100f** (external radome) of the base station antenna **100** than the radio unit.

[0035] Further details of example base station antennas **100** with an antenna housing **100h** that includes a passive antenna assembly **190** (**FIGS. 6, 14**) can be found in U.S. Patent Number 11,482,774, the contents of which are hereby incorporated by reference as if recited in full herein. The term "passive antenna assembly" refers to an antenna assembly having arrays of radiating elements that are coupled to radios that are external to the antenna, typically remote radio heads that are mounted in close proximity to the base station antenna **100**/housing **100h.** The arrays of radiating elements included in the passive antenna assembly are configured to form static antenna beams. The passive antenna assembly can comprise radiating elements such as one or both low band radiating elements and/or mid-band or high band radiating elements. The passive antenna assembly **190** is mounted in the base station antenna housing **100h** and the base station antenna housing **100h** can releasably (detachably) couple (e.g., directly or indirectly attach) to one or more active antenna modules **110** that is/are separate from the passive antenna assembly **190.**

[0036] Turning again to **FIGs. 3A-3B**, the mounting frame **60** comprises a top portion **60t**, a bottom portion **60b** and laterally spaced apart side portions **61** that extend between the top and bottom portions in a longitudinal direction. The mounting frame **60** can comprise an open region **62** extending between the top portion **60t** and the bottom portion **60b** and the laterally spaced apart side portions **61.** The size of the open region **62** can vary and is not required to extend an entire length or width between the opposing sides **61.** Additional details of the mounting system can be found in co-pending U.S. patent Application Serial Number 17/905,291, the contents of which are hereby incorporated by reference as if recited in full herein.

[0037] Referring to **FIGs. 3A**, **3B**, **4A** and **4B**, the mounting frame **60** can be coupled to at least one active antenna bracket **150**, shown as first and second longitudinally spaced apart active antenna brackets, **150_1, 150_2,** each with slanted bracket arms **152.** A laterally extending segment **151** can have apertures **112** that receive fasteners to be attached to a rear **110r** of an active antenna module **110** and the slanted bracket arms **152** are coupled to long sides **61** of the mounting frame **60.** The mounting frame **60** is configured to couple to a passive antenna/base station antenna housing 100h with the active antenna module **110** behind a rear **100r** of the housing **100h** (**FIG. 6**) according to embodiments of the present invention. **FIGS. 3A** and **3B** show the respective brackets **150_1,150_2** in a first use orientation, with the slanted bracket arms **152** slanted upwards toward a top portion **60t** of the mounting frame **60. FIGS. 4A** and **4B** show the same respective brackets **150_1, 150_2,** but with the brackets in a second use orientation with the slanted bracket arms slanted downward toward a bottom **60b** of the mounting frame **60**, oriented in a second use direction according to embodiments of the present invention.

[0038] The long sides **61** of the mounting frame **60** have longitudinally spaced apart mounting apertures **61a.** The slanted bracket arms **152** allow the bracket **150** to be coupled to different sets of the mounting apertures **61a** on the long sides **61** of the mounting frame **60.** This allows the mounting frame **60** to accommodate different configurations of active antenna modules **110**, such as shorter ones (**FIGS. 3A**, **3B**) and longer ones (**FIGS. 4A**, **4B**).

[0039] The slanted bracket arms **152** can slant at an angle β between about 1 degree and about 45 degrees from the laterally extending segment **151** and/or a vertical use orientation and a free end can comprise mounting apertures **150a**. The bracket **150** can be provided as a set of different brackets **150**, at least some of which have different slanted angles β to allow for additional mounting options for different shaped active antenna modules **110** for better gap spacing in a front-to-back direction (**FIG. 7**). The slanted bracket arms **152** can provide a longitudinal offset relative to bracket arms that would be in-line with, and orthogonal to, the laterally extending segment **151.**

[0040] **FIGS. 6** and **7** illustrate the mounting frame **60** coupled to the active antenna module **110** and residing behind a top portion of a rear **100r** of the base station antenna **100**, each of which are mounted to a mounting structure (e.g., poled) using mounting structure brackets **160**, **162**. The top bracket **160** can have a lip **160l** that receives a lip **64** of the mounting frame **60.** A small gap, in a front-to-back (Z) direction may exist for some configurations of active antenna modules **110** and housing **100h**, under the top bracket **160** and under the top of the housing **100h.**

[0041] Referring to **FIGS. 3A** and **6,** the top portion **60t** of the mounting frame **60** can provide the lip **64.** The lip can include a plurality of laterally spaced apart apertures **65**, which may be provided as slots, which may be a circular region, merging into a narrower second region along its length (with its length oriented to extend in a width dimension of the AAU **110** and base station antenna **100**). The apertures **65** receive fasteners that can extend downward. However, other attachment configurations and members may be used. The lip **64** can have a free end facing in a forward direction.

[0042] Referring to **FIG. 8**, the different sets of mounting apertures **61a** can be provided at different Z heights, corresponding to a front-to-back direction of the base station antenna **100** (**FIG. 6**). The different sets of mounting apertures **61a** can include sets A, B and C, each at different height positions, **h1**, **h2**, **h3.** Although shown as three sets, two sets or more than three sets can be used. The different sets A, B, C can include a first mounting aperture **61a** and a second mounting aperture **61a**, longitudinally spaced apart on each of a right long side **61** and similarly aligned spaced apart pairs **61a** on a left long side **61** of the mounting frame **60.** The first mounting aperture 61a of each set are serially arranged under and the second mounting aperture of each respective second set. The respective different sets of mounting apertures 61a can reside in different planes that are coplanar at heights **h1**, **h2**, **h3**, corresponding to 1 mm to about 2 inches for the stepped positional differences, e.g., stepped increments, in some embodiments. The different heights can have a common stepped dimension or different stepped dimension, some with smaller and some with larger steps in the Z direction.

[0043] **FIG. 9** illustrates that a first set of the mounting apertures **61a** can be provided on a fabricated stepped region which may be provided by a planar rear welded surface segment attached to an extruded body. However, the stepped regions providing the different heights for the different sets A, B, C of mounting apertures **61a** can be provided in other manners, extruded, brazed, adhesively provided layers, and the like, as will be recognized by one of skill in the art.

[0044] Turning now to **FIGS. 10-12,** in some embodiments a spacer **260** can be arranged at a top portion **100t** of a rear **100r** of the base station antenna, between the rear **100r** of and the front **110f** of the active antenna module **110.** The spacer **260** can abut the rear **100r** and can reside above the gap between the rear **100r** and a front of the active antenna module **110** and provides an overlap in a front to back direction, with the active antenna module **110.** The spacer **260** can be metal, non-metallic, foam, rubber or any suitable substrate or combinations of substrates. The spacer **260** can have a width dimension that is greater than a length dimension. The spacer **260** can reside in front of a top portion of the mounting frame **60** and adjacent the top **100t** of the base station antenna **100** with the passive antenna therein. The spacer **260** can have a plurality of laterally spaced apart apertures that receive fasteners. The spacer **260** can have a length that is relatively short to extend a short distance above (e.g., 1 inch or less), below, or flush with a top **100t** of the base station antenna **100** and terminate adjacent to but above the active antenna module **110.**

[0045] **FIGS. 13A** and **13B** illustrate example overlap spacing depending on a mounting orientation of the spacer **260** with respect to the rear **100r** of the base station antenna **100** and a front of the active antenna module **110** using the spacer **260**, a fastener and washer of lesser height/length. The spacer **260** can provide a debris barrier over the gap space so as to avoid performance loss if debris may drop into and/or wedge between the active antenna module **110** and a rear **100r** of the base station antenna housing **100h.**

[0046] Turning now to **FIGS. 14** and **15**, depending on a size and position of an active antenna module **110** on the mounting frame **60**, an open space **A** can exist between a top portion of the mounting frame **60** and a top portion of the active antenna module **110**, under the top **100t** of the base station antenna **100** with the passive antenna **190** therein. It may be desirable to provide critter-resistance and/or debris-resistance protection by using a cover **360** to block this space **A.**

[0047] **FIGS. 16-18** show example covers **360. FIG. 16** shows a single piece cover **360** that is attached to the mounting frame **60** and extends in the space **A** between a top of the active antenna module **110** and the top of the mounting frame **60. FIG. 17** illustrates that the cover **360'** maybe configured to extend perpendicular to the long sides **61** of the mounting frame **60** over a top of the active antenna module **110. FIG. 18** illustrates that the cover **360** may be provided by cover segments **360s** that allow for customized sizing of the cover **360** depending on a size of the space **A.** The cover segments **360s** can be coupled together or be closely spaced apart and reside over the space **A.**

[0048] The cover **360** can extend laterally across the space and couple to each of the long sides **61.** The cover **360** can be provided by any suitable material. The cover **360** can have a three-dimensional body.

[0049] **FIG. 19** illustrates that the cover **360** can be provided by a defined substrate such as a frequency selective surface/substrate comprising an array of unit cells, or a screen or grate configuration, and/or optionally netting and/or a film.

[0050] The cover **360** can be transparent for the mMIMO radiating elements in the active antenna module **110.**

[0051] Thus, the cover **360** can be an external cover **360** that is outside of and between the rear **100r** of the housing of the passive antenna **100** and the front radome of the active antenna module **110.** The cover **360** can be held by other mounting structures and is not required to be coupled to the mounting frame **60**, nor be used with such a mounting frame **60.**

[0052] In some embodiments, the (external) cover **360** can comprise a FSS (frequency selective surface) that is configured to be transparent to high-band signal frequency to thereby allow RF signal to propagate therethrough. For examples of FSS structures, see co-pending U.S. Patent Application Serial No. 17/787,619, the contents of which are hereby incorporated by reference as if recited in full herein.

[0053] The cover **360** can be or comprise metal, can be non-metallic, can comprise a dielectric, foam, rubber, a thin film, or any suitable substrate or combinations of substrates. Where the cover **360** is positioned in-line with (in front or behind the radio of the active antenna module **110**), it may be non-metallic, such as plastic, to reduce PIM.

[0054] The cover **360** can be provided with bird and/or other critter repellent coatings, odorants, color and/or patterned surfaces that can fend off or make it less desirable for visits from critters. The cover **360** can comprise barbs or other physical or visual repellent indicia.

[0055] Thus, the mounting frame **60** can be configured to be a "multiple purpose" mounting frame **60** that can accommodate a plurality of different configurations of active antenna modules **110** using the different sets of mounting apertures **61a** on the long sides thereof.

[0056] Different active antenna modules **110** may be configured to have different radios, radiating elements or other components whereby the active antenna modules **110** can be different for different cellular service providers and even for the same cellular provider. The active antenna module **110** can be interchangeably replaced with another active antenna module **110** from the original equipment manufacturer (OEM) or from the same cellular communications service provider or from different cellular communications service providers. Thus, a plurality of different active antenna modules **110** that have different configurations, including different internal configurations and different external configurations, can be interchangeably coupled to the base station antenna housing **100h.** The different active antenna modules **110** can each have the same exterior (perimeter) footprint and connectors or may have different exterior footprints and/or connectors. The different active antenna modules **110** can have different depth dimensions (front to back) and/or different width (lateral) dimensions. A respective base station antenna **100** can, for example, accept different active antenna modules **110** from different service providers at a field installation and/or factory installation site using different adapter members or other mounting configurations that allow the interchangeable field installation/assembly. The base station antenna **100**/antenna housing **100h** can thereby allow different active antenna modules **110** to be interchangeably installed, upgraded, or replaced. The base station antenna **100** can concurrently hold first and second active antenna units **110**, one above the other, in some embodiments.

[0057] The antennas **100** may have a number of advantages over conventional antennas. As cellular operators upgrade their networks to support fifth generation ("5G") service, the base station antennas that are being deployed are becoming increasingly complex. It is desirable to minimize antenna size and/or integrate increased number of antenna or antenna elements inside a single bases station antenna/external radome. For example, due to space constraints and/or allowable antenna counts on antenna towers of existing base stations, it may not be possible to simply add new antennas to support 5G service. Accordingly, cellular operators are opting to deploy antennas that support multiple generations of cellular service by including linear arrays of radiating elements that operate in a variety of different frequency bands in a single antenna. Thus, for example, it is common now for cellular operators to request a single base station antenna that supports service in three, four or even five or more different frequency bands. Moreover, in order to support 5G service, these antennas may include multi-column arrays of radiating elements that support active beamforming. Cellular operators are seeking to support all of these services in base station antennas that are comparable in size to conventional base station antennas that supported far fewer frequency bands.

[0058] The active antenna modules **110** may also be readily replaced in the field. As is well known, base station antennas are typically mounted on towers, often hundreds of feet above the ground. Base station antennas may also be large, heavy and mounted on antenna mounts that extend outwardly from the tower. As such, replacing base station antennas may be difficult and expensive. The active antenna modules **110** with beamforming radios may be field installable and/or replaceable without the need to detach the base station antenna **100** from an antenna mount.

[0059] Embodiments of the present invention have been described above with reference to the accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

[0060] It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of the present invention. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0061] It will be understood that when an element is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present. It will also be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (*i.e.*, "between" versus "directly between", "adjacent" versus "directly adjacent", etc.)

[0062] Relative terms such as "below" or "above" or "upper" or "lower" or "horizontal" or "vertical" may be used herein to describe a relationship of one element, layer or region to another element, layer or region as illustrated in the figures. It will be understood that these terms are intended to encompass different orientations of the device in addition to the orientation depicted in the figures.

[0063] The term "about" used with respect to a number refers to a variation of +/-10%.

[0064] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" "comprising," "includes" and/or "including" when used herein, specify the presence of stated features, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, operations, elements, components, and/or groups thereof.

[0065] Aspects and elements of all of the embodiments disclosed above can be combined in any way and/or combination with aspects or elements of other embodiments to provide a plurality of additional embodiments.

Claims

1. A base station antenna assembly, comprising:

a housing of a base station antenna comprising a passive antenna assembly and a passive reflector in the housing;
a plurality of mounting structure brackets coupled directly or indirectly to a rear of the housing and to a mounting structure (e.g., pole);
a mounting frame coupled to the plurality of mounting structure brackets;
an active antenna module positioned at least partially between opposing long sides of the mounting frame;
at least one active antenna bracket coupled to the mounting frame and to the active antenna module whereby the mounting frame attaches the active antenna module to the housing of the base station antenna; and
a cover that is coupled to a top portion of the mounting frame and that extends downward over an open space between a top portion of the mounting frame and a top of the active antenna module.

2. The base station antenna assembly of Claim 1, wherein the cover has a length that is less than a length of the mounting frame and extends downward about a rear of the mounting frame.

3. The base station antenna assembly of either Claim 1 or Claim 2, wherein the cover has a width that extends across a laterally extending open space at a top portion of the mounting frame above the active antenna module and between the right and left long sides of the mounting frame thereby providing critter and/or debris resistant protection, optionally wherein the cover comprises netting.

4. A base station antenna assembly, comprising:

a housing of a base station antenna comprising

a passive antenna assembly and a passive reflector in the housing;
a plurality of mounting structure brackets coupled directly or indirectly to a rear of the housing and to a mounting structure;
a mounting frame coupled to the plurality of mounting structure brackets;
an active antenna module positioned at least partially between opposing long sides of the mounting frame; and
an active antenna bracket with right and left side bracket arms that are slanted and project rearward from a laterally extending segment of the active antenna bracket, wherein the right and left side bracket arms couple to the mounting frame, and wherein the laterally extending segment is coupled to a rear surface of the active antenna module whereby the mounting frame attaches the active antenna module to the housing of the base station antenna.

5. The base station antenna of any one of the previous Claims, wherein the mounting frame comprises a pair of laterally spaced apart long sides with a rear facing surface, each rear facing surface comprising a plurality of longitudinally spaced apart mounting apertures positioned at different height positions, measured in a Z dimension corresponding to a front to back direction of the base station antenna, and wherein different sets of the mounting apertures at respective corresponding height positions are configured to couple to different size or shape active antenna brackets and/or active antenna modules.

6. The base station antenna of Claim 5, wherein the active antenna bracket is configured to be selectively used in one of two use orientations, a first use orientation whereby the bracket arms are slanted downward and a second use orientation whereby the bracket arms are slanted upward.

7. The base station antenna of either Claim 5 or Claim 6, wherein in the first use orientation the bracket arms that are slanted downward comprise a first mounting aperture that aligns with a first one of the plurality of mounting apertures of the rear facing surface, and wherein in the second use orientation, the bracket arms are slanted upward and the first mounting aperture aligns with a second one of the plurality mounting apertures on the rear facing surface.

8. A base station antenna assembly, comprising:

a housing of a base station antenna comprising a passive antenna assembly and a passive reflector in the housing;
a plurality of mounting structure brackets coupled directly or indirectly to a rear of the housing and to a mounting structure;
a mounting frame coupled to the plurality of mounting structure brackets;
an active antenna module positioned at least partially between opposing long sides of the mounting frame;
at least one active antenna bracket coupled to the mounting frame and to the active antenna module whereby the mounting frame attaches the active antenna module to the housing of the base station antenna; and
a spacer extending above a top of the active antenna module, behind a rear of a top portion of the housing, wherein the spacer has a width that is greater than a length corresponding to a longitudinally extending direction of the base station antenna assembly.

9. The base station antenna of Claim 8, wherein the spacer comprises a plurality of laterally spaced apart apertures that are configured to allow fasteners to extend therethrough between a front of the mounting frame and the rear of the top portion of the housing.

10. The base station antenna of either Claim 8 or Claim 9, wherein the spacer extends between a top one of the plurality of mounting structures and the top portion of the rear of the housing.

11. A base station antenna comprising:

a housing comprising a passive antenna, wherein the housing has a front radome and a rear radome;
an active antenna module behind the rear radome of the housing; and
a cover that resides outside of the housing and outside of the active antenna module, between the rear radome of the housing and a front of the active antenna module.

12. The base station antenna of Any one of Claims 1 to 3 or Claim 11, wherein the cover comprises a frequency selective surface and/or substrate.

13. The base station antenna of any one of Claims 1 to 3 or Claim 11 or Claim 12, wherein the cover is configured to allow radio frequency signal transmitted from the active antenna module to propagate therethrough.

14. The base station antenna assembly of any of Claims 1-10, wherein the mounting frame is sized and configured to interchangeably serially couple to different configurations of active antenna modules.

15. The base station antenna assembly of any of Claims 1-10 or 14, wherein a top portion of the mounting frame includes a laterally extending lip.

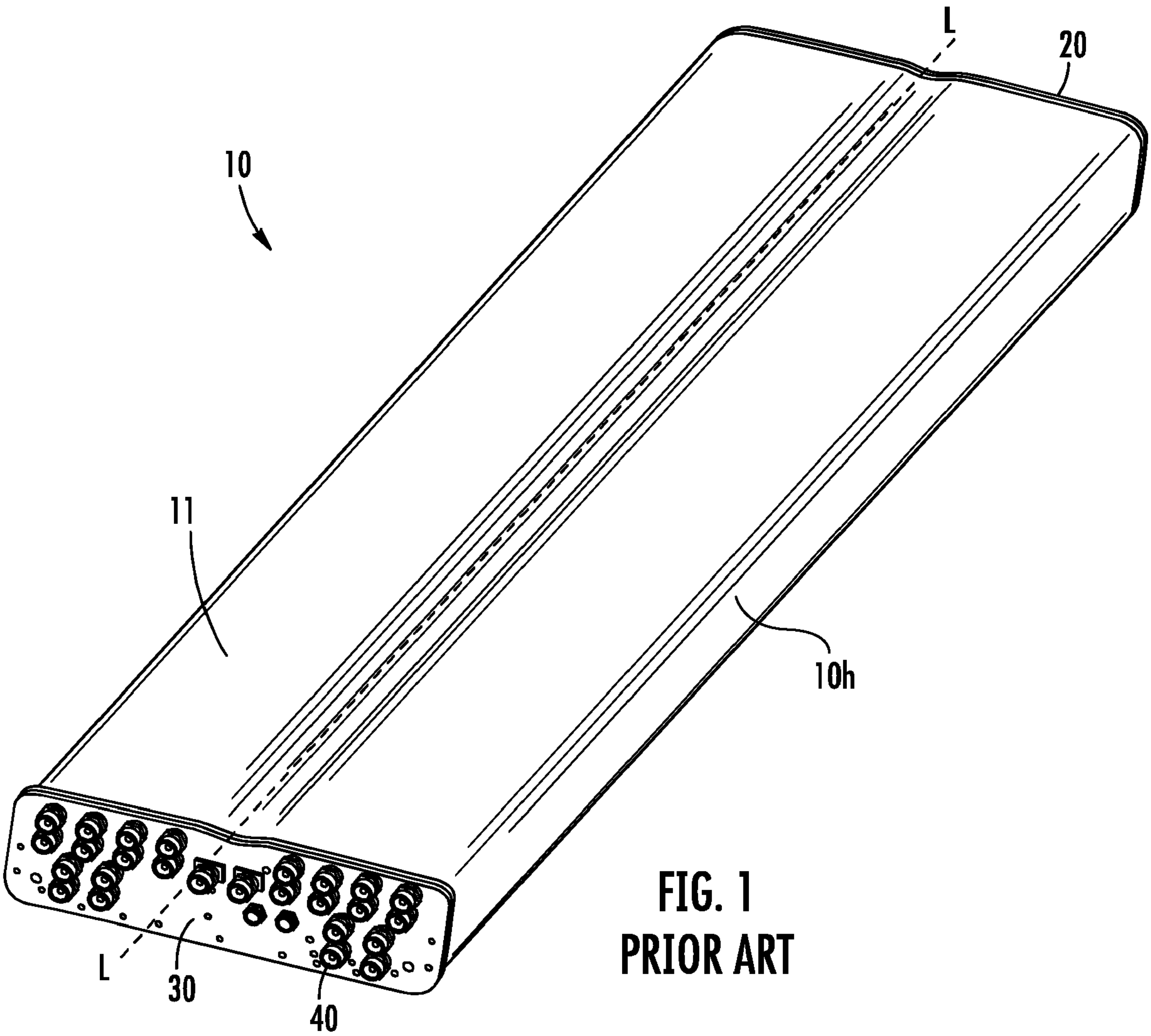


FIG. 1
PRIOR ART

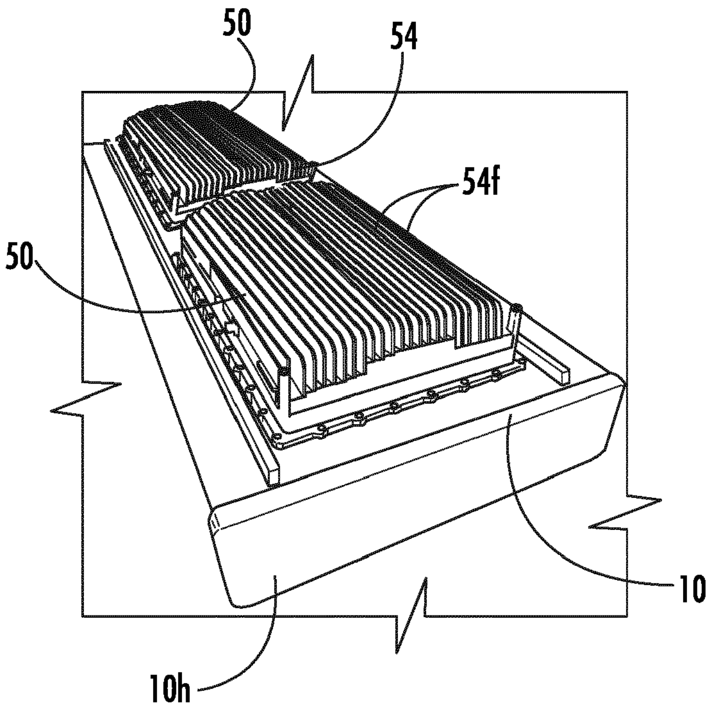
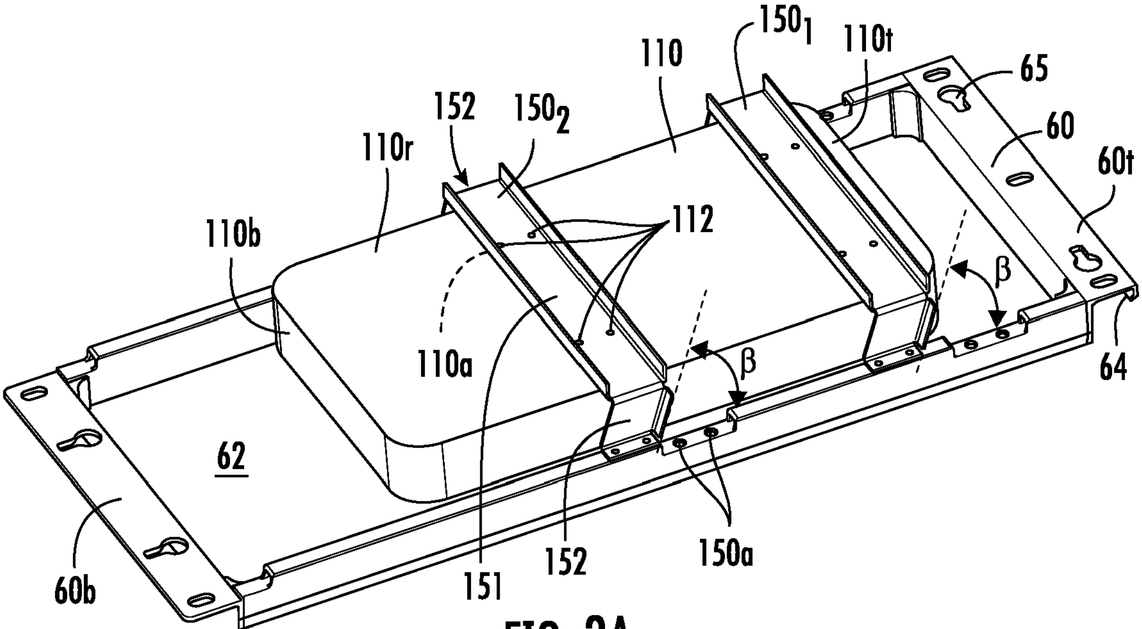


FIG. 2
PRIOR ART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65
60
60t
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110b
β
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β
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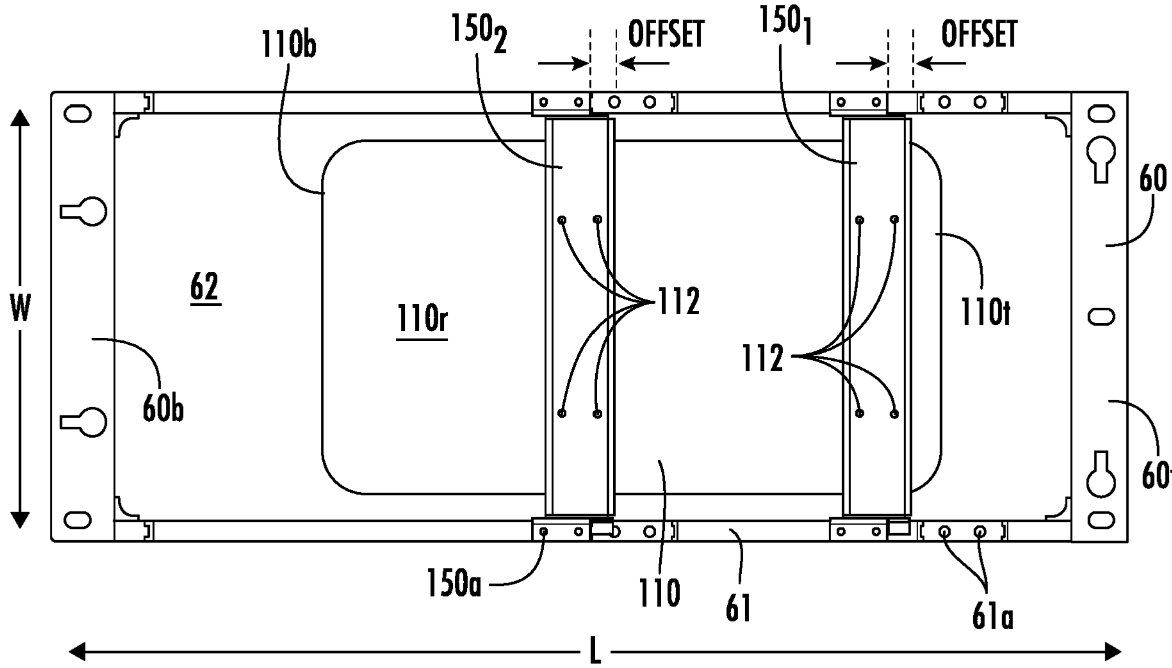
FIG. 3A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61a
L

FIG. 3B

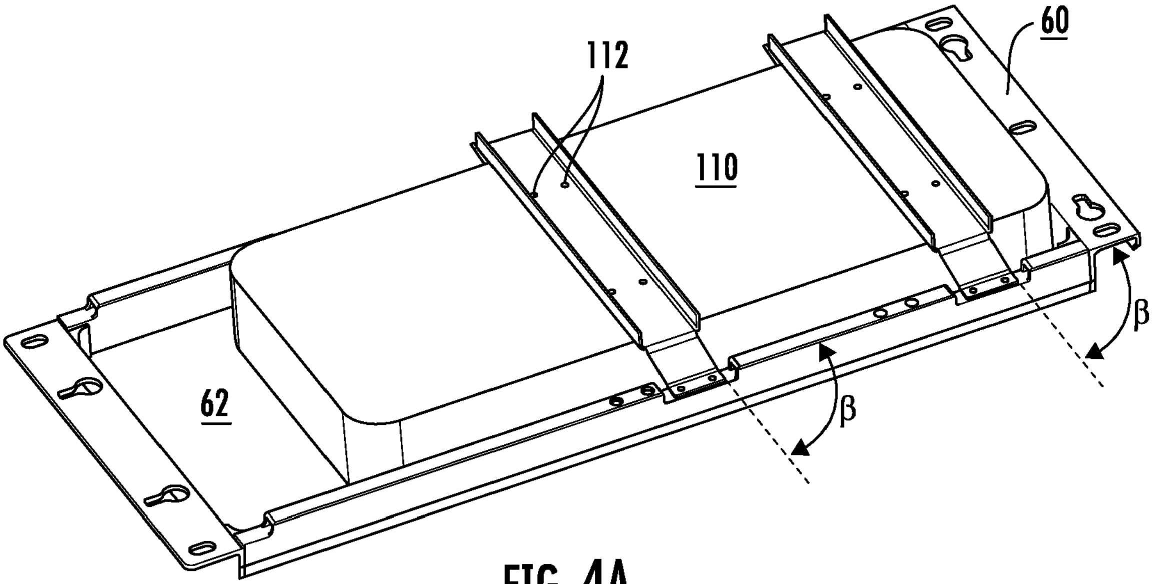

FIG. 4A

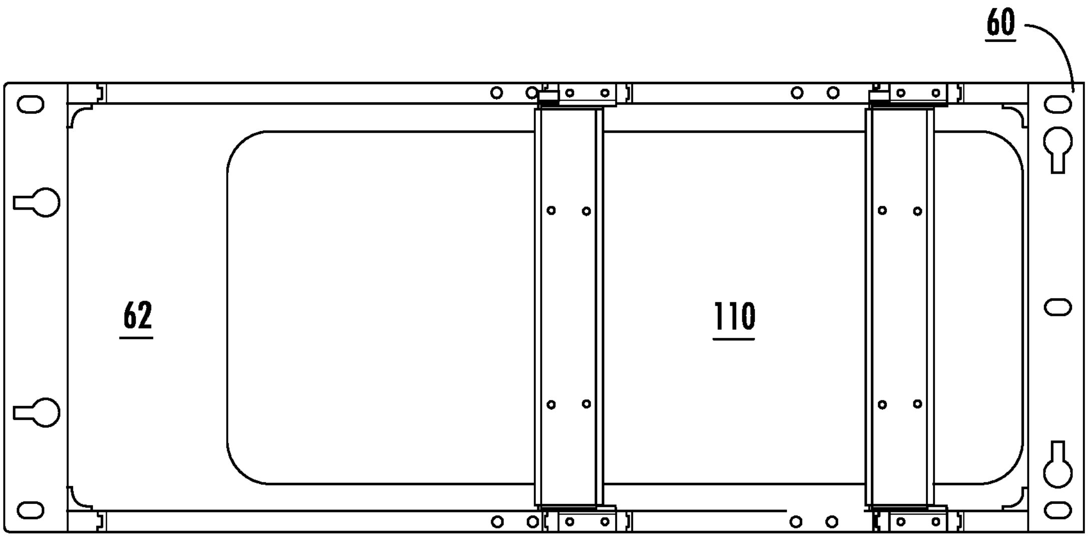

FIG. 4B

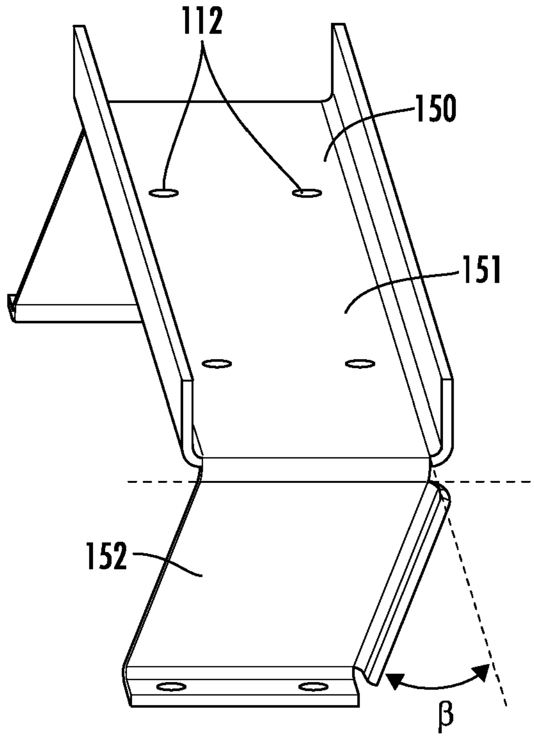

FIG. 5

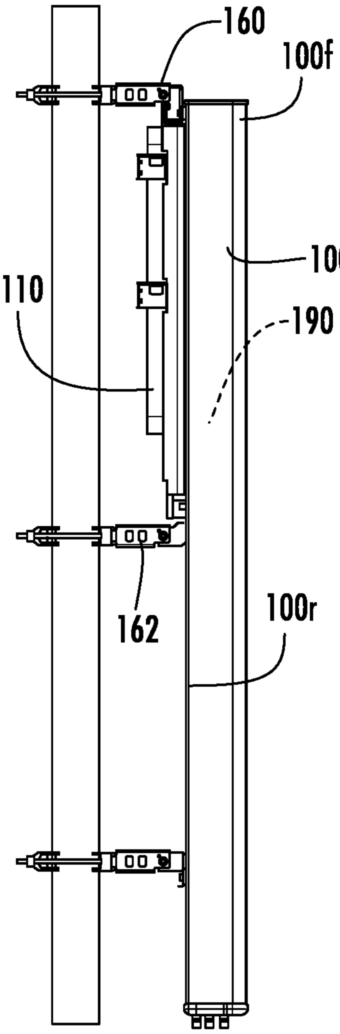

FIG. 6

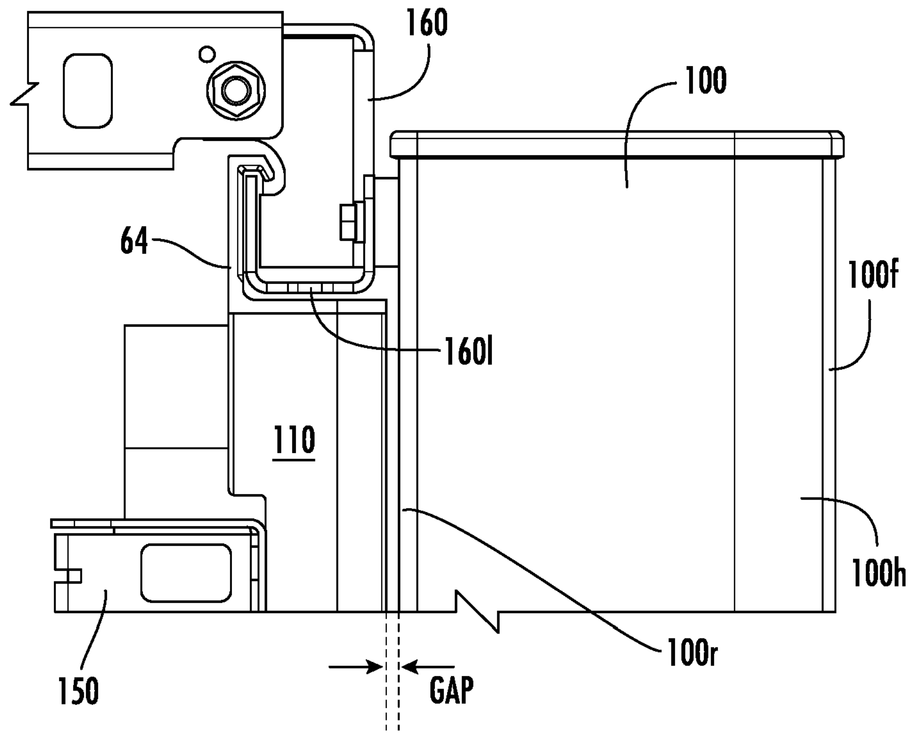

FIG. 7

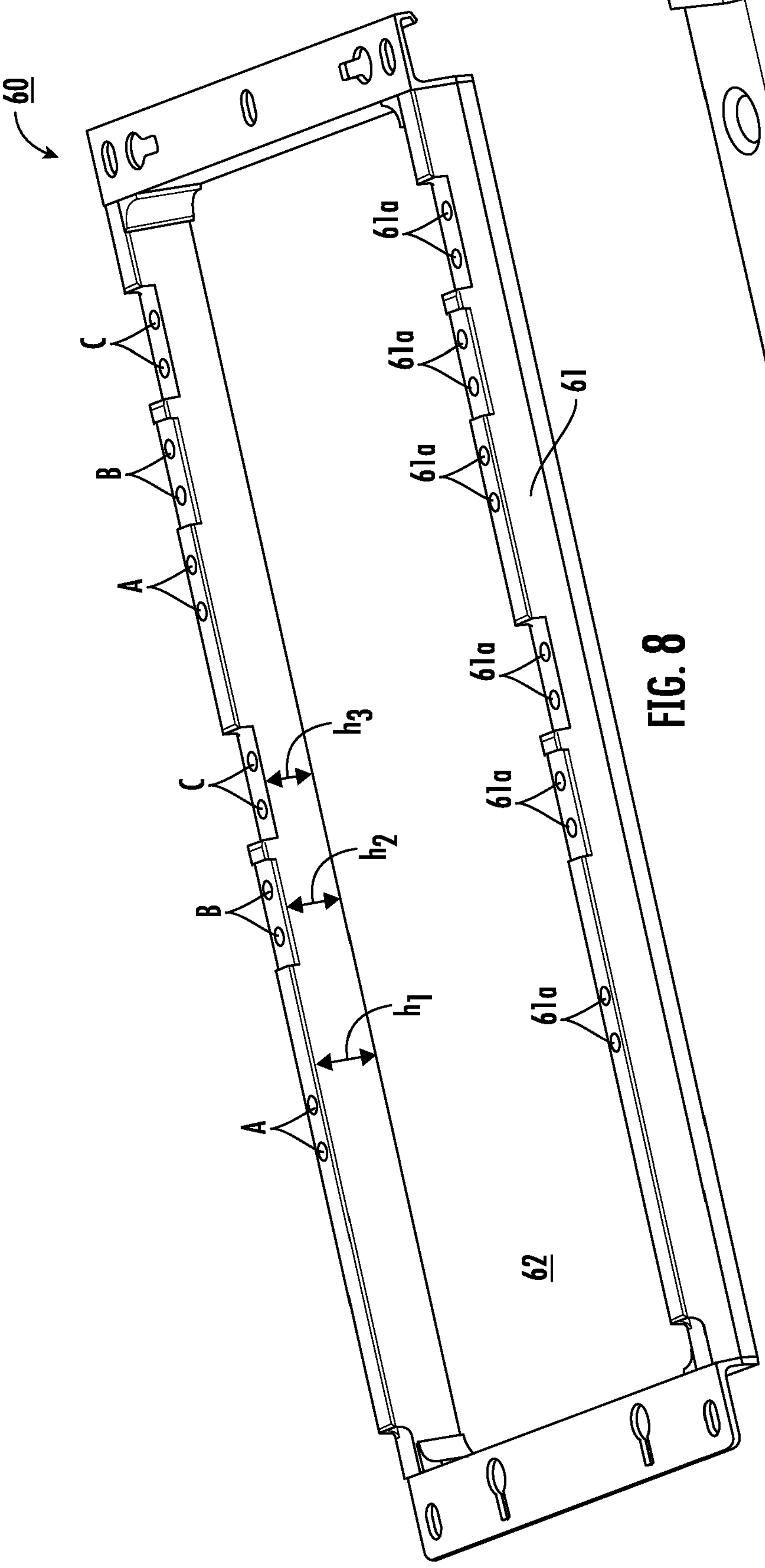

FIG. 8

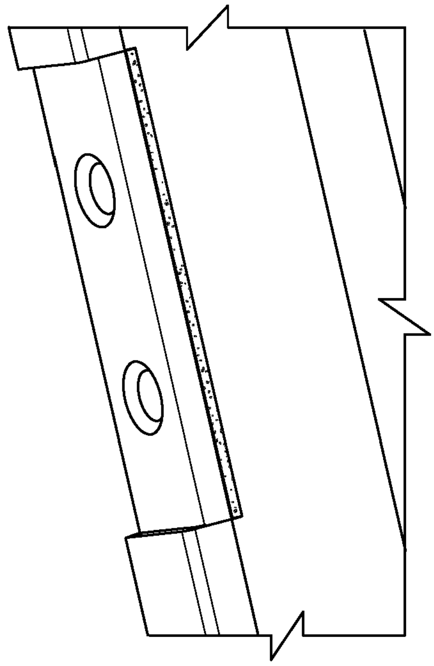

FIG. 9

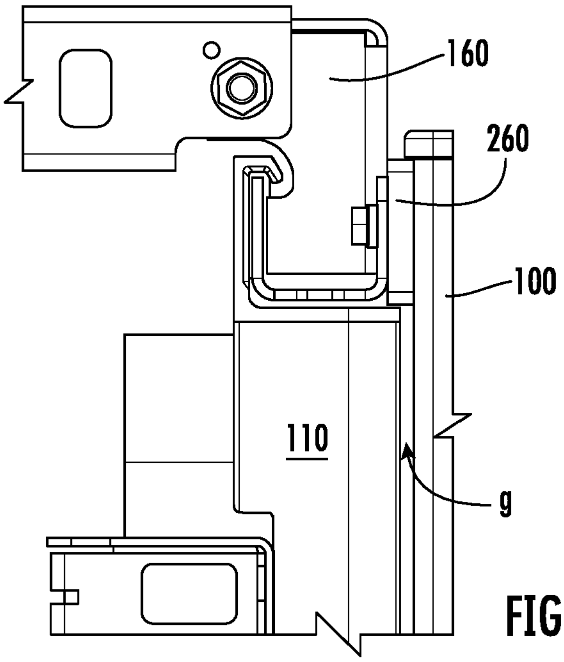

FIG. 10

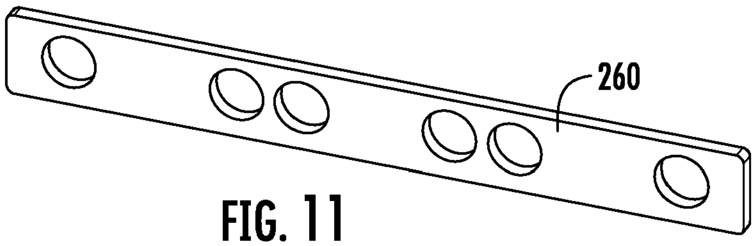

FIG. 11

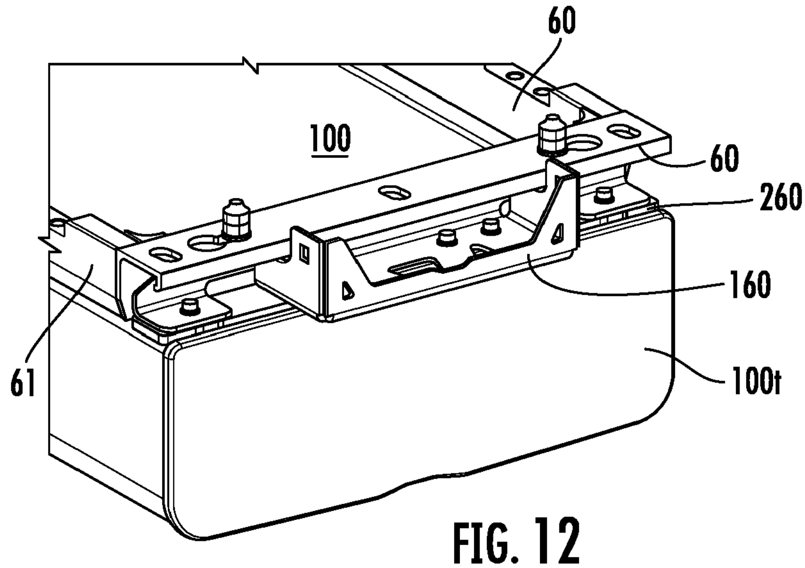

FIG. 12

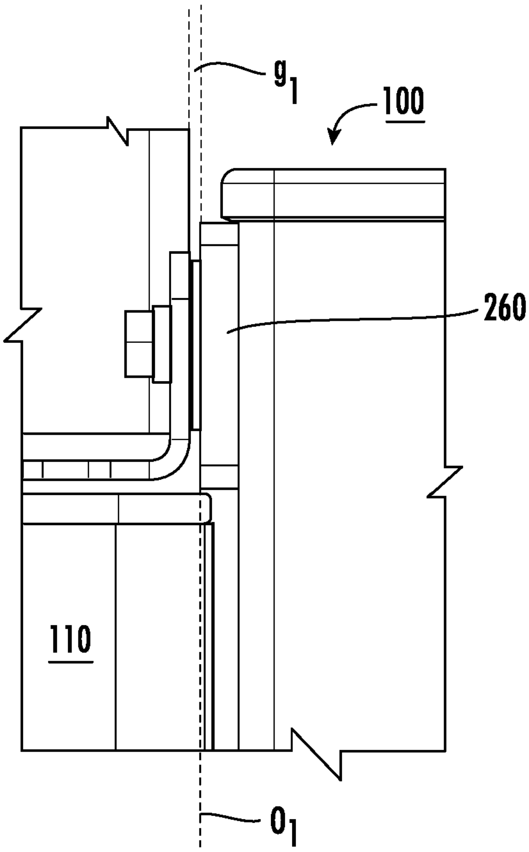

FIG. 13A

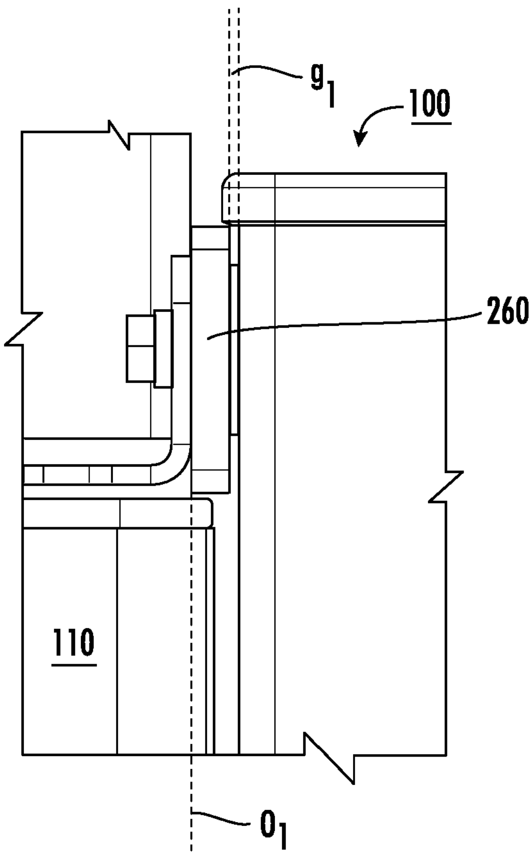

FIG. 13B

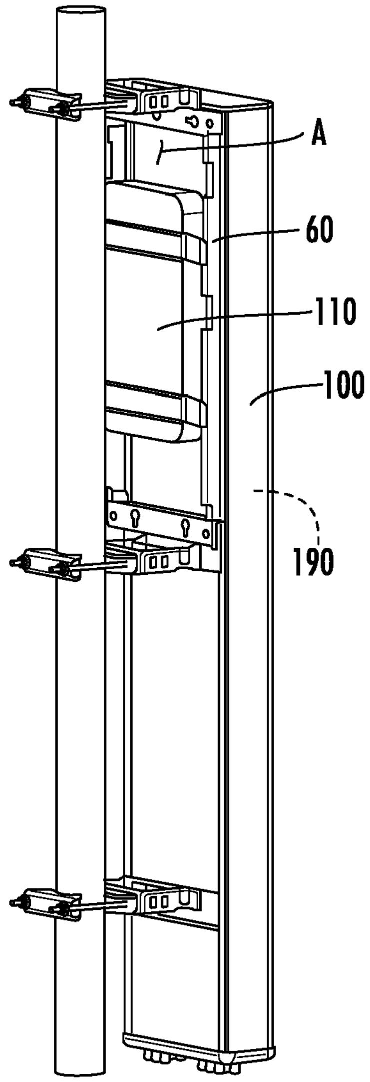

FIG. 14

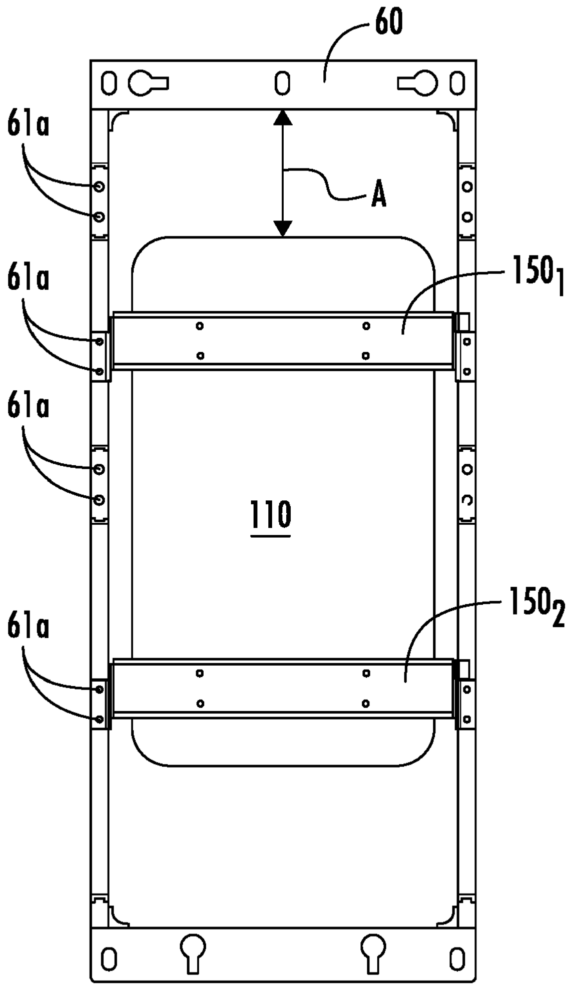

FIG. 15

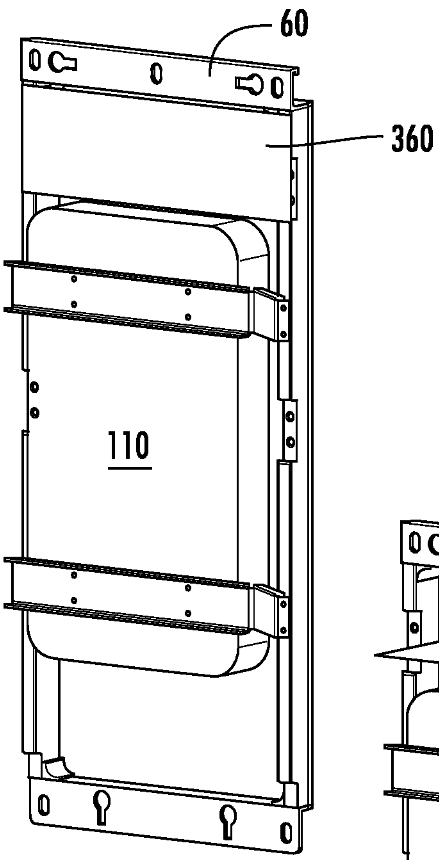

FIG. 16

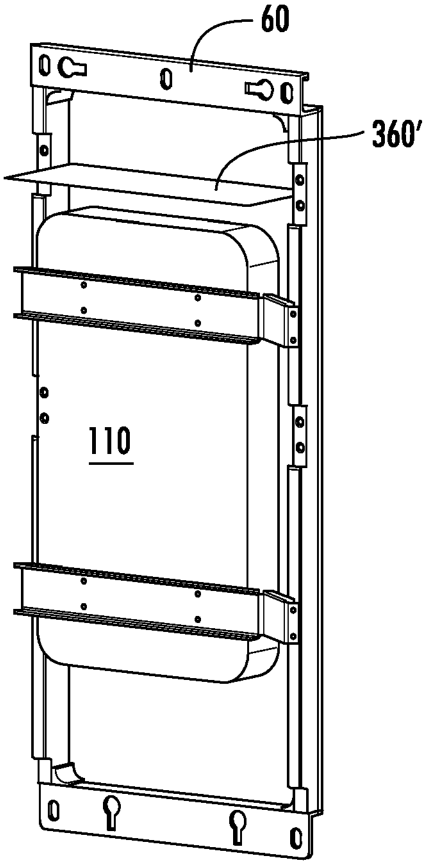

FIG. 17

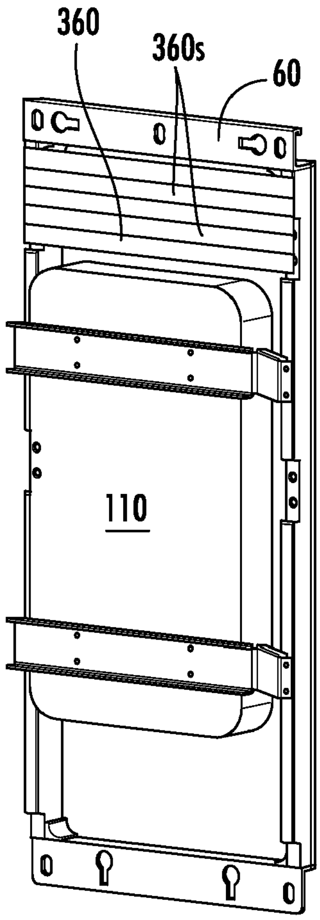

FIG. 18

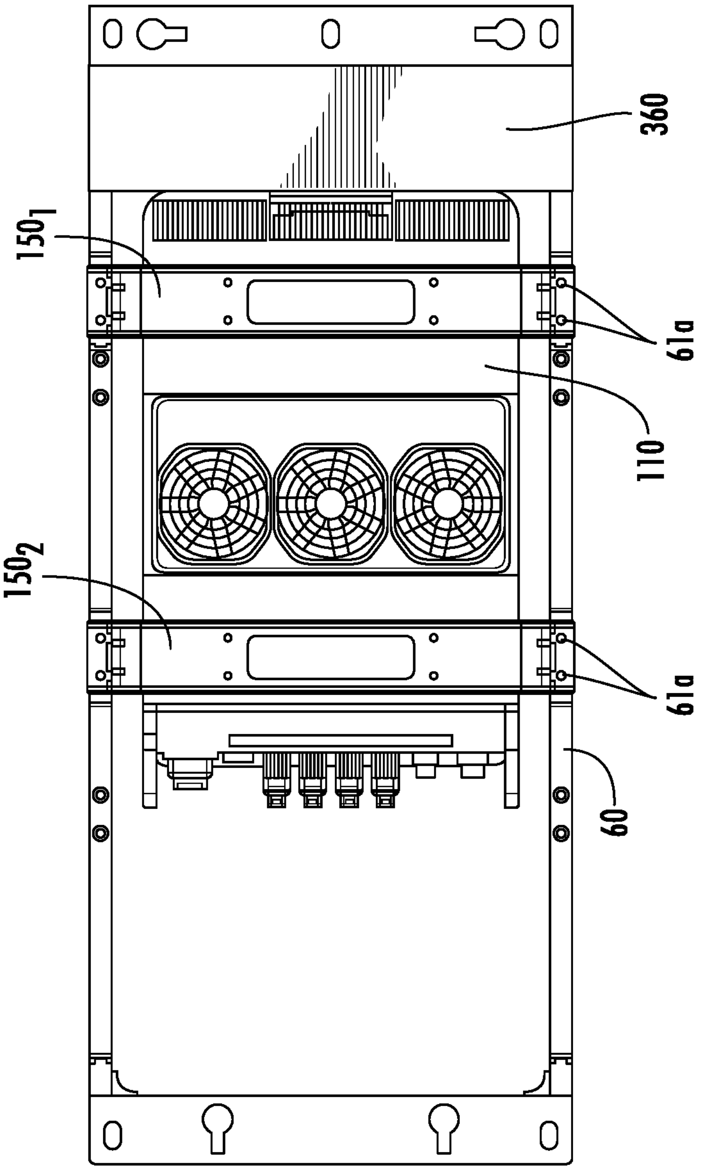

FIG. 19

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 63486343 **[0001]**
- WO 2019236203 A **[0006]**
- WO 2020072880 A **[0006]**
- US 11482774 B **[0035]**
- US 905291 **[0036]**
- US 787619 **[0052]**