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(71) Applicant: **COMMSCOPE TECHNOLOGIES LLC** [US/US]; 1100 CommScope Place SE, Hickory, North Carolina 28602 (US).

(72) Inventor: **BISIULES, Peter J.**; 1427 Blanchan Ave, LaGrange Park, Illinois 60526 (US).

(74) Agent: **CANNON, James, R.**; MYERS BIGEL, P.A., PO Box 37428, Raleigh, North Carolina 27627 (US).

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(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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(54) Title: SMALL CELL ANTENNA INTEGRATED WITH STREET SIGN

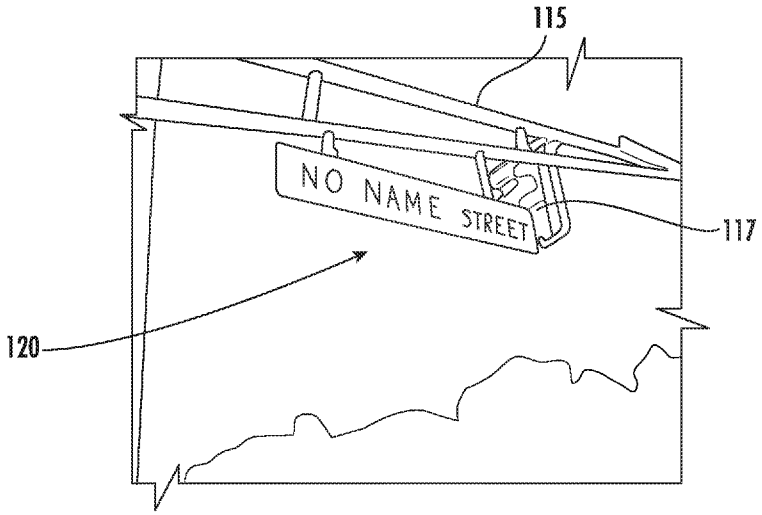

FIG. 2

(57) Abstract: A small cell base station includes: (a) an antenna including: a ground plane; a plurality of radiating elements mounted to the ground plane; a feed network connected with the plurality of radiating elements; and a cover that overlies the radiating elements, the cover including visual indicia that provides traffic information to motorists; and (b) a radio connected with the feed network.

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SMALL CELL ANTENNA INTEGRATED WITH STREET SIGN

RELATED APPLICATION

[0001] The present application claims the benefit of and priority from U.S. Provisional Patent Application No 62861491, filed June 14, 2019, the disclosure of which is hereby incorporated herein in its entirety.

FIELD OF THE INVENTION

[0002] Aspects of the present disclosure relate to cellular communications systems, including distributed antenna systems, communications systems that include small cell radio base stations, and communication systems that include macrocell radio base stations.

BACKGROUND

[0003] Cellular communications systems are well known in the art. In a typical cellular communications system, a geographic area may be divided into a series of regions that are referred to as "cells," and each cell is served by a base station. Typically, a cell may serve users who are within a distance of, for example, 2-20 kilometers from the base station, although smaller cells are typically used in urban areas to increase capacity. The base station may include baseband equipment, radios and antennas that are configured to provide two-way radio frequency ("RF") communications with mobile subscribers that are positioned throughout the cell. In many cases, the cell may be divided into a plurality of "sectors," and separate antennas may provide coverage to each of the sectors. The antennas are often mounted on a tower or other

raised structure, with the radiation beam ("antenna beam") that is generated by each antenna directed outwardly to serve a respective sector. Typically, a base station antenna includes one or more phase-controlled arrays of radiating elements, with the radiating elements arranged in one or more vertical columns when the antenna is mounted for use. Herein, "vertical" refers to a direction that is perpendicular relative to the plane defined by the horizon.

[0004] In order to increase capacity, cellular operators have, in recent years, been deploying so-called "small cell" cellular base stations. A small cell base station refers to a low-power base station that may operate in the licensed and/or unlicensed spectrum that has a much smaller range than a typical "macrocell" base station. A small cell base station may be designed to serve users who are within short distances from the small cell base station (e.g., tens or hundreds of meters). Small cells may be used, for example, to provide cellular coverage to high traffic areas within a macrocell, which allows the macrocell base station to offload much or all of the traffic in the vicinity of the small cell to the small cell base station. Small cells may be particularly effective in Long Term Evolution ("LTE") cellular networks in efficiently using the available frequency spectrum to maximize network capacity at a reasonable cost. Small cell base stations typically employ an antenna that provides full 360 degree coverage in the azimuth plane and a suitable beamwidth in the elevation plane to cover the designed area of the small cell. In many cases, the small cell antenna will be designed to have a small downtilt in the elevation plane to reduce spill-over of the antenna beam of the small cell antenna into regions that are outside the small cell and also for reducing interference between the small cell and the overlaid macro cell.

[0005] **FIG. 1** is a schematic diagram of a conventional small cell base station **10**. As shown in **FIG. 1**, the base station **10** includes an antenna **20** that may be mounted on a raised structure **30**. The antenna **20** may have an omnidirectional antenna pattern in the azimuth plane, meaning that the antenna beam(s) generated by the antenna **20** may extend through a full 360 degree circle in the azimuth plane.

[0006] As is further shown in **FIG. 1**, the small cell base station **10** also includes base station equipment such as baseband units **40** and radios **42**. A single baseband unit **40** and a single radio **42** are shown in **FIG. 1** to simplify the drawing. Additionally, while the radio **42** is shown as being co-located with the baseband equipment **40** at the bottom of the antenna tower

30, it will be appreciated that in other cases the radio **42** may be a remote radio head that is mounted on the antenna tower **30** adjacent the antenna **20**. The baseband unit **40** may receive data from another source such as, for example, a backhaul network (not shown) and may process this data and provide a data stream to the radio **42**. The radio **42** may generate RF signals that include the data encoded therein and may amplify and deliver these RF signals to the antenna **20** for transmission via a cabling connection **44**. The base station **10** of **FIG. 1** will typically include various other equipment (not shown) such as, for example, a power supply, back-up batteries, a power bus and the like.

[0007] It may be desirable to provide small cell antennas in different environments that capitalize on the presence of current structures.

SUMMARY

[0008] As a first aspect, embodiments of the invention are directed to a small cell base station comprising an antenna and a radio. The antenna comprises: a ground plane; a plurality of radiating elements mounted to the ground plane; a feed network connected with the plurality of radiating elements; and a cover that overlies the radiating elements, the cover including visual indicia that provides traffic information to motorists. The radio is connected with the feed network.

[0009] As a second aspect, embodiments of the invention are directed to a small cell antenna comprising: a ground plane; a plurality of radiating elements mounted to the ground plane; a feed network connected with the plurality of radiating elements; and a cover that overlies the radiating elements, the cover including visual indicia that provides traffic information to motorists.

[0010] As a third aspect, embodiments of the invention are directed to a small cell antenna comprising a ground plane having opposed front and rear surfaces; first and second pluralities of radiating elements mounted to the ground plane, the first plurality of radiating elements having a different operating frequency from the second plurality of radiating elements; a feed network connected with the pluralities of radiating elements; and a cover that overlies the radiating elements, the cover including visual indicia that provides traffic information to motorists. Some of the first plurality of radiating elements are mounted on the front surface of

the ground plane, and the remaining radiating elements of the first plurality are mounted on the rear surface of the ground plane. Some of the second plurality of radiating elements are mounted on the front surface of the ground plane, and the remaining radiating elements of the second plurality are mounted on the rear surface of the ground plane.

[0011] As a fourth aspect, embodiments of the invention are directed to a small cell antenna comprising: a ground plane; a plurality of radiating elements that form part of the ground plane; a feed network connected with the plurality of radiating elements; and a cover that overlies the radiating elements, the cover including visual indicia that provides traffic information to motorists.

BRIEF DESCRIPTION OF THE FIGURES

[0012] **FIG. 1** is a simplified schematic diagram illustrating a conventional small cell cellular base station.

[0013] **FIG. 2** is a perspective view of a street sign antenna according to embodiments of the invention.

[0014] **FIG. 3** is a schematic view of the groundplane and one surface of radiating elements of the street sign antenna of **FIG. 2**.

[0015] **FIG. 4** is a side section view of the street sign antenna of **FIG. 2**.

[0016] **FIG. 5** is a perspective view of an exemplary patch radiating element of the street sign antenna of **FIG. 2**.

DETAILED DESCRIPTION

[0017] Aspects of the present disclosure are described below with reference to the accompanying drawings. The present disclosure is not limited to the illustrated embodiments; rather, these embodiments are intended to fully and completely convey to those skilled in this art how to make and use the teachings of the present disclosure. In the drawings, like numbers refer to like elements throughout. Thicknesses and dimensions of some elements may not be to scale.

[0018] Spatially relative terms, such as "under", "below", "lower", "over", "upper", "top", "bottom" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be

understood that the spatially relative terms are intended to encompass different orientations of devices described herein in use or operation in addition to the orientation depicted in the figures. For example, if a device in the figures is turned over, elements described as "under" or "beneath" other elements or features would then be oriented "over" the other elements or features. Thus, the exemplary term "under" can encompass both an orientation of over and under. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0019] Well-known functions or constructions may not be described in detail for brevity and/or clarity. As used herein the expression "and/or" includes any and all combinations of one or more of the associated listed items.

[0020] 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 disclosure.

[0021] Referring now to the figures, **FIG. 2** illustrates a street sign antenna, designated broadly at **120**, hanging from a street pole **115** along with a stoplight **117.** The street sign antenna **120** is configured to function as both a street sign and as a small cell antenna. A typical street sign size has an area of about 30" x 6", which can allow for radiating elements in multiple bands that an operator can use, both licensed and unlicensed. The construction of the street sign antenna **120** is discussed in greater detail below.

[0022] Referring now to **FIGS. 3** and **4**, the street sign antenna **120** includes a ground plane **130**, arrays of radiating elements **140, 150, 160** on both sides of the ground plane **130**, and radomes **165** that cover the radiating elements **140, 150, 160** on which lettering and the like can be printed. One side of the ground plane **130** is shown in **FIG. 3**. As can be seen therein, the ground plane **130** (which is formed of metal) provides a reflector on which arrays of radiating elements **140, 150, 160** are mounted. A feed network **145** connects the radiating elements **140, 150, 160** with a connectivity hub **170** that in turn is connected with cables **175** that carry signals to and from the street sign antenna **120** to a radio **180** and/or other equipment located remotely from the street sign antenna **120**. Although **FIG. 3** illustrates a hub **170** connected to all of the

radiating elements **140, 150, 160**, in some embodiments a separate transmission line may be included for each frequency band.

[0023] Although any suitable radiating element may be employed, in the illustrated embodiment the radiating elements **140, 150, 160** are microstrip patch antennas (shown in **FIG. 3** as square patches). **FIG. 5** is a perspective view of a conventional patch radiating element **220**. As shown in **FIG. 5**, the conventional patch radiating element **220** is formed in a mounting substrate **210**. The mounting substrate **210** comprises a dielectric substrate **212** having lower and upper major surfaces, a conductive ground plane **214** that is formed on the lower major surface of the dielectric substrate **212** and a conductive pattern **216** that is formed on the upper surface of the dielectric substrate **212** opposite the conductive ground plane **214**. The patch radiating element **220** comprises a patch radiator **230** that is part of the conductive pattern **216**, as well as the portion **222** of the dielectric substrate **212** that is below the patch radiator **230** and the portion of the conductive ground plane **214** that is below the patch radiator **230** (not visible in **FIG. 5**). A feed line **234** is coupled to the patch radiator **230**. The feed line **234** may connect the patch radiating element **220** to a transmission line **218** such as, for example, a transmission line that is part of a feed network. The feed line **234** and the transmission line **218** are part of the conductive pattern **216** that is formed on the upper surface of the dielectric substrate **212**.

[0024] Additional information regarding patch radiating elements is set forth in U.S. Patent Application No. 16/163,601, filed October 18, 2018, the disclosure of which is hereby incorporated herein by reference in full. Other suitable radiating elements include, as examples, airstrip radiating elements and horn radiating elements.

[0025] Referring again to **FIG. 3**, in the illustrated example, the arrays of radiating elements **140, 150, 160** are configured to perform at different frequencies. For example, a mid-band 1.9 GHz set of radiating elements **140** can be arranged in the center of the ground plane **130,** while to the sides there can be a set of radiating elements **150** for CBRS 3.5 GHz and a set of radiating elements **160** for LAA 5 GHz. The radiating elements **140, 150, 160** can be arranged in a mirrored fashion on the front and back sides of the groundplane **130** (see **FIG. 4**).

[0026] The street sign antenna **120** as illustrated would form "peanut-shaped" antenna patterns in the azimuth plane (oriented perpendicular to the sign) which would aim the antenna

beams down the street in back and forth directions (e.g., to the north and to the south for a north-south roadway). Other pattern shapes may also be suitable for different coverage patterns.

[0027] The radomes **165** can be formed of any material and in any configuration known to be suitable for protecting radiating elements and permitting RF transmission therethrough. The radomes **165** may have lettering (such as the name of a street or roadway), or other indicia (such as a directional arrow or the like). In some embodiments, the "radome" may take the form of a film overlying the radiating elements **140, 150**, **160** that may include silkscreening or other printed material thereon.

[0028] As illustrated in **FIG. 3**, the connectivity hub **170** may be located in a mounting bracket that attaches the street sign antenna **120** to a pole, post, or the like. The connectivity hub **170** may be galvanically or capacitively coupled with the antenna **120**. Cables **175** may be routed from the antenna connectivity hub **170** to the radio **180** through channels in the mounting bracket to decrease visibility and/or provide protection for the cables **175** and connections. The antenna **120** and radio **180** thus serve as a small cell base station.

[0029] Those of skill in this art will appreciate that other types of signs may benefit from the inclusion of an antenna as described above. For example, other traffic signs that convey traffic information to motorists, such as stop, yield, speed limit, and directional signs may include an antenna.

[0030] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are to be included within the scope of the following claims.

That Which is Claimed is:

1. A small cell base station, comprising:

(a) an antenna comprising:

a ground plane;

a plurality of radiating elements mounted to the ground plane;

a feed network connected with the plurality of radiating elements; and

a cover that overlies the radiating elements, the cover including visual indicia that provides traffic information to motorists; and

(b) a radio connected with the feed network.

2. The small cell base station defined in Claim 1, wherein the plurality of radiating elements comprises first and second subsets of radiating elements, the first subset having a different operating frequency from the second subset.

3. The small cell base station defined in Claim 1 or Claim 2, further comprising a street pole, the antenna being mounted on the street pole.

4. The small cell base station defined in any of Claims 1-3, wherein the traffic information comprises information indicating the identity of a street.

5. The small cell base station defined in any of Claims 1-4, wherein the plurality of radiating elements comprises patch radiating elements.

6. The small cell base station defined in any of Claims 1-5, wherein the covers comprise radomes.

7. The small cell base station defined in any of Claims 1-6, wherein the ground plane includes opposed front and rear surfaces, and wherein the plurality of radiating elements are mounted on both the front surface and the rear surface.

8. The small cell base station defined in Claim 7, wherein the plurality of radiating elements are configured to create a peanut-shaped antenna beam having lobes extending in opposing directions that are normal to the front and rear surfaces of the ground plane.

9. A small cell antenna, comprising:

a ground plane;

a plurality of radiating elements mounted to the ground plane;

a feed network connected with the plurality of radiating elements; and

a cover that overlies the radiating elements, the cover including visual indicia that provides traffic information to motorists.

10. The small cell antenna defined in Claim 9, wherein the plurality of radiating elements comprises first and second subsets of radiating elements, the first subset having a different operating frequency from the second subset.

11. The small cell antenna defined in Claim 9 or Claim 10, further comprising a street pole, the antenna being mounted on the street pole.

12. The small cell antenna defined in any of Claims 9-11, wherein the traffic information comprises information indicating the identity of a street.

13. The small cell antenna defined in any of Claims 9-12, wherein the plurality of radiating elements comprises patch radiating elements.

14. The small cell antenna defined in any of Claims 9-13, wherein the covers comprise radomes.

15. The small cell antenna defined in any of Claims 9-14, wherein the ground plane includes opposed front and rear surfaces, and wherein the plurality of radiating elements are mounted on both the front surface and the rear surface.

16. The small cell antenna defined in Claim 15, wherein the plurality of radiating elements are configured to create a peanut-shaped antenna beam having lobes extending in opposing directions that are normal to the front and rear surfaces of the ground plane.

17. A small cell antenna, comprising:

a ground plane having opposed front and rear surfaces;

first and second pluralities of radiating elements mounted to the ground plane, the first plurality of radiating elements having a different operating frequency from the second plurality of radiating elements;

a feed network connected with the pluralities of radiating elements; and

a cover that overlies the radiating elements, the cover including visual indicia that provides traffic information to motorists;

wherein some of the first plurality of radiating elements are mounted on the front surface of the ground plane, and the remaining radiating elements of the first plurality are mounted on the rear surface of the ground plane; and

wherein some of the second plurality of radiating elements are mounted on the front surface of the ground plane, and the remaining radiating elements of the second plurality are mounted on the rear surface of the ground plane.

18. The small cell antenna defined in Claim 17, wherein the first and second pluralities of radiating elements comprise patch radiating elements.

19. The small cell antenna defined in Claim 17 or Claim 18, wherein the covers comprise radomes.

20. A small cell antenna, comprising:

a ground plane;

a plurality of radiating elements that form part of the ground plane;

a feed network connected with the plurality of radiating elements; and

a cover that overlies the radiating elements, the cover including visual indicia that provides traffic information to motorists.

21. The small cell antenna defined in Claim 20, wherein the radiating elements are slot-type radiating elements.

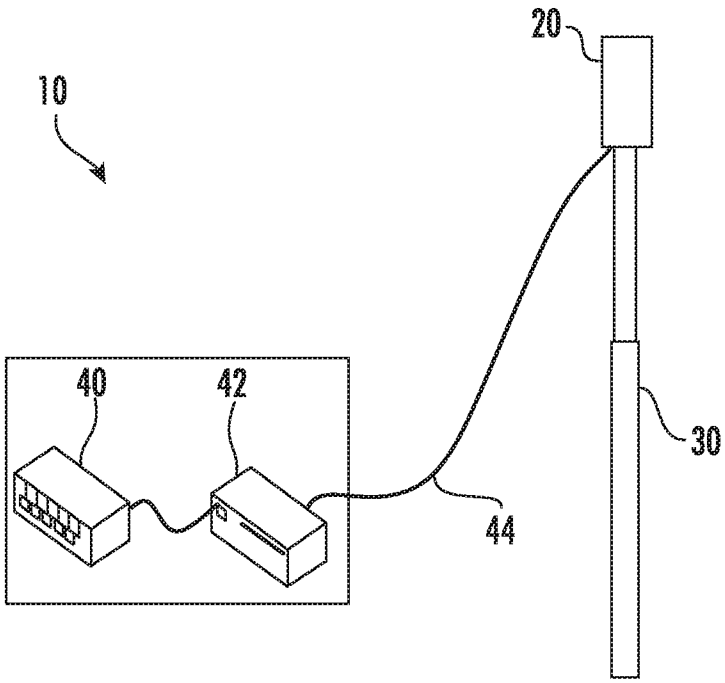

FIG. 1

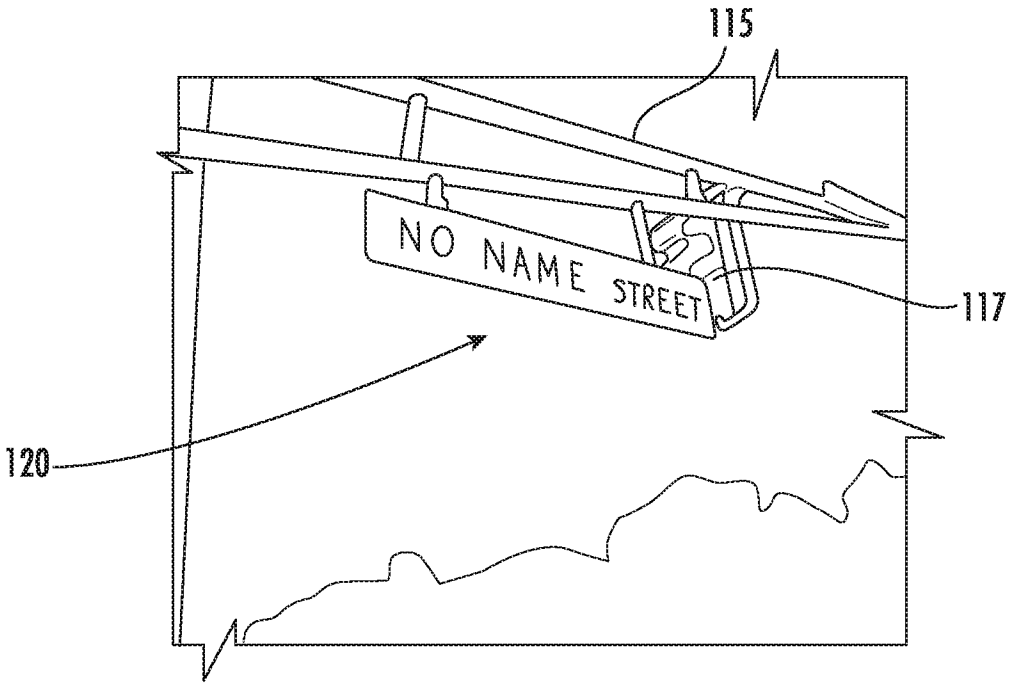

FIG. 2

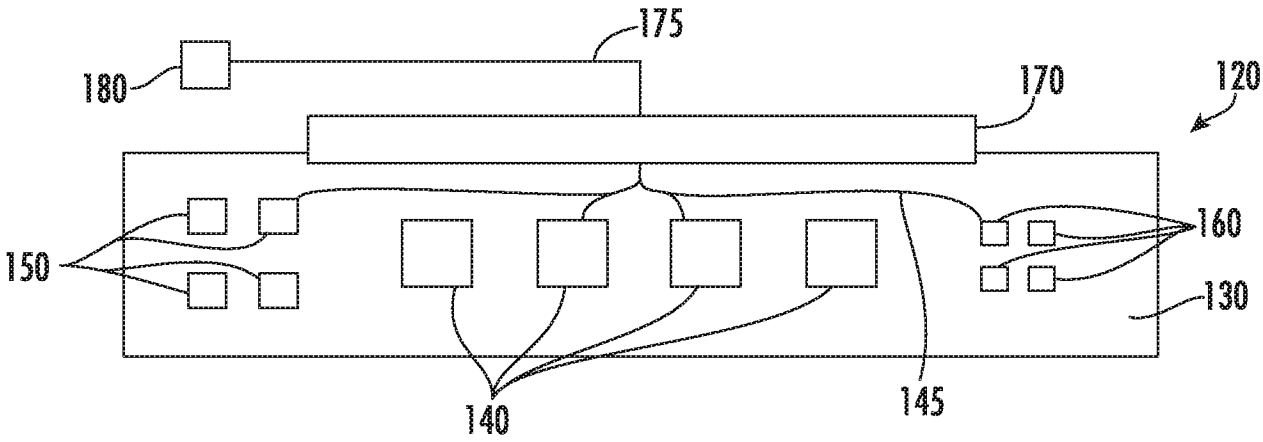

FIG. 3

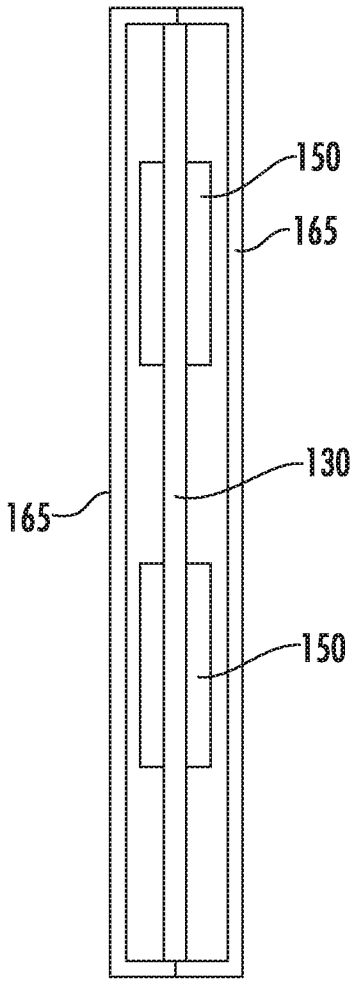

FIG. 4

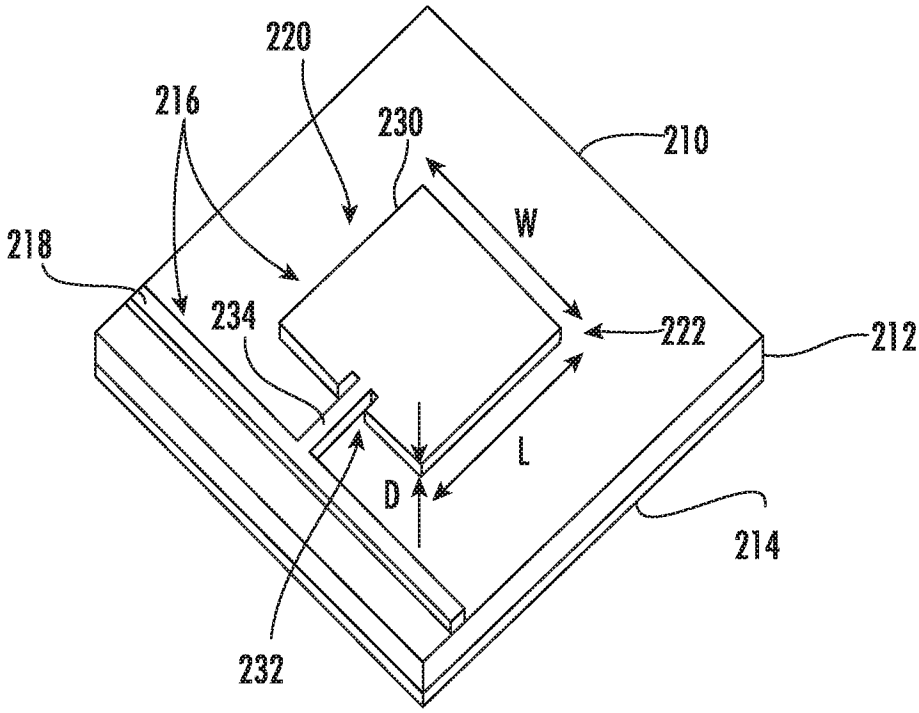

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/036937

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 8,16
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 8, 16 are regarded to be unclear because they refer to claims 7, 15 which do not comply with PCT Rule 6.4(a).

3. ☒ Claims Nos.: 4-7,12-15
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/036937

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 1/22(2006.01)i, H01Q 9/04(2006.01)i, H01Q 1/42(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q 1/22; G08G 100; H01Q 1/00; H04B 7/06; H04W 16/28; H04W 84/10; H04W 88/08; H01Q 9/04; H01Q 1/42

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: antenna, small-cell, ground, feed, radio

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2019-0020392 A1 (COMMSCOPE TECHNOLOGIES L.L.C.) 17 January 2019 paragraphs [0014]-[0029]; claim 1; and figures 1-3A	1-3,9-11,17-21
Y	US 6344803 B1 (TOSHIMICHI TSUBOUCHI et al.) 05 February 2002 column 6, line 1 - column 10, line 37; claim 1; and figures 4-11	1-3,9-11,17-21
A	US 2017-0324154 A1 (COMMSCOPE TECHNOLOGIES L.L.C.) 09 November 2017 paragraphs [0039]-[0044]; claim 1; and figure 7	1-3,9-11,17-21
A	US 2010-0188301 A1 (KENGO KISHIMOTO et al.) 29 July 2010 paragraphs [0093]-[0139]; claim 20; and figure 4	1-3,9-11,17-21
A	JP 2016-509444 A (ZHONGXING CORPORATION SLU) 24 March 2016 paragraphs [0025]-[0035]; claim 1; and figure 2	1-3,9-11,17-21

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 2020 (25.09.2020)	**25 September 2020 (25.09.2020)**

Name and mailing address of the ISA/KR
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Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
JANG, Gijeong
Telephone No. +82-42-481-8364

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2020/036937

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		DE 60007234 T2	03/06/2004
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		EP 1073142 A3	25/09/2002
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